

TRANSFORMING NIGERIA'S URBAN INFRASTRUCTURE FOR A SUSTAINABLE FUTURE

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In Collaboration with

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FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA**



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Forward

Sustaining African Cities in the 21st Century Global Urbanization

Africa is not new to urbanization as large and successful urban settlements of pre-industrial era have been reported in many African works. However, the present rate of uncontrolled rapid urban growth on this continent calls for deeper re-evaluation of her potentials to effectively harness resources in every sphere of today's world frontier of global human population growth and survival endeavours. This is aside the often over indulged issues of the burden of underdevelopment, hunger, malnutrition, and civil unrest in recent times (Adewumi & Akintayo, 2022; Bayramov, Viltres, & Doubre, 2023; Dutta & Cavanagh, 2025; Jimmy et al., 2025; Li, Chen, & Hu, 2016; Tekdemir, 2025). With child birth rapidly declining in the global north, sub-Saharan Africa and other developing countries will soon become the main sources of labour to run factories and farms at the required efficiency to retain and keep awake many global markets (Scholvin, Turok, Visagie, & Diez, 2022; Yeung, 2022). That is on the economic and social aspects, the physical environments in which many yet unborn populations will reside to carry out many new and evolving livelihood activities is also another avenue in need of deeper assessment. How we built, develop, and manage the environment has a lot of input on how we define what could be done in terms of peace and peace building in the era of increasing adversaries from nature and fellow humans far and near.

The ACMAN 8th Annual Conference was convened to highlight on the state of African cities in the different aspects of the 21st century urbanization. Taking the main theme of *Transforming Nigeria's Urban Infrastructure for a Sustainable Future*, the conference was able to draw contributions from a wide range of perspectives. Although many of the contributions were first-timers to a forum of this kind, the message many conveyed calls for action and further actions even where there are plans, programmes or projects already set in place and running. The need to act and the scale of the activities to act on are so enormous that one group, community or government cannot shoulder everything successfully. In many instances, those already empowered and expected to confront these increasingly important environmental and socioeconomic issues are often distracted by other engagements (Ahmad, Afolabi, Nda, & Daura, 2018; Darazo & Kawu, 2026; Isunju, Orach, & Kemp, 2016; Omoegun, 2025; Squire & Alozie, 2023). In many instances, these submissions have shown what should concern sub-Saharan African development today (The Urban Century) – that is: uninterrupted development and management of human settlements. A common message is that Africa should not underplay or miss the opportunities of urbanization in 21st century as it happened in the 20th century that the continent was largely dominated by over-bearing colonial powers. Opportunities abound today than in the immediate past or as never before – one of such is large scale urbanization and the far-reaching advantages that usually comes with it.

Many contributors highlighted building and re-building sustainable housing and urban environment as an entity in order to shelter life and livelihood activities in a much more dignified way than we have today. This trend, if followed, will meet global and regional goals of building and retaining sustainable communities and environments (Ameer & Ghannam, 2025; Arabi, Toloo, Yang, Zhang, & Xu, 2024; Okoye et al., 2025). An environment that is resilient, thriving with developments at every facet of life and does not deprive future generations, in any conceivable way, the ability to have their own development (Brundtland et al., 2012; Cecchin, Salomone, Deutz, Raggi, & Cutaia, 2021; Chatterjee, 2011). The environmental assessments presented here are what many have studied to further highlight the established aspirations of individuals and communities committed to building dignified living in a world ecosystem of sustainability as against the option of suppressing the mother earth by the untethered indulgence of just few of us (Chen, 2025; Guillen-Royo, 2019; Kernaghan & Sturgeon, 2024; Kubiszewski et al., 2013; Zheng, Chen, Zhang, Zhu, & Jin, 2026).

Many of the authors have shown how liveable environment, in urban and rural environments, can be achieved by individuals, groups, communities and governments through different but mutually reinforcing commitment to sustainability at all levels. For example; Musa, Aremu and Shuaibu, as the opening chapter brought to the fore the main hindrances to desirable socioeconomic wellbeing in many Nigerian homes and also a major contributor to negative environmental impacts - 'Urban and Residential Power Outage' and the many different ways urban dwellers navigate the menace in order to eke out living in decent environment. This is followed by Olanipekun and Owocyte who, still, drew attention to the roles of functional urban infrastructure and what residents can achieve through its effective development and management. These two portray solutions to the present urban Africa's main hindrance to self-reliance and achievement of the SDGs and similar global or regional development agenda. And, as many of these works rightly show, far from being unsurmountable, these are not issues that cannot be effectively addressed to entrench the needed self-dependent sustainability, rather, they are, in most cases, the crucial stage of infrastructure development that the government and city managers have relegated to the background.

However, the people who are daily facing widening limitations of infrastructure deficiencies in both rural and urban areas in 21st century Africa, are using every opportunity available to mainstream life, living and livelihood opportunities in this naturally endowed continent. This was shown by the works of: Olowere and Kawu – in addressing urban security challenges in many residential neighbourhoods of Minna largely peopled by the low-income groups, but with the least police presence; Panti et al - in highlighting visible cultural values amidst the vagaries of environmental changes; and, Dowell, Shaba and Ayuba – who documented elements of psychological wellbeing through effective landscape design. These works showcased people and communities' resolve to address increasingly peculiar growing urban vulnerabilities of this clime and time expressed through dwindling infrastructure performance and epileptic services. Again, while Eya et al; Attah et al; and, Bello and Isah; emphasized on efforts towards environmental wellbeing; Iornumbe and Zubairu, and, Orugun and Bala enlisted social and environmental considerations to be inculcated into building and developing facilities meant for the wellbeing of people through healthcare service provisions and the sustenance of enabling environment for comfort, healing and recovery.

These are works that further portrayed not only the growing challenges of the urban century, but, the main people, groups, communities and institutions left in the seemingly lonely field to walk through the woods. This is the engulfing characteristics portrayed in many urban centres in sub-Saharan Africa – a situation where urban and regional authorities too often leave those with the least resources to confront daunting and life threatening environmental and disaster events even when quick intervention can avert dangers and could usher in positive development to the environment, the cities and the region at large (Elorduy, Sinha, & Marx, 2024; Kawu, 2022, 2025; Kawu & Owoyele, 2008; Lu, Alahmari, & Mohammed, 2026; Messmer et al., 2021; Spaling, Brouwer, & Njoka, 2014). In this compiled work – ‘Transforming Nigeria’s Urban Infrastructure for a Sustainable Future’, emphasis is placed on results of human survival and growing transformational approaches to the challenges of the time by investing in participatory activities where every person’s action counts toward self-reliance, resilience and overall sustainability of cities and town – man’s dominant settlement type in today’s world. Perhaps, this way, and through the results of these efforts, the scenario of lagging behind infrastructure and facilities would cease to be attributed to Africa’s main socioeconomic trait, but, rather the larger resolve by the people, despite mounting hurdles, to have and retain pro-active and responsive populations. This, like many other interventions, also have the overwhelming capacity to keep the people and the continent together and focused on social and economic self-determination in a desired direction.

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Socio-Economic and Environmental Impacts of Urban Residential Power Outages: A Case Study of Federal Capital City Phase 1, Abuja, Nigeria

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ABSTRACT

This study assesses the socio-economic and environmental impacts of power outages on residential users in Federal Capital City (FCC) Phase 1, Abuja, Nigeria, through the lens of Protection Motivation Theory (PMT). The research examines how power outages are affecting residents' livelihood activities socio-economically and environmentally. Using a systematic random sampling technique, data were collected from 400 households and analyzed with the Relative Importance Index (RII). Findings revealed that power outages significantly disrupt residents' socio-economic and environmental well-being. Noise pollution from electricity power generating sets' emerged as the most critical environmental effect (RII = 0.726), causing stress, disrupting sleep, and posing security risks. Expenditure on alternative power sources was the most significant socio-economic burden (RII = 0.691), increasing financial strain and threatening household economic stability. These challenges trigger threat appraisal in PMT, as residents perceive the severity of disruptions to health, comfort, and economic stability. Unlike previous studies focusing on commercial impacts of power outages, this research highlights the livelihood and health implications for urban residential households, contributing to knowledge on energy poverty in Nigeria's capital. The study recommends adopting reliable and sustainable energy solutions, particularly solar energy, to mitigate these adverse effects.

Keywords: energy poverty, socio-economic impact, environmental effects, Protection Motivation Theory, power outage. Sustainability

INTRODUCTION

Urbanisation has sharply increased the demand for reliable and sustainable energy, yet power outages persist as a major impediment to socio-economic development across many sectors globally (Vo et al., 2024; Avordeh et al., 2024). These interruptions disrupt daily livelihoods, exacerbate energy poverty, and drive environmental degradation through heightened reliance on fossil fuel-based backup systems, such as electric power generating sets (Rateau & Choplin, 2022). In Nigeria, where erratic electricity supply costs the economy an estimated US\$25 billion (World Bank, 2021), understanding the impacts on urban households is critical for advancing sustainable energy solutions. This paper examines the socio-economic and environmental effects of power outages in Federal Capital City (FCC) Phase 1, Abuja, applying Protection Motivation Theory (PMT) to explore residents' threat appraisals and adaptive responses, such as solar energy adoption.

Global electricity demand rose by 4.0% in 2024, driven by heatwave-related cooling needs (208 TWh). This led to a 1.4% increase in fossil generation and a 1.6% rise in power sector emissions to 14.6 billion tonnes of CO₂, as clean energy growth could not fully meet demand (Graham & Fulghum, 2025). Sub-Saharan Africa faces acute power outages challenges, with 600 million people lacking electricity access in 2022, reducing business productivity and deepening poverty (International Energy Agency [IEA], 2023). Nigeria has an energy shortfall of 5,398 MW for over 200 million people in 2025 (Lot et al., 2025). In Nigeria, approximately 94% of grid-connected households face reliability issues, with 69.8% experiencing 4–14 power outages per week lasting over two hours, and 97% receiving less than 23 hours of daily electricity supply, driving reliance on polluting backups such as electric power generating sets (Luzi et al., 2020). Audu and Sule (2025) contend that rapid urban expansion in Abuja has intensified energy demand, with outages causing financial strain, noise pollution, and health risks from diesel powered generator emissions.

The research problem addressed by this study stems from the persistent unreliability of the national grid, which perpetuates energy insecurity among residential users in FCC Phase 1. Despite extensive analysis of outages in industrial and commercial contexts (Ogunlami et al., 2021; Chinedu et al., 2025), residential-specific insights on alternative power sources and pollution remain limited. The aim is to analyse the socio-economic and environmental effects of power outages on residential users in FCC Phase 1, Abuja. The objective is to assess these effects using data from households surveyed in 2023, highlighting how perceived threats drive sustainable adaptations. The scope covers residential neighbourhoods in FCC Phase 1, excluding administrative zones.

This study aligns with Sustainable Development Goal 7, promoting affordable and clean energy, and Nigeria's commitment to a 47% reduction in carbon emissions (United Nations Development Programme [UNDP], 2025). By illuminating residential impacts, it informs policies for resilient energy infrastructure, fostering equitable access and environmental sustainability globally.

CONCEPTUAL ANCHOR AND RELATED LITERATURE

Conceptual Framework

Power Outage

Power outages refer to the temporary loss of electrical power supply, disrupting essential services and household activities (Ayodele-Olajire et al., 2023). This study adopts the concept to analyze how outages affect residents' livelihoods, focusing on their economic and environmental impacts in urban residential settings.

Renewable Energy

Renewable energy encompasses energy sources derived from naturally replenishing resources but flow-limited, such as solar, wind, and geothermal (U.S. Energy Information Administration [EIA], 2024). It offers a sustainable alternative to unreliable grid power in Nigeria, reducing energy poverty and environmental degradation (Idoko et al., 2024). This study adopts renewable energy to explore its potential to mitigate outage-related disruptions, emphasizing its role in promoting economic stability and environmental health in FCC Phase 1.

Theoretical Framework

Protection Motivation Theory (PMT)

Developed by Rogers in 1975 and refined by Maddux and Rogers (1983), Protection Motivation Theory (PMT) explains how individuals respond to perceived threats through protective behaviors. PMT comprises two processes: threat appraisal, assessing the severity and vulnerability of a threat, and coping appraisal, evaluating the efficacy and feasibility of a response. In this study, PMT frames residents' responses to power outages, where the severity of socio-economic (e.g., financial strain) and environmental (e.g., noise pollution) impacts triggers threat appraisal, and solar energy's reliability and affordability drive coping appraisal, encouraging adoption (Ezzati et al., 2025). PMT is relevant as it links outage-induced challenges to residents' motivation to adopt sustainable energy solutions in FCC Phase 1.

Empirical Review

Globally, power outages pose significant challenges to sustainable development, impacting socio-economic activities and environmental health. In Pakistan, Ali et al. (2024) surveyed 349 community members across diverse regions, using a 22-factor questionnaire. They found that outages reduced manufacturing output, leisure, public administration efficiency, and educational opportunities, while increasing reliance on traditional energy sources. The study recommends timely energy project completion to meet community needs and enhance sustainability.

In Africa, studies highlight the severe impacts of power outages on businesses and households, compounded by limited infrastructure. In Accra, Ghana, Nduhuura et al. (2021) surveyed 496 urban households, employing correlation and regression analyses. They reported that outages disrupted safety, food access, social services, and caused appliance damage, with low income and large household size linked to higher impact severity. The study advocates for improved electricity reliability to support sustainable development. In Collins Chabane Local Municipality, South Africa, Mabunda et al. (2023) used a mixed-methods approach with 100 questionnaires and 25 interviews to assess loadshedding impacts on SMEs. Results showed a 61% revenue loss and 59% employee layoffs, with no demographic influence on impact severity. They recommend government subsidies for solar panels to mitigate economic losses. In Zambia, Ahmed et al. (2023) surveyed 54 households, using Bayesian inference. They found outages caused food spoilage, reduced work capacity, limited cooking options, and self-reported depression in 21% of respondents, with sleep disruptions as a significant predictor. The study suggests reliable electricity to reduce mental health impacts.

In Nigeria, power outages significantly affect both businesses and households, with reliance on electric power generating sets exacerbating socio-economic and environmental challenges. In Gwagwalada, Adekanbi (2024) investigated outage impacts on small businesses, though methodology details were limited. Frequent outages increased operational costs and reduced profitability due to reliance on electric power generating sets, which also caused environmental degradation. The study recommends reforms to enhance power reliability. In Kogi State, Abaukaka (2023) surveyed businesses and households, using inferential statistics. Unstable electricity increased business overhead costs, contributing to inflation, and led households to use unsafe fuels like firewood, posing health and environmental risks. The study recommends solar and wind energy solutions. In the Federal Capital Territory, Yelwa and Awe (2018) used a survey and logit model to analyze outage impacts on SMEs. Outages reduced productivity due to costly electric power generating sets, with small-scale operators most affected. They recommend institutional reforms for reliable power supply. In Uyo, Michael and Ekong (2018) surveyed 50 urban households using descriptive analysis. Households spent 5–15% of income on electric power generating sets and firewood, causing health and environmental risks. They recommend household ownership of electricity infrastructure to reduce vandalism.

While these studies provide critical insights into the impacts of power outages, gaps remain in understanding their effects on urban residential households in FCC Phase 1, Abuja. Existing research focuses on SMEs (Adekanbi, 2024; Yelwa & Awe, 2018; Mabunda et al., 2023), mixed populations (Abaukaka, 2023), or broader household/community contexts (Nduhuura et al., 2021; Ahmed et al., 2023; Michael & Ekong, 2018; Ali et al., 2024). Specific wards, such as Garki, Wuse, and Maitama in FCC Phase 1, with diverse socio-economic profiles, remain underexplored in terms of residential-specific socio-economic impacts (e.g., expenditure on alternatives) and environmental effects (e.g., noise pollution from electric power generating sets). This study addresses these gaps, contributing to knowledge on energy poverty in Nigeria's capital.

METHODOLOGY

Study Area

The study area is Federal Capital City (FCC) Phase 1, located in the Federal Capital Territory (FCT), Abuja, Nigeria (Latitude 9° 0' to 9° 8' N, Longitude 7° 27' to 7° 32' E). FCC Phase 1 comprises five districts: Garki, Wuse, Maitama, Asokoro, and Central Area, covering approximately 58 km² with an elevation of 631 m above sea level (Figures 1 &

2) The projected population in 2023 is 544,409, with an average household size of 4.7, yielding 115,832 households (National Population Commission, 2019). Excluding the administrative Central Area, the effective population is 99,594 households across residential districts (Musa et al., 2016). The area features a tropical climate with a rainy season (April–October, 1000–1500 mm rainfall) and dry season (November–March, temperatures 19°C to 34°C), influencing solar energy potential (Nigerian Meteorological Agency, 2025; Weatherspark, 2023).

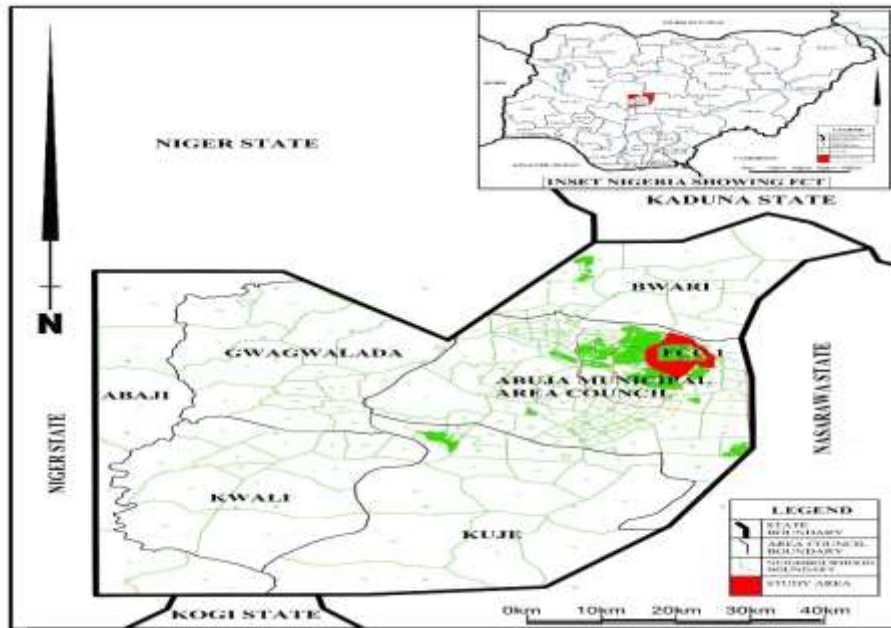


Figure 1: Federal Capital City Phase 1, in FCT, Location

Source: Abuja Geographical Information System (AGIS) (2008)



Figure 2: Federal Capital City Phase 1, FCT

Source: Abuja Geographical Information System (AGIS) (2008)

Methods

This study employs a descriptive research design to assess the socio-economic and environmental effects of power outages on urban residential households in Federal Capital City (FCC) Phase 1, Abuja, Nigeria. The design focuses on survey methods to evaluate residents' perceptions of outage impacts. Primary data were collected using a structured questionnaire administered to households in FCC Phase 1, targeting variables such as food spoilage, communication disruption, appliance damage, sleeping discomfort, water interruption, lateness to work, expenditure on alternatives, air pollution from electric power generating sets, and noise pollution from electric power generating sets. Multistage

sampling was used: stratified sampling delineated districts (Garki, Wuse, Maitama, Asokoro), while random sampling selected households.

The sample size was calculated using Yamane's (1967) formula, yielding 400 questionnaires, with 330 (82.5%) retrieved for analysis. Data were ranked on a 5-point Likert scale (Extremely Insignificant = 1 to Extremely Significant = 5) and analyzed using the Relative Importance Index (RII) to rank effects, computed as

Relative Importance Index (RII) is given by the formula:

$$RII = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{A * N}$$

Where, according to Johnson and Lebreton (2004):

n_5 = Number of respondents for extremely significant

n_4 = Number of respondents for significant

n_3 = Number of respondents for slightly significant

n_2 = Number of respondents for insignificant

n_1 = Number of respondents for extremely insignificant

A (Highest Weight) = 5, and N (Total number of respondents) = 330.

Analysis was conducted via SPSS version 25. Ethical considerations included informed consent and confidentiality. Results were presented textually and tabular.

FINDINGS AND DISCUSSION

Socio-Economic and Environmental Effects of Power Outage in FCC Phase 1

This subsection discusses the objective to analyse the socio-economic effects of the urban darkness period in FCC Phase 1, Abuja. Data collected for each socio-economic variable were ranked on a five-point scale: Extremely Insignificant (EI) = 1, Insignificant (I) = 2, Slightly Significant (SS) = 3, Significant (S) = 4, and Extremely Significant (ES) = 5. The results of this analysis are presented in Table 1.

Table 1: The Socio-Economic Effects of Urban Darkness Period in the Study Area

Variables	EI	I	SS	S	ES	Total
Food Spoilage	71	50	69	19	121	330
Communication/Entertainment disruption	31	89	59	60	91	330
Damage to electrical appliances	81	100	58	10	81	330
Sleeping Discomfort	30	71	68	60	101	330
Water supply Interruption	50	60	49	71	100	330
Air Pollution from Generators	50	61	39	70	110	330
Noise Pollution from Generators	60	41	19	51	159	330
Lateness to Work	110	50	59	81	30	330
Expenditure on other Alternatives	61	49	19	81	120	330

Source: Field Survey (2023).

Table 1 displays the frequency distribution of respondents' perceptions of power outage impacts. Noise pollution from electric power generating sets was rated highest, with 159 respondents considering it extremely significant. The persistent noise, especially at night, disrupts sleep, causes stress, and poses security risks as distress calls at night may go unheard. Food spoilage came next, with 121 respondents rating it extremely significant, as outages compromise refrigeration, leading to financial losses and health risks from spoiled food. In contrast, lateness to work was considered least significant, with 110 respondents rating it extremely insignificant. This suggests that most residents have adapted to the challenges of power outages and have found ways to mitigate their impact on their work schedules such as preparing or ironing their clothes in bulk prior to getting ready to go to work. These findings are consistent with studies in Ghana by Nduhuura et al. (2021) and in Zambia by Ahmed et al. (2023), which identified sleep disruption and food insecurity as major impacts of power outages.

Relative Importance Index (RII) Analysis of Socio-Economic Effects

To further assess the significance of the socio-economic effects, the Relative Importance Index (RII) formula was applied. This analysis ranks the variables based on their weighted importance from the survey data, shown in Table 2.

Table 2: Relative Importance Index (RII) of the Socio-Economic Effects of Urban Darkness Period in FCC Phase 1

Variables	Total Response	N	A*N	RII	Rank
Noise Pollution from Generators	1198	330	1650	0.726	1
Expenditure on Other Alternatives	1140	330	1650	0.691	2
Sleeping Discomfort	1121	330	1650	0.679	3
Air Pollution from Generators	1119	330	1650	0.678	4
Water Supply Interruption	1101	330	1650	0.667	5
Communication/Entertainment Disruption	1081	330	1650	0.655	6
Food Spoilage	1059	330	1650	0.642	7
Damage to Electrical Appliances	900	330	1650	0.545	8
Lateness to Work	861	330	1650	0.522	9

Source: Field Survey (2023)

Note: A (Highest Weight) = 5; N = 330

The results from Table 2 presented the Relative Importance Index (RII), which provides a more robust measure of the significance of each variable. Noise pollution from generators again emerged as the most critical impact (RII = 0.726), followed by expenditure on alternative energy sources (RII = 0.691) and sleeping discomfort (RII = 0.679). This confirms that environmental and financial burdens are at the forefront of residents' experiences during outages. Conversely, lateness to work had the lowest RII (0.522), followed by appliance damage (0.545).

The ranking demonstrates that residents are more concerned with effects that directly affect daily well-being (noise, discomfort) and financial security (high spending on alternatives) than with productivity losses such as lateness. These findings resonate with studies in Ghana (Nduhuura et al., 2021) and Nigeria (Michael & Ekong, 2018), which reported that urban households spend between 5–15% of income on generator fuel and experience health and lifestyle disruptions as more severe than workplace productivity losses.

Theoretical and Policy Implications

The results align with Protection Motivation Theory, where power outages trigger threat appraisal, with residents perceiving noise pollution, air pollution from electric power generating sets, food spoilage, and expenditure on alternatives as severe, recurring threats to health, finances, and comfort. Frequent outages and unreliable grid supply heighten vulnerability, consistent with findings in Nigeria (Abaukaka, 2023) and Ghana (Nduhuura et al., 2021). These findings underscore the need for urban energy policies in FCC Phase 1, such as subsidies for solar PV systems and noise regulations for electric power generating sets, to reduce environmental and financial burdens caused by expenditure on fuel for generators. Such measures support Sustainable Development Goal 7 for affordable, clean energy (UNDP, 2025).

CONCLUSION AND RECOMMENDATIONS

This study concludes that power outages in Federal Capital City (FCC) Phase 1, Abuja, create serious socio-economic and environmental challenges. Noise pollution from generators was identified as the most critical environmental effect, while expenditure on alternative energy sources emerged as the leading socio-economic burden. These findings highlight the need for sustainable solutions to reduce household vulnerabilities and advance Nigeria's clean energy goals under SDG 7.

From the findings of this study, the following recommendations are made:

- i. The Federal Ministry of Power, in partnership with private energy providers, should prioritise investment in renewable energy infrastructure, particularly solar photovoltaic systems, through subsidies and incentives to reduce reliance on polluting generators.
- ii. The National Environmental Standards and Regulations Enforcement Agency (NESREA) and the Federal Capital Territory Administration (FCTA) should enforce stricter regulations on generator noise and emissions, while promoting the adoption of quieter and cleaner alternatives.
- iii. Abuja Municipal Area Council (AMAC), community groups, and NGOs should collaborate on public awareness campaigns that highlight the health, economic, and environmental risks of prolonged generator use while educating households on affordable renewable energy options.
- iv. Urban planners and policymakers should integrate reliable energy supply into Abuja's development strategy, ensuring that residential districts like FCC Phase 1 are prioritised for stable electricity provision to enhance household well-being and economic productivity.

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Infrastructure Quality and Its Influence on Socio-Economic Livelihood in Peri-Urban Communities of Akure, Nigeria: A Pathway to Achieving SDG 11

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ABSTRACT

Infrastructure remains a cornerstone for achieving inclusive and sustainable urban development in the rapidly growing cities of sub-Saharan Africa. This study examined the quality of infrastructure and its impact on socio-economic livelihoods in the peri-urban areas of Akure, south-western Nigeria. It specifically focused on evaluating the current state of infrastructure in the three peri-urban communities (Oda, Adofure, and Ipinsa), examining how the quality of infrastructure affects residents' livelihoods, and suggesting planning and policy measures for inclusive and sustainable development. Utilizing stratified sampling method, 150 respondents were selected proportionally from the three neighbourhoods. Primary data were collected through structured questionnaires and analysed using descriptive statistics. Findings revealed that, out of 16 infrastructures assessed, only four (education, health, roads, and electricity) were functional across the study area. Education and health facilities were generally in fair condition and moderately accessible. Roads were widely available but often in poor condition and difficult to access during the rainy season. Electricity was fairly accessible in Oda and Adofure, but largely unreliable in Ipinsa community. The stepwise regression analysis revealed that educational facilities and road conditions were statistically significant predictors of residents' monthly income across the three peri-urban communities. Educational facilities had a positive effect ($\beta = 0.534$, $p < 0.001$), while the condition of roads had a negative effect ($\beta = -0.282$, $p = 0.004$) on income, indicating that improved access to education enhances livelihood opportunities, whereas poor road conditions hinder economic activities and progress. The study concluded that infrastructure inequality contributes to persistent livelihood disparities across peri-urban areas. It further recommends equitable provision of essential infrastructure across peri-urban communities, upgrading of existing and underperforming facilities, particularly roads and electricity, to foster inclusive and sustainable development. This aligns with SDG 11, which aims to make human settlements inclusive, safe, resilient, and sustainable in Nigeria.

KEYWORDS: Infrastructure, Inequality, Livelihoods, SDG 11, Sustainable development

INTRODUCTION

Infrastructure is universally acknowledged as a critical driver of sustainable development, underpinning many of the Sustainable Development Goals (SDGs) established by the United Nations (Thacker et al., 2019). It encompasses essential systems and services such as transportation, energy, telecommunications, governance, and public utilities that enable the functioning and development of societies (Frischmann, 2007; Memon & Bilali, 2020). Despite its significance, Africa continues to lag behind other developing regions in infrastructure provision and performance. World Bank (2017) documented that Africa's infrastructure performance ranks below all other developing regions. The report also estimates that closing the infrastructure quantity and quality gap could lift GDP per capita growth by up to 2.6% per year.

Infrastructure investment accounts for more than half of the difference in productivity between developing and developed countries. According to the African Development Bank (2022), Africa needs between \$130 billion - \$170 billion annually to meet its infrastructure demands, yet it faces an Africa financing shortfall of nearly \$100 billion each year. Idira (2014) argues that rural development faces challenges, primarily due to inadequate infrastructure, which forces rural dwellers to struggle to sustain their livelihood or to migrate to urban areas in search of better opportunities. Over 60% of the rural population has limited access to all-season roads, and only a limited share enjoys reliable electricity, safe drinking water, or adequate health and education facilities. These deficits contribute to persistent poverty, reinforce inequality, and limit opportunities for upward socio-economic mobility.

The U.S. Environmental Protection Agency (EPA, 2011) notes that rural communities with limited socio-economic resources often face challenges in managing infrastructure sustainably. Factors such as aging infrastructure, lack of funding, and insufficient technical expertise hinder these communities from maintaining and improving their essential services. The National Bureau of Statistics (2022) estimated that approximately 55% of Nigeria's rural population lacks access to clean water, and about 50% do not have electricity. Poorly maintained or non-existent road networks significantly hinder access to schools and healthcare services, impacting educational attainment and health outcomes (Adeniyi & Ogundeji, 2017; Oyelola & Oluwatosin, 2019; Osabohien et al., 2021; Omeje & Ugwunna, 2022). According to the National Bureau of Statistics (NBS, 2022), 63% of Nigerians, about 133 million people, experience multidimensional poverty, highlighting that poverty is not only about low income but also includes deprivations in health, education, living standards, and employment. These multiple deprivations affect individual well-being and constrain national goals such as food security, economic development, and social equity.

In southwestern Nigeria, Ondo State exemplifies the uneven distribution of infrastructure between urban and rural areas. The state capital, Akure, is surrounded by rural communities such as Ipinsa, Adofure, and Oda, where infrastructure remains grossly inadequate. Although, Akure town has seen expansion in road construction and public utility services, the surrounding villages remain largely underdeveloped. Many of these communities depend on

unpaved roads, lack access to clean water sources, and have limited health and educational facilities. Poor road networks increase travel time and transportation costs, limiting market access for farmers and traders. Erratic power supply undermines local businesses and affects students' learning outcomes. The lack of essential services drives rural-urban migration, contributing to urban congestion and the neglect of rural settlements. Thus, infrastructure is not just a technical concern; it is deeply connected to the socio-economic well-being of rural dwellers. In this context, this study seeks to assess the quality of infrastructure and examines its influence on the socio-economic livelihoods of residents in rural communities of Akure, Nigeria, with a view to suggesting policy and planning interventions targeted at achieving inclusive and sustainable rural development. The study addressed the following questions: What is the current state of infrastructure quality in rural communities of Akure? How does the quality of infrastructure influence the socio-economic livelihoods of residents in rural communities around Akure? And, What policy and planning interventions can be implemented to improve infrastructure quality and promote sustainable development in rural Akure?

LITERATURE REVIEW

Infrastructure encompasses both tangible structures and the services that facilitate economic activity and societal development. Oyedele (2012) & UNOPS (2019) described infrastructure as an interconnected system of assets that collectively have the potential to support the entire structure of development. The World Bank's Development Report (2004) emphasizes that infrastructure, particularly in transportation and communication, serves as a vital link between people in various geographical areas, reducing the barriers created by distance and fostering connectivity. In the same vein, United Nations (2011) noted that the role of infrastructure development in rural communities is significant due to its direct influence on agricultural productivity, which is the economic backbone of most rural areas.

Nigeria has yet to witness rapid development in rural areas, despite its major role in the process of economic liberation before the beginning of oil production (Gbadamosi & Olorunfemi, 2016). Okakunori (2006), Ugwuanyi & Chukwuemeka (2013), and Olorunfemi & Basorun (2013) revealed that the lack of infrastructural facilities has resulted in the pitiable quality of life with its consequential implications on the rural dwellers. Ekong (2003) asserted that the spread of needed infrastructure and the introduction of appropriate technology in rural areas would markedly improve the rural economy and its output. This means that infrastructural development is sine-qua-non to improving the living standard of the majority of the nation's populace. Reliable infrastructure supports job creation, facilitates access to essential services, and opens up economic opportunities, particularly for underserved populations (World Bank, 2019).

Nevertheless, several persistent challenges undermine the effective provision and sustainability of infrastructure in rural Nigeria. One of the most pressing challenges is inadequate funding and low levels of investment, as rural projects are often underfunded due to competing priorities and perceptions of limited economic return (Ayodele & Ojedokun, 2023). Consequently, rural infrastructure continues to face serious neglect, as key sectors such as roads, electrification, water supply, and sanitation remain underdeveloped (Otto *et al.*, 2025). This challenge is further worsened by the reluctance of private investors to venture into rural projects, particularly electrification, which is often considered high-risk with limited returns (Ogunjuyigbe *et al.*, 2024). More broadly, rural investments are perceived as less profitable due to low population density and limited commercial activity, further discouraging private sector participation (Arimoro, 2021). Many rural development initiatives suffer from weak governance structures, poor inter-agency coordination, and limited technical expertise. These institutional weaknesses lead to mismanagement of resources, abandonment of projects, or inefficient execution (Adeniyi, Akinrinmade & Abiodun, 2018). In several cases, the lack of consistent policies and political will hampers continuity and disrupts the progress of infrastructure delivery, especially when there are changes in government or shifts in political agendas (Olasunkanmi & Ibrahim, 2018).

Several studies have explored how infrastructure quality influences socio-economic livelihoods in rural communities, particularly in developing countries. Salisu (2018) studied the effect of socio-economic infrastructure on rural development in Katsina state, Nigeria, utilizing qualitative and quantitative methods of data analysis. Findings of the study indicated that there is a positive and significant relationship between the provision of socio-economic infrastructure and rural development. Similarly, Zakari and Chima (2021) researched the effect of socio-economic infrastructure on the rural economy in Kaduna State, Nigeria. The study adopts a correlation analysis, a Multicollinearity and Cronbach Alpha Reliability tests, as well as regression analysis on primary data. Findings from the study reveal that there is a positive relationship between socioeconomic infrastructure and rural economy. The regression analysis indicates that socio-economic infrastructure, particularly roads, electricity supply, market, and telecommunication infrastructure, all have positive and statistically significant effects on the rural economy. In the same vein, Wasurum & Kpagih (2023) worked on Socio-economic infrastructure and standard of living in Nigeria. The study used per capita income as a proxy for standard of living, while investments in health, education, telecommunications, and electric power supply were used as infrastructure. The findings revealed that the coefficient of electric power supply has a positive effect on the standard of living and is significant, while in the long run, the coefficient of telecommunication infrastructure has a positive influence on the standard of living and is significant.

In a review of rural development programmes in Nigeria, Akpan (2012) found that, despite its contribution to the national economy and GDP, rural areas in Nigeria remain very poor and deeply neglected. Investments in physical, social, and economic infrastructures have been focused largely on the cities. As a result, the rural population has

extremely limited access to services such as schools and health centres, while the highest number of the populace lacks access to safe drinking water. In the Nigerian context, the rural areas are associated with poverty and, as such, are not attractive to live in. A study conducted by Fasorsanti (2012) found a long-run relationship between the growth of the economy and government expenditure in agric, education, security, and transport. Also, Nwankwoala (2011) found that governance, government policies, and priorities are responsible for poor service in terms of infrastructure. While previous studies, such as Salisu (2018), Zakari & Chima (2021), and Wasurum & Kpagih (2023), have established a positive and statistically significant relationship between socio-economic infrastructure and rural development across various Nigerian states, they have primarily centered on aggregate state-level analyses or focused on specific economic groups such as farmers and smallholders. Similarly, the studies by Akpan (2012) & Fasoranti (2012) highlight the disproportionate infrastructural investment in urban areas compared to rural settlements, contributing to persistent poverty and socio-economic exclusion in rural Nigeria. However, little attention has been paid to community-level assessments that consider multiple types of infrastructure (e.g., roads, electricity, water, education, health) and their combined effect on the socio-economic livelihoods of rural residents. Moreover, there is a lack of evidence on how infrastructural deficiencies uniquely affect rural communities surrounding rapidly urbanizing centers like Akure, where rural-urban disparities are increasingly pronounced. This study fills this gap by assessing the current state of infrastructure, its influence on livelihoods, and proposing context-specific policy and planning interventions to enhance sustainable development in rural Akure.

CONCEPTUAL FRAMEWORK

Infrastructure refers to the essential systems and services required for the effective functioning of a society, including transportation networks, electricity, water supply, healthcare, and education (Cambridge Dictionary, 2010). It is typically categorized into economic infrastructure, such as roads, electricity, and telecommunications, and social infrastructure, like schools and health centers (Snieska & Simkunaite, 2009). In rural areas, these facilities are critical for enhancing access to services, boosting productivity, and improving livelihoods. Infrastructure goes beyond physical structures; it includes dimensions such as physical access (e.g., roads and telecommunications), economic access (e.g., affordability of services like electricity and water), and policy or institutional infrastructure (e.g., governance and regulatory systems) that support service delivery (Fung *et al.*, 2005; Torrisi, 2009).

In rural Nigeria, poor infrastructure limits market access, increases transportation costs, and affects health and education outcomes (Estache & Fay, 2007). Empirical studies show that quality rural infrastructure reduces poverty and increases income through improved agricultural productivity and economic opportunities (Fan & Zhang, 2004; Adeoye *et al.*, 2013). However, rural infrastructure in Nigeria is often underfunded and poorly maintained, with development projects plagued by political interference and a lack of community participation. These shortcomings reduce effectiveness and sustainability. Despite numerous studies on infrastructure access in Nigeria, few have explored how infrastructure quality specifically influences livelihood strategies. This study seeks to fill that gap by examining how the quality of infrastructure affects socio-economic wellbeing in rural communities around Akure.

Theoretical Framework

The provision of infrastructure as a strategy for rural development and sustainable livelihood is widely adopted by developing countries. Traditionally, this approach has been linked to the trickle-down theory of development, which suggests that economic growth in urban or core areas will eventually benefit rural or peripheral areas through a flow or "trickle-down" effect (Oguzor, 2011). This theory, originally postulated by economist Hirschman in 1958, assumes that growth spreads evenly across regions, ensuring balanced development. However, this assumption has been challenged by the Growth Pole Theory, which provides a more nuanced understanding of spatial development. According to Perroux (1955), growth does not occur uniformly across an economy but rather concentrates in specific points or "poles" of development. These poles act as centers of economic activity that attract resources and investment (centripetal forces) and, over time, generate outward effects (centrifugal forces) that stimulate growth in surrounding areas. Obateru (2006) describes a growth pole as a focal point from which developmental influences radiate throughout its field of influence.

The Growth Pole Theory has become a fundamental concept in regional and rural development planning because it recognizes the uneven nature of growth and the importance of strategic investment in key locations to stimulate broader regional development. Okafor & Onokerhoraye (1986) highlight that this model allows for an integrated approach, encompassing both urban and rural areas within the national spatial economy, thereby avoiding the pitfalls of uneven or "parasitic" development. Similarly, Ayeni (1980) argues that growth poles, as spatial development systems, can prevent imbalanced growth that disadvantages peripheral regions. In this study, the Growth Pole Theory provides a robust theoretical framework for understanding how targeted infrastructure development in specific rural areas can catalyze sustainable livelihoods and broader regional growth.

MATERIALS AND METHODS

The study was conducted in selected rural communities within the Akure region, the capital of Ondo State, Nigeria. Geographically, Akure is located between Latitude 7°15' and 7°17" North and Longitude 5°14' and 5°15" East, covering an estimated land area of 340 km² (Ojo *et al.*, 2014). The selected rural communities, Adofure (7.1904° N, 5.1667° E), Oda (7.1384° N, 5.2580° E), and Ipinisa (7.3210° N, 5.1445° E), are situated on the rural periphery of

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Akure and are gradually transitioning due to urban expansion and population growth (Figures 1,2, and 3). Despite their proximity to the city, these communities continue to grapple with inadequate infrastructure, such as poorly maintained roads, unreliable electricity supply, insufficient access to clean water, and weak health and educational facilities. These infrastructural challenges hinder mobility, reduce economic opportunities, and limit access to essential services, thereby impacting the socio-economic livelihoods of residents. The study adopted a social survey design comprising a pilot and full-scale survey to evaluate the quality of infrastructure in these areas and assess how it affects residents' economic activities, well-being, and access to services. The research further aims to provide evidence that can guide policy and planning interventions toward enhancing infrastructure quality and promoting sustainable rural development in the Akure region.



Figure 1: Ondo State Map within the National Setting
Source: Adapted from Akinluyi et al. (2021)

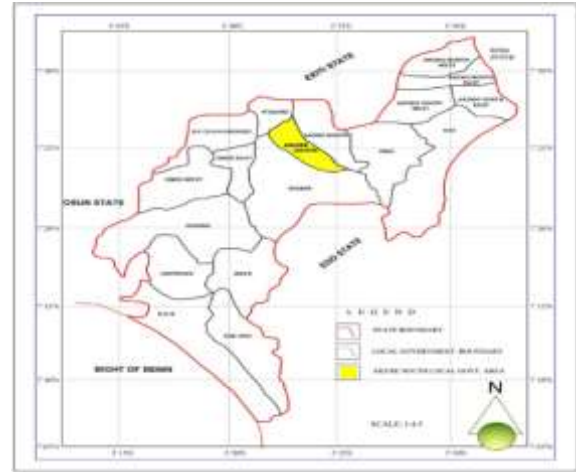


Figure 3: Ondo State Map Showing Akure South LGA
Source: Adapted from Akinluyi et al. (2021)

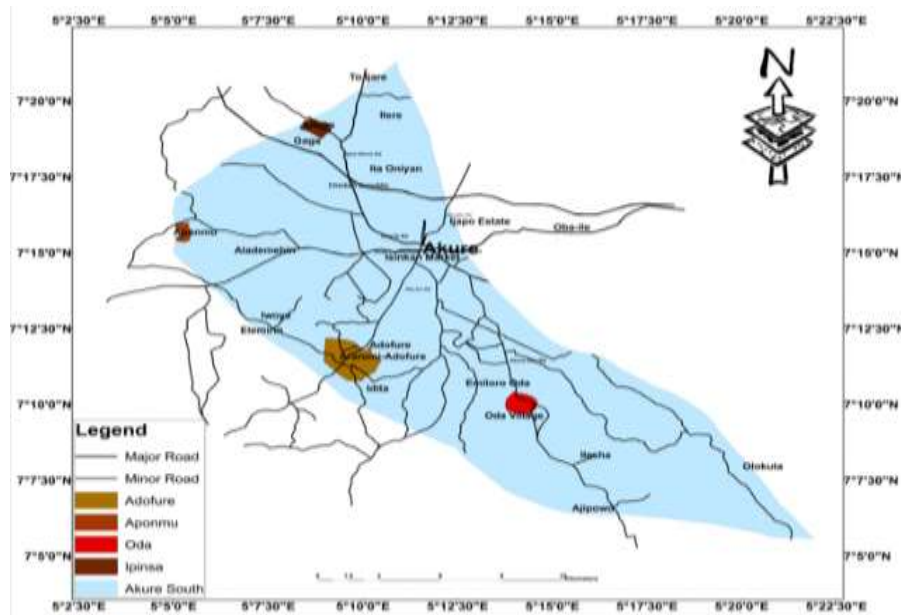


Figure 3: Akure South Local Govt. Map Showing Selected Peri-urban Areas
Source: Akure South LGA (2014) and Authors' Updated Version (2025)

Research Design

A mixed-method approach was adopted to address the research objectives. Quantitative methods were employed to assess the current state of infrastructure quality, while regression analysis was used to explore how infrastructure influences the socio-economic livelihoods of residents.

Data Collection

A building demographic survey of the research area was conducted using Geographic Information Systems (GIS) to digitize Google Earth imagery and identify 3006 buildings from which 5% (245 individuals) were systematically sampled to participate in a questionnaire survey. This sample size was deemed adequate given the homogeneity of the study area in terms of physical morphology, socio-economic background, cultural characteristics, and linguistic uniformity. For the qualitative component, data were collected through semi-structured interviews and focus group

discussions with selected community members and local stakeholders. These qualitative methods aimed to explore residents' perceptions, experiences, and challenges related to infrastructure quality and its impact on their socio-economic livelihoods. Participants were purposively selected to ensure representation from different demographic and occupational groups within the rural communities.

Table 1. The number of buildings in the selected study areas

Sample Unit	Approximate distance From the city center (km)	Population of Residential Buildings	Sample taken at 5%
Ipinsa	10.72	843	42
Adofure	8.38	1046	52
Oda	12.14	1117	56
Total		3006	150

Source: Author's field survey (2025)

Stepwise Multiple Regression Analysis

Stepwise multiple regression analysis was employed to examine the influence of infrastructure quality on the socio-economic livelihoods of residents in the study area. This method helps identify the most influential predictors among the independent variables, which include: Electricity, Educational facilities, Road, and Public health facilities.

The regression model can be expressed as:

- $Y = a + b_1X_1 + b_2X_2 + b_3X_3 + \varepsilon$, where
- a = Constant
- b_1 -Regression coefficients
- X_1 - poor building maintenance
- X_2 - Lack of access to essential amenities
- ε - Error term

Data Analysis

Quantitative data collected through questionnaires were analyzed using descriptive and inferential statistics to evaluate the quality of infrastructure and its influence on livelihoods. Qualitative data from interviews and focus group discussions were analyzed thematically to capture residents' perceptions and experiences regarding infrastructure and socio-economic well-being. The findings from both analyses were synthesized to propose policy and planning interventions aimed at improving infrastructure quality and promoting sustainable socio-economic development in the rural communities of Akure.

FINDINGS AND RESULTS

An evaluation of infrastructure availability in the rural areas of Adofure, Ipinsa, and Oda provides important insights into how infrastructure quality impacts socio-economic livelihoods in Akure, Nigeria. The results indicate that Oda has a notably higher presence of essential infrastructure, particularly in terms of roads (83.3%), health facilities (80.8%), and educational institutions (70.5%). These amenities are crucial for facilitating transportation, providing healthcare access, and fostering human capital development, all of which are key elements for sustainable rural livelihoods. Nevertheless, despite this relative advantage, the region still faces significant challenges with limited access to drainage (9%), electricity (19.2%), and water supply (41%), which could obstruct productivity, particularly in household and agricultural activities that heavily depend on clean water and dependable power.

In contrast, Adofure exhibits a similar trend regarding the availability of critical social infrastructure such as roads (89%), health services (80.8%), and education (72.6%), which may aid fundamental livelihood functions. However, it is marked by a total absence of water facilities, public restrooms, markets, and banking services, along with a severely restricted electricity supply (4.1%). These shortcomings can greatly hinder income-generating possibilities, limit access to financial resources, and diminish the overall effectiveness of daily socio-economic activities. Ipinsa, conversely, seems somewhat better equipped in terms of basic utilities, with electricity access at 71% and a modest presence of water facilities (10.2%), as well as strong coverage in health (84.7%) and education (79.7%). The presence of a police/security post (64.4%) in Ipinsa further augments the feeling of safety and institutional presence, which can promote both formal and informal economic endeavors.

Overall, the examination of the three communities highlights a vital connection between the quality of infrastructure and socio-economic outcomes. While access to roads, healthcare, and educational institutions is comparably consistent and serves as a foundational basis for rural development, the absence of essential services such as water, electricity, sanitation, and economic infrastructure restricts the full potential of these communities. These deficiencies impact both the quality of life and the ability of residents to diversify their livelihoods beyond subsistence farming. Consequently, enhancing the quality and distribution of rural infrastructure, especially in underdeveloped sectors, remains essential for improving socio-economic resilience and encouraging inclusive rural development in Akure and similar contexts.

Table 2: Availability of Infrastructure in Adofure and Ipinsa Communities

S/N	Infrastructural Facilities	Adofure			Ipinsa		
		Yes	No	%	Yes	No	%
1	Roads	89	11	100	81	19	100
2	Drainage Channel	16.4	83.6	100	8.4	91.6	100
3	Public Toilet	0	100	100	0	100	100
4	Post Office	0	100	100	0	100	100
5	Open Market	0	100	100	0	100	100
6	Electricity	4.1	96	100	71	29	100
7	Water facilities	0	100	100	10.2	89.8	100
8	Educational Facilities	72.6	27.4	100	79.7	20.3	100
9	Health facilities	80.8	19.2	100	84.7	15.3	100
10	Filling station	86.3	13.7	100	0	100	100
11	Waste management	0	100	100	0	0	100
12	Recreation centre	0	100	100	0	0	100
13	Shopping complex	0	100	100	0	0	100
14	Banking Institution	0	100	100	0	0	100
15	Police/Sec. Post	0	100	100	64.4	35.6	100
16	Civic Centre	0	100	100	0	0	100

Source: Field Work, 2025

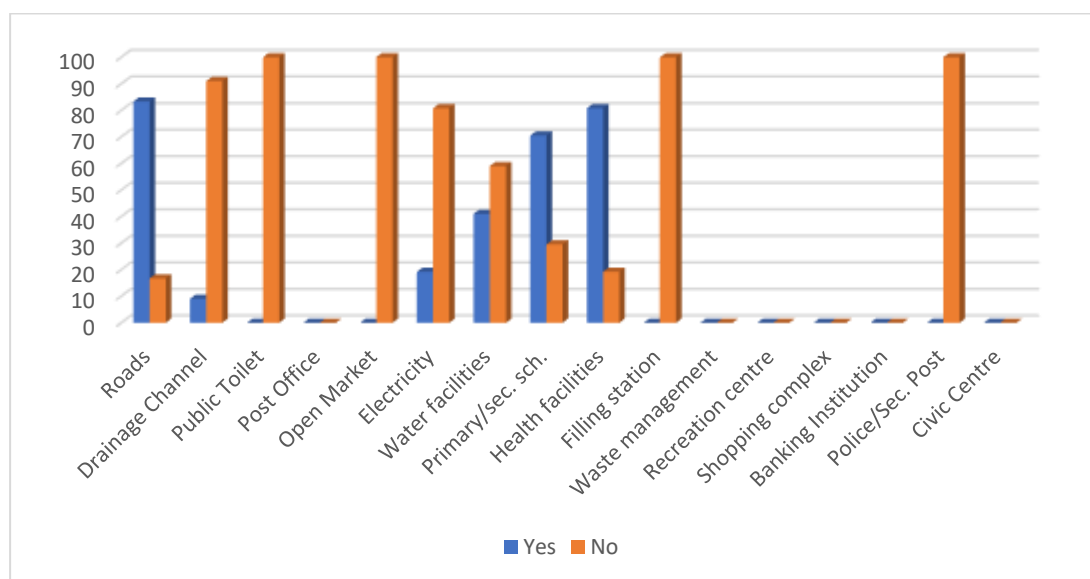


Figure 4: Availability of Infrastructure in Oda Community

Source: Field Work, 2025

Functionality of Infrastructure in Adofure, Oda, and Ipinsa Communities

The functionality of infrastructure in the three communities shows both strengths and weaknesses that directly affect the well-being and livelihoods of residents. In Adofure, electricity (86.3%) and educational facilities (91.8%) are largely functional, contributing to learning opportunities, household stability, and overall community development. However, the situation of roads (41.1%) and health facilities (11%) presents challenges that may restrict mobility, access to healthcare, and the overall effectiveness of service provision (See Figure 6). Poor road conditions limit mobility, reduce access to markets, schools, and jobs, and restrict emergency response, while weak health infrastructure compromises residents' access to quality healthcare.

In Ipinsa, most key facilities perform relatively well. Roads (71.2%), electricity (86.4%), health services (84.7%), and education (86.4%) are functional. Nevertheless, the water supply presents a serious challenge, with nearly half of the facilities not functional (42.4%). This situation undermines public health, food production, and women's welfare, since access to clean water is essential for hygiene and daily living. The water challenge remains the most pressing threat to sustainable livelihoods within the community. A functional police post (62.7%) provides a measure of safety and order, which is important for maintaining social stability, protecting livelihoods, and encouraging economic activities (See Figure 7). In Oda, education (82.1%) and health facilities (87.2%) are mostly functional, contributing positively to human development. However, electricity infrastructure is in critical condition, with only 5.1% functional and more than 94% either non-functional or moribund. This lack of reliable power supply severely limits business opportunities, reduces productivity, and affects modern living standards. Road infrastructure is also poor, with 28.8% moribund and 12% not functional, creating barriers to transportation, trade, and social interaction (See Table 3). Overall, the findings indicate that while all three communities have some functional infrastructure, persistent deficiencies in roads, electricity, health, and water services continue to weaken residents' socio-economic livelihoods.

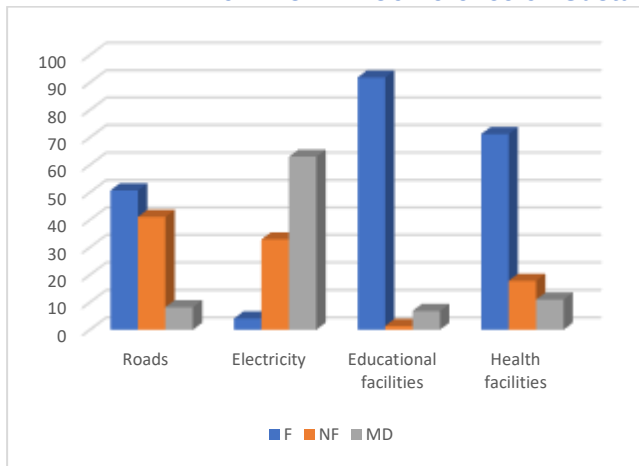


Figure 6: Functionality of Infrastructure in Adofure Community
Source: Field Work, 2025

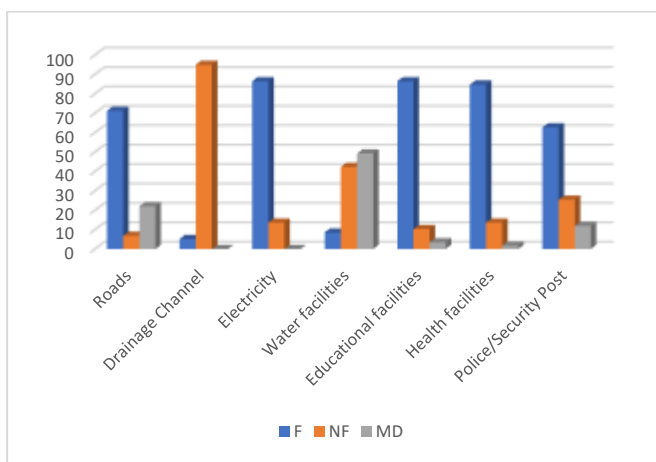


Figure 7: Functionality of Infrastructure in Ipinsa Community
Source: Field Work, 2025

Table 3: Functionality of Infrastructure in Oda Community

Oda			Functionality (%)		
S/N	Infrastructural	Not functional	Functional	Moribund	Total
1	Roads	12	60.3	28.8	100
2	Electricity	43.6	5.1	51.3	100
3	Educational Facilities	17.9	82.1	0	100
4	Health facilities	9	87.2	3.8	100
5	Drainage Channel	0	0	0	0
6	Public Toilet	0	0	0	0
7	Police post	0	0	0	0

Source: Field Work, 2025

Condition of Infrastructure in Adofure, Oda, and Ipinsa communities

Analysis in Table 4 reveals the condition of public health facilities in Adofure rated moderately well, with many respondents perceiving them as good or very good. However, major concerns emerge regarding education and electricity. Nearly three-quarters of educational facilities (73%) are rated as bad or very bad, suggesting that the environment for learning is severely constrained and may weaken opportunities for skill acquisition and long-term human capital development. Even more critical is electricity, with close to 89% of respondents rating it as bad or very bad. Such poor power conditions restrict productivity, limit small-scale business operations, and reduce access to modern services that are essential for improving rural livelihoods. Road conditions are more mixed, yet about a quarter fall into bad or very bad categories, posing risks to mobility and limiting access to healthcare, markets, and other services vital for sustaining economic life.

Ipinsa presents a more favorable scenario where public health, educational, and electricity infrastructures are largely rated as good or very good. This relatively strong performance across essential sectors supports better socio-economic outcomes by facilitating access to healthcare, providing a conducive learning environment, and enabling electricity-dependent activities such as trading, artisan work, and information access. Despite these advantages, the road network stands out as a major weakness, with almost 60% rated very bad. Such poor road conditions could isolate communities,

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increase transport costs, and constrain access to markets, thereby diminishing the economic gains made possible by other functional infrastructure. Moreover, Oda community faces severe challenges with roads and electricity. More than 58% of its roads are rated bad, and about 80% of its electricity infrastructure is also rated bad or very bad. These conditions directly translate into socio-economic disadvantages: poor roads hinder the movement of goods and people, limit trade opportunities, and restrict timely access to services, while unreliable electricity undermines business productivity, affects educational activities, and lowers overall quality of life. Taken together, the findings highlight that while health and education facilities in these communities are relatively supportive of socio-economic well-being, the critical deficits in electricity and road infrastructure represent major bottlenecks. These weaknesses undermine rural residents' ability to fully exploit livelihood opportunities, reduce economic productivity, and perpetuate cycles of poverty, thus demonstrating the strong influence of infrastructure quality on socio-economic livelihoods in rural Akure.

Table 4: Condition of Infrastructure in Adofure, Oda, and Ipinsa

ADOFURE	VG	G	F	B	VB	Total
Public Health facilities	16(30.77%)	12 (23.08%)	24 (46.15%)	0 (0.00%)	0 (0.00%)	52(100%)
Road Condition	3 (5.77%)	11 (21.15%)	25 (48.08%)	5 (9.62%)	8 (15.38%)	52(100%)
Educational facilities	0 (0.00%)	0 (0.00%)	14 (26.92%)	28 (53.85%)	10 (19.23%)	52(100%)
Electricity	0 (0.00%)	0 (0.00%)	6 (11.54%)	27 (51.92%)	19 (36.54%)	52(100%)
Total	19 (9.13%)	23 (11.06%)	69 (33.17%)	60 (28.85%)	37 (17.79%)	208(100%)
IPINSA	VG	G	F	B	VB	Total
Public Health facilities	14 (33.33%)	18 (42.86%)	10 (23.81%)	0 (0.00%)	0 (0.00%)	42(100%)
Road Condition	0 (0.00%)	0 (0.00%)	0 (0.00%)	17 (40.48%)	25 (59.52%)	42(100%)
Educational facilities	16 (38.10%)	20 (47.62%)	6 (14.29%)	0 (0.00%)	0 (0.00%)	42(100%)
Electricity	11 (26.19%)	22 (52.38%)	9 (21.43%)	0 (0.00%)	0 (0.00%)	42(100%)
Total	41 (24.40%)	60 (35.71%)	25 (14.88%)	17 (10.12%)	25 (14.88%)	168(100%)
ODA	VG	G	F	B	VB	Total
Public Health facilities	13 (23.21%)	17 (30.36%)	26 (46.43%)	0 (0.00%)	0 (0.00%)	56(100%)
Road Condition	0 (0.00%)	0 (0.00%)	0 (0.00%)	33 (58.93%)	23 (41.07%)	56(100%)
Educational facilities	12 (21.43%)	27 (48.21%)	17 (30.36%)	0 (0.00%)	0 (0.00%)	56(100%)
Electricity	1 (1.79%)	0 (0.00%)	10 (17.86%)	31 (55.36%)	14 (25.00%)	56(100%)
Total	26 (11.61%)	44 (19.64%)	53 (23.66%)	64 (28.57%)	37 (16.52%)	224 (100%)

Source: Field Work, 2025

Accessibility to Infrastructure in Adofure, Oda, and Ipinsa

An examination of Table 5 indicates that approximately one-third of the residents in the Oda community face inadequate access to essential infrastructure. The most critical issue is electricity, with over two-thirds of the community lacking access, while only a small portion experiences a reliable supply. Public health facilities also show poor performance, as more than a third of residents do not have access. Roads and schools provide moderate accessibility, with only limited percentages of residents benefiting from these services. In Adofure, the situation is even more severe, with nearly two-fifths of residents excluded from basic services. Electricity and healthcare are the primary concerns, as more than half of the residents do not have access to these amenities within their communities. Meanwhile, roads fare relatively better, with more than half of the residents able to access these facilities. In contrast, Ipinsa shows a lower level of deprivation, with around 30.4% of residents lacking access to essential infrastructure. Electricity and road access perform notably better than in the other communities, as a majority of residents report having access to these services. However, healthcare and education still pose significant challenges, with approximately half of the residents lacking access to health facilities and over a third reporting no access to schools in their community. In summary, the results highlight that electricity and healthcare represent the most significant deficiencies across the three communities, and their absence directly limits livelihood opportunities and diminishes quality of life. While road networks perform comparatively better, enhancing mobility and access to markets, educational institutions, and other resources, the presence of good roads cannot adequately substitute for the lack of dependable electricity and sufficient healthcare. Therefore, improving access to these two fundamental services is crucial for reducing deprivation, enhancing overall well-being, and promoting inclusive development in the peri-urban regions of Akure.

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Table 5: Accessibility to Infrastructure in Adofure, Oda, and Ipinsa

ODA	NA	FA	A	VA	Total
Public Health facilities	20 (35.7%)	12 (21.4%)	16 (28.5%)	8 (14.2%)	56 (100%)
Road Condition	6 (10.7%)	24 (42.8%)	15 (26.8%)	11 (19.6%)	56 (100%)
Educational facilities	9 (16.1%)	23 (41.1%)	14 (25%)	10 (17.9%)	56 (100%)
Electricity	38 (67.8%)	7 (12.5%)	3 (5.35%)	8 (14.2%)	56 (100%)
Total	73 (32.59%)	66 (29.46%)	48 (21.43%)	37 (16.52%)	224 (100%)
ADOFURE	NA	FA	A	VA	TOTAL
Public Health facilities	27 (51.9%)	8 (15.4%)	13 (25%)	4 (7.6%)	52 (100%)
Road Condition	1 (1.92%)	3 (5.8%)	20 (38.5%)	28 (53.8%)	52 (100%)
Educational facilities	19 (36.5%)	17 (32.7%)	9 (17.3%)	7 (13.5%)	52 (100%)
Electricity	36 (69.23%)	6 (11.5%)	7 (13.5%)	3 (5.8%)	52 (100%)
Total	83 (39.90%)	34 (16.35%)	49 (23.56%)	42 (20.19%)	208 (100%)
IPINSA	NA	FA	A	VA	TOTAL
Public Health facilities	21 (50%)	5 (11.9%)	12 (28.6%)	4 (9.5%)	42 (100%)
Road Condition	8 (19%)	7 (16.7%)	20 (47.6%)	7 (14.7%)	42 (100%)
Educational facilities	16 (38.1%)	14 (33.3%)	2 (4.8%)	10 (23.8%)	42 (100%)
Electricity	6 (14.3%)	10 (23.8%)	18 (42.8%)	8 (19.0%)	42 (100%)
Total	51 (30.36%)	36 (21.43%)	52 (30.95%)	29 (17.26%)	42 (100%)

Source: Field Work, 2025

Socio-Economic Livelihood Characteristics of Residents

This section examines the socio-economic livelihood characteristics of residents in the study area by analyzing key variables, including occupation, household income, educational attainment, and household size. These indicators provide insight into the economic activities, income levels, educational background, and living conditions of the population, which are essential for understanding their overall livelihood status and well-being. Findings from the occupation of the respondents revealed that 38% of respondents were artisans engaged in various trades such as carpentry, tailoring, and mechanics, while 29.4% were traders operating small businesses within the community. Civil servants made up 19.6%, and farmers accounted for 13.1% of the respondents. Analysis of household income indicated that a significant portion of residents earned below the national minimum wage of ₦30,000 per month, with 64.1% earning less than this threshold. Specifically, 9.8% earned below ₦10,000, 34.7% earned between ₦11,000 and ₦20,000, and 19.6% earned between ₦21,000 and ₦30,000 monthly. This income distribution suggests prevalent poverty and deprivation, impacting residents' ability to afford quality housing and adequate nutrition. Moreover, education levels were generally low, with 35.1% having no formal education. Secondary education was attained by 27.3%, primary education by 18.4%, while only 11.4% and 7.8% had tertiary and postgraduate education, respectively. Low educational attainment may undermine awareness of environmental and health standards, affecting community livability. Household size was relatively large, with 39.6% of respondents living in households of 7-9 persons and an average household size of 8 persons per dwelling. Such overcrowding poses significant health risks and can strain household resources, further influencing livelihood quality.

Regression Analysis: Impact of Infrastructure Quality on Socio-Economic Livelihoods

The result of the stepwise regression analysis revealed that among the four infrastructure components examined, only the condition of roads and education facilities had significant predictive power on residents' monthly income in peri-urban Akure. The remaining variables, electricity and public health condition, were excluded from the final model. As shown in the Model Summary, the two regression models demonstrated a progressive improvement in explaining the variance in residents' income. Model 1, which included only the condition of educational facilities as a predictor, accounted for 25.3% of the variance in monthly income ($R^2 = 0.253$). When road condition was added in Model 2, the explained variance increased to 29.5% ($R^2 = 0.295$). This progression indicates that both the quality of educational facilities and roads significantly influence income levels in peri-urban communities.

Table 5: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.503a	.253	.247	1.181
2	.543b	.295	.285	1.151

Please Note: Model 1: $Y = 1.291 + 0.581x_1$ / Model 2: $Y = 2.540 + 0.534x_1 + 0.282x_2$

Source: Author's Compilation, 2025

As presented in the Coefficients table, the regression results highlight the importance of educational facilities and road infrastructure in shaping income outcomes. In Model 1, educational facilities had a positive and statistically significant coefficient ($B = 0.581$, $p < 0.001$), indicating that improvements in educational infrastructure are strongly associated with higher income levels. In Model 2, the condition of educational facilities remained a significant predictor ($B = 0.534$, $p < 0.001$), while road condition also emerged as a significant contributor ($B = -0.282$, $p = 0.004$). The negative

coefficient for road condition implies that deteriorating road quality is associated with a reduction in income levels, underscoring the role of road infrastructure in facilitating access to jobs, markets, and essential services. Based on the findings from the regression analysis, the null hypothesis, which posited that there is no significant relationship between infrastructure quality and residents' income, is rejected. The results affirm a statistically significant relationship between the state of infrastructure and socio-economic livelihoods in peri-urban Akure.

Table 6: Regression coefficient

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	1.291	.237		5.453	.000
Educational facilities	.581	.082	.503	7.071	.000
(Constant)	2.540	.481		5.284	.000
Educational facilities	.534	.082	.462	6.552	.000
Condition of the road	-.282	.095	-.209	-2.962	.004

Dependent Variable: Monthly Income

Source: Author's Compilation, 2025

CONCLUSION AND RECOMMENDATIONS

This study assessed the quality of infrastructure and its influence on the socio-economic livelihoods of residents in peri-urban communities of Akure, Nigeria. Out of the sixteen types of infrastructure investigated, only four, namely water supply, electricity, roads, and educational and health facilities, were available to residents. However, even among these, only a few were functional, while most were in poor condition and unable to adequately meet community needs. Although roads were physically present in many locations, their poor state significantly limited accessibility, increased travel costs, and undermined their potential contribution to economic activities. Similarly, educational and health facilities, though available, were unevenly distributed and poorly maintained, restricting their role in enhancing human capital and well-being. Based on these findings, the following recommendations are proposed:

1. Government and planning authorities should prioritize a holistic infrastructure development approach. Rather than isolated or politically motivated projects, efforts must focus on integrated planning that ensures the simultaneous availability of basic infrastructure such as roads, water, electricity, and education in all peri-urban communities.
2. Many of the existing facilities, especially roads and schools, are in poor condition. Immediate interventions are needed to rehabilitate and maintain these structures. For roads, improving surface conditions and drainage would enhance accessibility, reduce travel time, and facilitate better economic integration.
3. Governments should encourage PPPs in infrastructure delivery, especially in sectors like electricity and water supply, where private innovation and efficiency can complement public goals.
4. Infrastructure projects should be guided by spatial equity and actual needs rather than political considerations. Communities lacking basic services must be identified and prioritized to reduce disparities and foster inclusive development.
5. Residents of peri-urban communities should be involved in infrastructure planning and maintenance. Community-based strategies, including training for local management of infrastructure, will increase ownership, reduce vandalism, and improve sustainability.

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Assessment Of User Preferences Towards Daylighting In University Libraries

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ABSTRACT

As sustainable design principles increasingly shape higher education facilities, effective daylighting strategies are vital for enhancing comfort, productivity, and energy efficiency in university libraries. Despite the technical advancements in daylighting design, limited attention has been given to understanding user preferences, satisfaction, and behavioural responses within naturally lit library environments, particularly in hot climate regions like Niger State, Nigeria. This study aims to assess user preferences to daylighting conditions in university libraries, with particular emphasis on how natural lighting influences spatial use, visual comfort, and overall learning experience. The research adopts a quantitative method approach, to capture both user experiences and architectural performance of daylighting in university libraries. Data were obtained from students, academic staff, and administrators to examine how daylight conditions such as window orientation, shading control, daylight penetration, and glare affect reading behaviour, spatial choices, and visual comfort. Quantitative and qualitative analyses reveal a strong user preference for naturally lit spaces, which are associated with improved concentration and well-being. However, dissatisfaction was recorded in zones with excessive glare or thermal discomfort, leading to avoidance of certain areas despite their intended use. The findings highlight the importance of incorporating post-occupancy user feedback into daylighting evaluation and highlight the need for user-inclusive, climate-responsive design frameworks. This study concludes that there should be balance of daylight accessibility with user comfort in the development of sustainable university libraries within hot tropical climates so as to aid achieving sustainable and functional learning environments in Nigeria's climatic setting.

Keywords: Daylighting, User Satisfaction, University Libraries, Visual Comfort, Behavioural Response, Sustainable Design

INTRODUCTION

Indoor environmental quality has a well-established influence on occupant well-being, particularly in educational buildings where users spend long hours engaged in cognitively demanding tasks (Boubekri et al., 2020). Among the determinants of this quality, daylighting is central to enhancing visual comfort, productivity, and energy efficiency. Yet, despite abundant sunlight in tropical climates such as Nigeria's, university libraries often fail to optimize its use due to ineffective architectural design strategies (Bakr & Nagy, 2020). This results in excessive reliance on artificial lighting, glare-related discomfort, and elevated operational costs (Swaris & Perera, 2023).

Daylighting directly shapes the spatial qualities of library reading environments, with significant implications for user satisfaction and sustained academic engagement (Aram & Alibaba, 2018). However, many institutional buildings in West Africa remain poorly adapted to their climatic context, revealing a persistent disjunction between building design and the region's daylighting potential (Ayoosu, 2020). Poorly moderated exposure often leads either to under-illumination, which reduces visibility, or overexposure, which causes glare and discomfort (Baker & Steemers, 2022). These shortcomings are compounded by widespread electricity shortages, making dependence on artificial lighting both costly and unsustainable (Mebarki et al., 2021; Christiana et al., 2024).

Although the benefits of daylighting in academic environments are widely documented (Bellia et al., 2024), Nigerian university libraries continue to rely on generic, imported design solutions that are misaligned with local climatic and cultural conditions (Okonkwo & Dauda, 2021; Eze et al., 2020). A recurrent problem is the mismatch between spatial zoning such as reading areas, collaborative zones, and digital labs, and the quality or controllability of daylight these zones receive. This often results in poor daylight distribution, glare-related discomfort, and reduced spatial efficiency (Udoakah et al., 2022).

Despite these issues, limited research has examined how user preferences and behaviours such as seating choice, duration of stay, or time-of-day use, mediate the performance of daylighting strategies in Nigerian university libraries. This under-researched area is necessary because architectural solutions that overlook user-centred dynamics risk failing to achieve their intended outcomes. Addressing this gap, the present study investigates how climate-responsive, spatially aligned, and behaviourally informed daylighting strategies can enhance user comfort, satisfaction, and overall performance in university library settings.

LIBRARIES, SPATIAL EVOLUTION, AND ENVIRONMENTAL QUALITY

Libraries have historically functioned as repositories of knowledge, cultural heritage, and collective memory. Despite technological advances and the near-ubiquity of digital resources, they continue to serve as vital academic and social infrastructures (Eze & Adedeji, 2020). In the present-day, their role extends beyond storing collections to facilitating collaborative learning, research, exhibitions, and recreation. As stated by Nguyen and Partridge (2020), this diversification in function has redefined libraries as multifaceted spaces whose architectural quality directly influences patterns of use, user satisfaction, and long-term relevance. As a result of the evolution of these institutions from static repositories into vibrant academic hubs, the environmental conditions of their interiors

became a central concern. Among these, lighting which consists of both natural and artificial emerges as a defining component of the architectural identity of libraries.

As stated by Knoop et al. (2020), daylighting refers to the controlled admission of natural light into a building through apertures such as windows, clerestories, skylights, and light wells. More than an aesthetic device, it is widely recognized as a fundamental environmental strategy with implications for energy performance, cognitive functioning, and overall well-being (Boubekri et al., 2020). In addition, Cheung and Suen (2021), highlighted the physiological benefits of daylight stating that, exposure to high-quality natural light regulates circadian rhythms, enhances mood, reduces visual fatigue, and improves concentration during academic tasks.

Historically, daylight was the primary source of illumination in institutional and residential buildings until the widespread adoption of gas and electric lighting in the nineteenth century (Mohamed et al., 2022). Okonkwo and Dauda (2021) asserted that, even in traditional African architecture, strategies such as shaded openings, compact volumes, and courtyard arrangements demonstrated an early awareness of the climatic implications of daylight and heat. Moreso, in the Nigerian situation, where energy supply is often unstable, reliance on artificial lighting is not always feasible, thereby reinforcing the necessity of climate-responsive daylighting.

Conversely, daylighting in tropical climates introduces risks of glare and overheating. For instance, Ogunlade et al. (2023) found that unshaded glazing in institutional buildings contributed significantly to heat gain, adversely affecting user comfort during extended occupancy periods. This duality of daylight as both an asset and a liability makes strategic integration of shading devices, selective glazing, and reflective surfaces indispensable. Consequently, daylighting should not be considered a passive environmental factor but an active design tool that requires deliberate standardization to achieve thermal and visual balance.

DAYLIGHTING AND USER SATISFACTION

The studies of Kim et al. (2021) and Chowdhury et al. (2018) reveal the strong correlation between daylight availability and user satisfaction in educational and workplace settings. As opined by Kim and Casement (2024), adequate daylight enhances mood, alertness, and productivity, whereas environments dominated by artificial light are often associated with discomfort, fatigue, and reduced cognitive engagement. Satisfaction is not determined solely by the presence of daylight but also by the degree of user control over it. Ismail et al. (2020) report that user-adjustable shading systems and operable windows significantly improve perceived satisfaction by allowing individuals to modulate glare and brightness. This finding highlights the importance of adaptable environmental systems in supporting diverse user preferences. In libraries, where users often spend long hours on visually demanding tasks, control mechanisms become central to sustaining comfort and engagement.

Daylight is also an active psychological stimulus that influences emotional well-being and spatial behaviour. According to Lee and Kim (2020), well-lit spaces tend to be perceived as more open, welcoming, and conducive to concentration, while dimly lit or glare-prone spaces may induce perceptions of crowding, stress, or disorientation. These perceptions directly shape user preferences for seating, task performance, and patterns of movement within libraries. Thus, the relationship between daylight and satisfaction is not merely instrumental but experiential, linking physiological, psychological, and behavioural perspectives.

DAYLIGHTING IN LIBRARY ENVIRONMENTS

Libraries represent a unique situation for daylighting research because of their extended occupancy patterns and diverse functional zones. Reading areas, in particular, demand high levels of visual comfort over long durations, making the provision of balanced daylight a critical architectural consideration (Zomorodian et al., 2019). Garcia-Fernandez & Omar (2023) asserted that, while artificial lighting technologies have advanced considerably, natural daylight remains unmatched in its ability to enhance cognitive performance and reduce energy use which is corroborated by the study of Riffat et al. (2024). However, architectural and spatial constraints often limit daylight penetration in deep-plan libraries. Strategies such as clerestory glazing, light wells, and reflective surfaces have been shown to improve distribution, while design standards recommend illuminance levels of 300–500 lux for reading and writing activities (IESNA, 2021). In tropical regions such as Nigeria, orientation and shading become particularly important, as poorly designed fenestration can result in thermal discomfort and excessive glare (Ogunlade et al., 2023).

Therefore, beyond functional performance, daylight contributes to spatial and social perception within libraries. Sadeghi et al. (2021) note that brighter, naturally lit environments reduce feelings of crowding and improve tolerance for proximity, while poorly lit spaces heighten sensitivity to personal space and privacy. These behavioural responses highlight that daylighting influences not only visual comfort but also the social affordances of academic spaces. Meanwhile, the Nigerian situation presents additional layers of significance. With inconsistent electricity supply, libraries that effectively harness daylight can reduce reliance on artificial systems while simultaneously promoting user comfort. This dual imperative of sustainability and usability reinforces the value of investigating user preferences for daylighting in university libraries.

DAYLIGHTING STRATEGIES AND TECHNIQUES

Architectural strategies for daylighting typically encompass orientation, building form, glazing, and shading devices. While their technical details are well established, their relevance for this study lies in how they affect user comfort and satisfaction. For example, orientation along the north–south axis is widely recommended to optimize daylight while reducing unwanted heat gain (Qahtan et al., 2024). Similarly, narrow building footprints and multi-wing configurations allow for greater penetration of daylight compared to compact square forms (Tregenza & Wilson, 2013). However, while transparent glazing maximizes daylight, it also increases glare and solar gain, requiring the integration of shading systems (Beltrán et al., 1997), as such, advanced strategies, such as light shelves, have been shown to increase horizontal illuminance by up to 25% and reduce glare potential without compromising energy efficiency (Hao et al., 2021).

Importantly, shading, in particular, represents an important factor. External overhangs, dynamic blinds, and internal light shelves offer varying degrees of control, with studies showing that well-designed systems significantly enhance visual comfort and reduce energy consumption (Konis, 2018; Wang et al., 2020). In Nigerian libraries, where high solar intensity is a constant factor, adaptive shading systems may be the most effective means of balancing user comfort with energy performance (Lawal & Agboola, 2023). Collectively, these strategies highlight that daylight performance is context-dependent, requiring careful alignment of environmental control with user needs. For this study, the focus lies less on their technical optimization and more on how users perceive and evaluate their outcomes in terms of satisfaction, comfort, and usability.

METHODOLOGY

This study adopted a quantitative method design to capture both user experiences and architectural performance of daylighting in university libraries. Quantitative data were generated from a structured questionnaire survey. The research was conducted in Minna, Niger State, Nigeria, a city within the tropical savannah climate zone where daylight management is critical for comfort and energy efficiency. Empirical data were obtained from users of the Federal University of Technology, Minna (FUTMINNA) Library, which served as a representative case for assessing existing daylighting conditions. The study targeted undergraduate and postgraduate students, academic staff, and library facility managers at FUTMINNA, owing to their frequent engagement with library spaces. A purposive sampling strategy ensured participation from informed respondents with direct experience of daylighting conditions. A total of 200 valid responses were analysed, providing a statistically sufficient sample size to reveal trends in daylight-related satisfaction (Creswell & Poth, 2018). A structured questionnaire was administered online to library users. The instrument covered demographic characteristics, daylight accessibility, visual comfort, energy perceptions, and user preferences. Items employed Likert scales and closed-ended formats, supplemented with limited open-ended prompts. Quantitative data were analysed using descriptive statistics (frequency distributions, means, and percentages) and inferential statistics (chi-square) with SPSS v26.0, supplemented by tables. Reliability was established through Cronbach's alpha ($\alpha \geq 0.70$), confirming internal consistency. Participation was voluntary and anonymous, with informed consent obtained prior to data collection. Respondents were assured of confidentiality and the exclusive use of data for academic purposes.

FINDINGS AND DISCUSSION OF RESULTS

The demographic profile reveals a student-dominated user base (90.5% students, 89.5% under 35 years of age), necessitating a library design that prioritizes academic activities such as reading and research, which are central to user behaviour. This emphasizes that Nigerian university libraries primarily serve students, requiring environments conducive to scholarly tasks. The high weekly usage rate (42.5%) indicates significant reliance on library facilities, yet the 21.5% who rarely use the library highlight environmental barriers, particularly poor lighting (41.9%) and ventilation (32.6%). These findings corroborate Okonkwo and Dauda (2021), who note that inadequate lighting and thermal discomfort deter library use in tropical climates, where glare and heat exacerbate user dissatisfaction.

The moderate visit duration (48.5% at 1–3 hours) suggests that environmental discomfort, such as poor lighting or ventilation, may prompt users to leave early, a pattern noted in Aflaki et al. (2023), who highlight the impact of suboptimal daylighting on user retention in tropical libraries. To explore potential differences in usage patterns, a chi-square test was conducted for usage frequency by academic status. The results showed no significant differences ($\chi^2 = 12.45$, $df = 16$, $p > 0.05$), indicating that usage barriers (such as poor lighting) are consistent across undergraduates (58.5%) and postgraduates (32.0%). This suggests that environmental factors, rather than user type, drive rare usage, reinforcing the need for improved daylighting and ventilation in the library design. The prevalence of reading and research activities (71.5% and 55.0% respectively) emphasises the library's role as an academic hub, necessitating well-lit spaces to support visual tasks.

Current Daylighting Experience and Challenges

The result presented in Table 1 shows an assessment of existing library's daylighting performance. It reveals that only 36.0% rate natural lighting as good or excellent, with 59.0% finding daylight insufficient sometimes, occasionally, or never. It was also noted that, entrance areas (36.5%) and reading rooms (30.0%) receive the most

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daylight, but 69.0% report sections as too dark (46.5% yes, 22.5% sometimes). Glare affects 64.5% at least occasionally, and 88.5% note that artificial light is frequently used during the day. A chi-square test for dark sections by academic status showed no significant difference ($\chi^2 = 5.32$, $df = 8$, $p = 0.62$), suggesting darkness is a universal issue.

Table 1: Daylighting Experience and Challenges

Question	Category	Count	Percentage (%)
Natural Lighting Rating	Very poor	9	4.5
	Poor	41	20.5
	Fair	78	39.0
	Good	56	28.0
	Excellent	16	8.0
Daylight Sufficiency	Always	39	19.5
	Most times	43	21.5
	Sometimes	77	38.5
	Occasionally	25	12.5
	Never	16	8.0
Areas with Most Daylight (Multi- select)	Entrance areas	73	36.5
	Reading rooms	60	30.0
	Computer zones	12	6.0
	Study areas	42	21.0
	None noticeably	13	6.5
Too Dark in Sections	Yes	93	46.5
	No	62	31.0
	Sometimes	45	22.5
Glare/Discomfort	Never	71	35.5
	Occasionally	52	26.0
	Sometimes	61	30.5
	Often	15	7.5
	Always	1	0.5
Artificial Lights During Day	Yes, always	75	37.5
	Sometimes	102	51.0
	Rarely	16	8.0
	Never	7	3.5

Impact of Daylighting on Performance and Comfort

Table 2 evaluate daylighting's impact on productivity and comfort. The responses indicate that a majority of students (55.5%) either strongly agreed or agreed that adequate lighting supports focus and productivity. By contrast, 28.5% expressed disagreement, while 18.0% remained neutral. This suggests a broad consensus that lighting is a facilitator of academic engagement, yet also reveals that nearly one-third of respondents do not perceive lighting as consistently effective for productivity. This divergence may be attributed to variations in seating location, task type, or individual sensitivity to light, as reported in prior studies (Cheung & Suen, 2021; Kim et al., 2021). The relatively high neutral response further accentuates the complexity of lighting perception: while the majority benefit, some users appear indifferent or adaptive to suboptimal conditions.

Adverse Effects of Poor Lighting

When asked to identify the negative consequences of poor lighting, respondents most frequently cited eye strain (61.0%), followed by limitations on study duration (52.5%) and reduced productivity (45.0%). Only 10.0% reported no adverse effect. These findings reinforce evidence that poor visual environments compromise both comfort and performance (Okonkwo & Dauda, 2021). The predominance of eye strain aligns with the physiological challenges of prolonged reading under inadequate light, while the reduction in study duration indicates a behavioural response whereby students self-regulate by leaving poorly lit environments. For designers, this points out that inadequate lighting does not simply create discomfort but actively curtails the functional utility of library spaces.

Daylight and Perceived Comfort

Daylight emerged as a strongly positive influence: 86.0% of respondents agreed or strongly agreed that it contributes to comfort, with only 3.5% expressing disagreement. This near- consensus reflects the role of natural light as a universally valued environmental quality in academic settings. It is consistent with earlier studies demonstrating that daylight regulates circadian rhythms, improves mood, and supports sustained cognitive performance (Boubekri et al., 2020; Cheung & Suen, 2021). The low proportion of disagreement suggests that barriers to daylight comfort such as

glare or heat gain, are either well-managed in the studied settings or outweighed by the psychological and functional benefits.

Lighting as a Determinant of Staying or Leaving

Notably, 72.0% of respondents indicated that lighting conditions influence whether they choose to remain in or leave a library space. Only 17.5% denied such an influence, while 10.5% were uncertain. This finding confirms that lighting is not merely a background condition but a decisive factor shaping spatial behaviour and occupancy patterns. It resonates with Lee and Kim (2020) argument that lighting affects perceptions of openness and crowding, thereby influencing willingness to engage in prolonged study. For university libraries in Nigeria, where energy reliability is inconsistent, this behavioural link highlights the dual necessity of maximizing daylight access and ensuring stable artificial lighting alternatives.

Preferences for Daylight-Adjacent Seating

User preference for seating near daylight is especially pronounced: 44.5% reported always choosing daylight-adjacent seats, 28.5% often, and 26.0% sometimes. Only 1.0% never preferred such seating. This overwhelmingly positive orientation toward daylight proximity underscores its psychological salience in study environments. It also suggests a potential inequity of access: if daylight-adjacent seats are consistently occupied, students relegated to artificially lit zones may experience lower satisfaction and productivity. This aligns with Sadeghi et al. (2021), who found that spatial distribution of daylight affects perceptions of crowding and fairness. For architects and facility managers, this highlights the need for design strategies that distribute daylight more evenly across reading zones, reducing competition for limited prime seats

Table 2: Impact on Performance and Comfort

	Category	Percentage (%)
Lighting for Focus/Productivity	Strongly Agree	12.5
	Agree	43.0
	Neutral	18.0
	Disagree	23.0
	Strongly Disagree	5.5
Poor Lighting Effects (Multi-select)	Causes eye strain	61.0
	Reduces productivity	45.0
	Limits study time	52.5
	No effect	10.0
Daylight for Comfort	Strongly Agree	40.0
	Agree	46.0
	Neutral	10.5
	Disagree	3.0
	Strongly Disagree	0.5
Lighting Influences Stay/Leave	Yes	72.0
	No	17.5
	Not sure	10.5
Prefer Seating Near Daylight	Always	44.5
	Often	28.5
	Sometimes	26.0
	Never	1.0

Design Preferences and Daylighting Issues

Table 3 was designed to evaluate user preferences toward daylighting features in university libraries. The responses highlight strong patterns in user expectations regarding preferred daylighting features, brightness levels, control mechanisms, spatial differentiation, and common problems associated with daylight use.

Among the daylighting features presented, large windows were overwhelmingly preferred, with 76.5% of respondents selecting them. This aligns with global studies emphasizing windows as both the most visible and intuitive source of natural light and a symbolic link to the external environment. Skylights (46.0%) and light shelves (30.5%) received moderate support, suggesting that while users appreciate diverse daylighting strategies, their awareness and valuation of more technical interventions are comparatively lower. Only 21.5% highlighted clear roof openings, reflecting either limited familiarity or reduced perceived functionality in library contexts. The high preference for large windows suggests that users value visual connection to the outdoors and direct daylight penetration. However, the relatively low preference for more technical devices indicates a potential knowledge gap between user perceptions and architectural practices. This divergence has implications for user education, design

communication, and participatory planning in library projects.

Preferred Brightness Levels

When asked about brightness preferences, the majority (58.5%) preferred moderately bright environments, followed by soft/natural light (26.0%). Only 14.5% preferred very bright spaces, while low lighting (1.0%) was almost universally rejected. This distribution highlights a strong preference for balanced daylight conditions. Overly intense brightness, though often assumed desirable, may cause glare or discomfort, whereas insufficient brightness is clearly unacceptable for academic tasks. The dominant preference for moderate or soft light reinforces the principle of visual comfort in daylighting design, aligning with findings that task-oriented academic spaces require 300–500 lux for optimal performance.

Importance of Controlling Natural Light

A striking 93.5% of respondents rated control over daylight as either very important (50.0%) or important (43.5%), while only 0.5% considered it unimportant. This indicates that users not only value daylight but also demand agency over its modulation. Preferences for operable shading, adjustable blinds, and user-responsive systems align with literature emphasizing the role of perceived environmental control in user satisfaction. For architects, this underlines the need to integrate adaptive systems rather than static daylighting solutions, particularly in climates prone to fluctuating solar intensity like Nigeria.

Variation of Lighting by Space Use

A large majority (83.0%) supported varying daylighting levels depending on the functional zone (such as reading carrels, group study, circulation, exhibitions), while only 9.5% disagreed and 7.5% were unsure. This reflects an advanced level of user awareness that different library functions require different lighting conditions. For instance, individual reading zones benefit from steady, diffuse daylight, while collaborative areas may accommodate more varied brightness levels. This preference is in line with the growing design paradigm of multi-zonal, user-centred libraries, where spatial and environmental adaptability enhance overall usability.

Significant Daylighting Issues

When asked about problems associated with daylight, the most frequently cited issue was insufficient natural light (57.0%), followed closely by poor window placement (47.5%). Thermal and visual problems were also reported, with overheating from sunlight affecting 32.0% of respondents and excessive glare reported by 29.0%. These findings reveal a paradox: while users overwhelmingly desire large windows, they simultaneously report shortcomings in daylight quality and distribution. Poor window placement emerges as a design flaw, reflecting inadequacies in spatial planning rather than user preference. The combination of insufficient daylight and glare/overheating highlights the challenge of designing climate-responsive fenestration systems in tropical regions.

Table 3: Design Preferences and Daylighting Issues

Question	Category	Count	Percentage (%)
Important Features (Multi-select)	Large windows	153	76.5
	Skylights	92	46.0
	Light shelves	61	30.5
	Louvers/shading devices	56	28.0
	Clear roof openings	43	21.5
Preferred Brightness	Very bright	29	14.5
	Moderately bright	117	58.5
	Soft/natural	52	26.0
	Low lighting	2	1.0
Control Natural Light Importance	Very important	100	50.0
	Important	87	43.5
	Neutral	12	6.0
	Not important	1	0.5
Vary Lighting by Space Use	Yes	166	83.0
	No	19	9.5
	Not sure	15	7.5
Significant Issues (Multi-select)	Insufficient natural light	114	57.0
	Excessive glare	58	29.0
	Overheating from sunlight	64	32.0
	Poor window placement	95	47.5

CONCLUSIONS

This study assessed user preferences toward daylighting in university libraries, highlighting how environmental design features directly influence satisfaction, comfort, and usability. The findings confirm that while users strongly value the presence of large windows and moderately bright conditions, they also demand effective control mechanisms to regulate glare, heat gain, and variations in brightness across different functional zones. Consistently

throughout the results, the users expect libraries to provide abundant yet moderated daylight that supports visual comfort, academic engagement, and psychological well-being. However, reports of insufficient daylight, poor window placement, and overheating emphasise persistent design shortcomings that undermine the full potential of natural light in library environments. The results contribute to the broader discourse on user-centred and climate-responsive design by showing that daylight is not simply an energy-saving measure but an important determinant of spatial quality and user satisfaction. In the Nigerian setting, where unstable energy infrastructure limits reliance on artificial lighting, daylighting assumes an even greater importance. The evidence presented here reinforces the argument that user perspectives must inform the planning and implementation of daylighting strategies in academic libraries if these facilities are to remain relevant, functional, and supportive of learning in the twenty-first century. Based on these insights, it is recommended that library design prioritise large but strategically positioned windows that maximise natural illumination while minimising glare and solar heat gain. Architects should integrate adaptive shading systems, light shelves, and selective glazing to provide users with a sense of control and ensure balanced visual conditions across different zones. Additionally, post-occupancy evaluations should be institutionalised to capture ongoing user feedback, ensuring that libraries evolve in response to shifting user needs and environmental challenges.

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Transforming Nigeria's Urban Infrastructure for a Sustainable Future
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Climate Variability Assessment on the Occurrence of Common Diseases in Bida and Minna, Niger State, Nigeria

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ABSTRACT

Climate variability poses a growing challenge to environmental and public health systems by increasing the unpredictability of weather patterns and influencing disease dynamics globally. This study assesses the impact of climate variables specifically rainfall and temperature on the occurrence of climate sensitive diseases in Bida and Minna in Niger State, Nigeria. It identifies the most prevalent diseases, compares the level of community vulnerability, and evaluates the relationship between climate factors and malaria incidence. The objectives include: (i) examining seasonal trends of rainfall and temperature from 2009 to 2024; (ii) identifying common climate-sensitive health outcomes; (iii) analysing temporal trends in malaria incidence from 2009 to 2024; and (iv) determining the relationship between climate variables and malaria cases. A mixed-methods approach was employed, utilizing 16 years of meteorological data from NASA, and hospital records from Federal Medical Centre Bida and General Hospital Minna, and data from structured questionnaires from 384 households. Data analysis involved graphical presentation, correlation, regression, and ANOVA. Findings indicate that Bida experiences higher average temperatures than Minna, with both towns showing increasing climate variability. The most common diseases identified include malaria, diarrhoea, heatstroke, and pneumonia with malaria being the most prevalent. Statistical analysis revealed a significant relationship between rainfall and malaria in both towns: in Bida, rainfall correlated significantly with malaria incidence ($r = -0.813$ at 1% level $p < 0.001$), while temperature showed a weak negative correlation ($r = -0.285$; $p < 0.001$). In Minna, rainfall also showed a significant relationship at the 5% level ($r = -0.178$; $p = 0.014$), with a similarly weak negative correlation between temperature and malaria ($r = -0.210$; $p = 0.003$). The study concludes that climate variability significantly influences disease occurrence, though vulnerability patterns differ. Localized health adaptation strategies are essential to enhance climate resilience in both urban centres.

Keywords: Climate; Climate Sensitive Diseases; Public Health; Rainfall-Temperature Vulnerability

INTRODUCTION

The latest IPCC assessment reports broad agreement among the international scientific community that climate variability, vulnerabilities, and impacts are increasing across the world in urban centers of all sizes [3]. Although the report stresses climate variability has profound impacts on a broad spectrum of infrastructure systems, services, the built environment, and ecosystem services, it recognizes urban centers around the world face severe constraints to raising and allocating resources to implement adaptation.

Climate variability poses significant challenges to human health worldwide, particularly in regions with high environmental sensitivity and limited adaptive capacity [10]. In Nigeria, the impacts of climate variability, such as rising temperatures, altered rainfall patterns, and extreme weather events, have been linked to increased incidences of vector borne diseases, food insecurity, and waterborne illnesses [8].

Niger State, located in North Central Nigeria, is particularly susceptible to the impacts of climate variability due to its unique topography, reliance on agriculture, rapid urbanization, and climatic conditions [6]. The state is characterized by a tropical climate, with distinct wet and dry seasons. However, over recent decades, it has experienced irregular rainfall patterns, increased temperatures, and more frequent extreme weather events. These shifts have resulted in conditions that can foster the spread of climate sensitive diseases and worsen existing health challenges, affecting vulnerable populations such as children, the elderly, and low-income households.

In recent years, climate variability poses a great threat in the environment resulting in more unpredictable weather patterns that are influencing health outcomes worldwide [12]. Niger State, like many regions in Nigeria, is witnessing shifts in climate systems, including fluctuating rainfall, rising temperatures, and an increase in extreme weather events. These changes have not only disrupted traditional agricultural practices and water supply but have also heightened health risks, particularly for diseases sensitive to climate conditions. Despite the public health implications of the changes, there is a lack of comprehensive studies examining the direct and indirect health risks associated with climate variability in Niger State.

The study focuses on examining the relationship between climate variables (rainfall and temperature) and the most prevalent disease in Bida and Minna. These two locations are two urban areas in Niger state, each with unique climatic conditions, socioeconomic structures, population densities, and varied exposure to climate related health risks and public health challenges.

STUDY AREA

The study area for this study is Bida and Minna local government area of Niger state, Nigeria. Bida lies at Latitude $9^{\circ}07'33''$ N and Longitude $6^{\circ}01'67''$ E [2]. Historically significant for its cultural and commercial activity, it is part of the Nupe Kingdom and serves as the capital of the Bida Local Government Area [7]. Minna is the state capital of

Niger State, Nigeria. Minna is geographically located between latitudes 9°25'0"N and 9°60'0"N and longitudes 6°55'0"E and 6°60'0"E, covering an area of roughly 80 000 square kilometers [11].

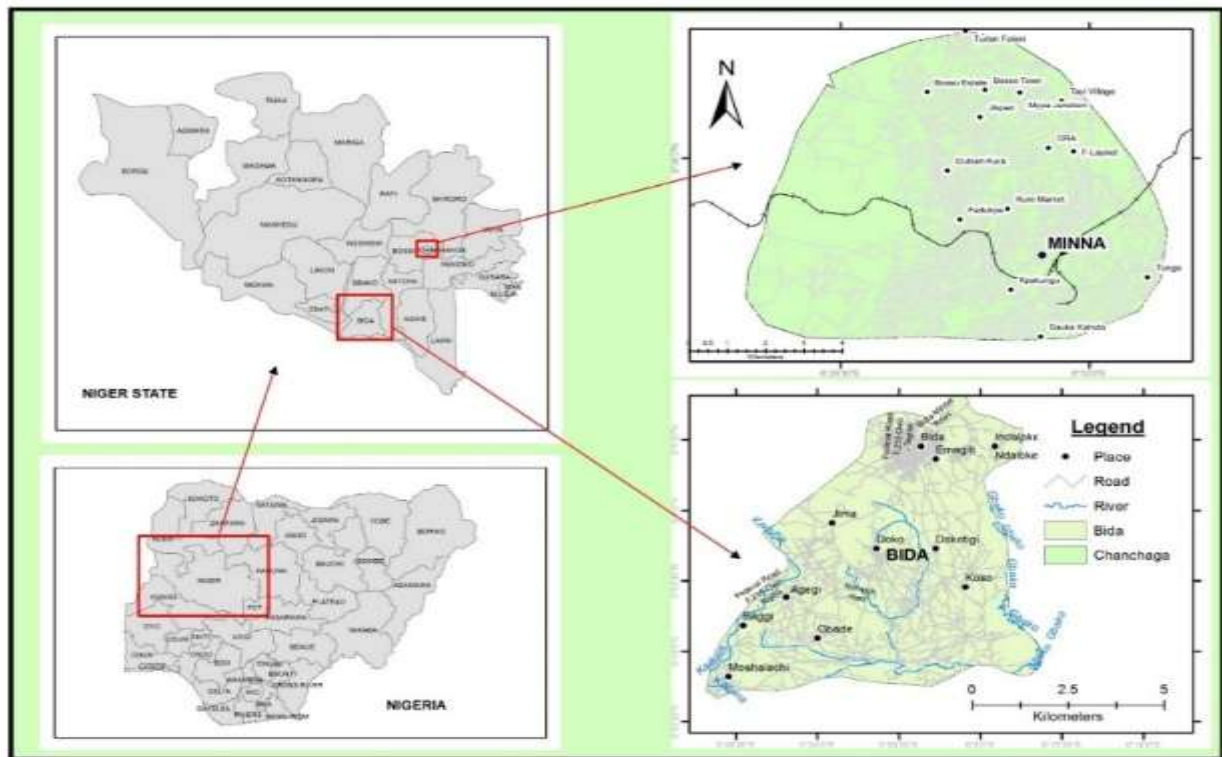


Figure 1: Locational Map of the Study Area

Source: Authors Analysis adopted from Niger State Ministry of Land and Survey (2024)

METHODS OF DATA COLLECTION

This study employed both the primary and secondary data to obtain important and useful information which is relevant for this research in order to ensure the validity and reliability of the findings.

The primary data type was obtained through physical field surveys which included questionnaires, interviews, and personal observation. These questionnaires captured information on resident's perceptions on the observed climate variability in the area, diseases experienced during extreme weather events and their access to healthcare services related to climate sensitive diseases. Also, metrological data on temperature and rainfall were source from the National Aeronautics and Space Administration (NASA). Healthcare records were source from Federal Medical Centre Bida and General Hospital Minna. All data were used to examine the relationship between climate variables (rainfall and temperature) and the most prevalent disease.

Method of Data Analysis

The mean monthly rainfall (mm) and mean monthly temperature (C°) data gotten from National Aeronautics and Space Administration (NASA) were further analyzed using the descriptive and inferential statistics. The monthly means for the most prevalent disease was obtained from the data gotten from the hospitals which are then merged into a single spreadsheet for relationship test. Graphs and tables were presented to show results. Correlation analysis (Pearson correlation) was used to test the strength and direction of the relationships between independent variables (rainfall and temperature) and are dependent on cases of the most prevalent disease over the study period from 2009 to 2024. This correlation determines whether the increase in rainfall or temperature is associated with the increase or decrease in malaria cases. Regression was used to determine the relations between the multiple climate variables (rainfall and temperature) and the most prevalent disease in the study.

RESULTS

Relationship between Temperature, Rainfall and Most Prevalent Disease for Bida

Correlation Analysis of Bida

In malaria cases and rainfall, Figure 2 presents the Pearson correlation analysis which reveals that there is a strong positive coefficient (r) which is (0.813, $p < 0.01$). This shows that malaria cases tend to increase as rainfall increases. In malaria and temperature relationship, it is observed that there is a moderate negative relationship due to the correlation efficient (r) = -0.285. This result means that as temperature increases, there is a slight decrease in malaria cases. However, the relationship is statistically significant means that temperature plays significant role in influencing

malaria cases in Bida. It may be that temperature average affects mosquito development and malaria transmission, or that the influence of temperature is masked by other climatic or non-climatic variables. Lastly, the correlation between temperature and rainfall was a moderate weak but statistically significant ($r = -0.308$). This implies that during periods of higher rainfall, temperature tends to decrease and vice versa.

Correlations				
		Rainfall	Malaria_cases	Temp
Rainfall	Pearson Correlation	1	.813**	-.308**
	Sig. (2-tailed)		<.001	<.001
	N	192	192	192
Malaria_cases	Pearson Correlation	.813**	1	-.285**
	Sig. (2-tailed)	<.001		<.001
	N	192	192	192
Temp	Pearson Correlation	-.308**	-.285**	1
	Sig. (2-tailed)	<.001	<.001	
	N	192	192	192

** . Correlation is significant at the 0.01 level (2-tailed).

Figure 2: Pearson Correlation Coefficient of Bida

Regression Analysis for Bida

The R value of 0.814 suggests a strong correlation between the observed and predicted values of malaria cases while the $R^2 = 0.662$ means that only 66.2% of the variation in malaria cases is explained by rainfall and temperature combined. The Adjusted $R^2 = 0.659$ accounts for the number of predictors in the model and confirms that the model explains very much of the variance. The standard error of the estimate (936.71) indicates the average deviation of observed malaria cases from the predicted values is a relatively small value, suggesting a good model fit.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.814 ^a	.662	.659	936.710

a. Predictors: (Constant), Temp, Rainfall

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	324932206.7	2	162466103.4	185.162	<.001 ^b
	Residual	165833618.2	189	877426.552		
	Total	490765825.0	191			

a. Dependent Variable: Malaria_cases
b. Predictors: (Constant), Temp, Rainfall

Figure 3: Regression analysis of Bida

The ANOVA test shows the F-statistic = 185.162 which means these two variables together provide a statistically reliable model for predicting malaria incidence in Bida when there are no other predictors.

Coefficients ^a					
Model		Unstandardized Coefficients		Standardized Coefficients	
		B	Std. Error	Beta	t
1	(Constant)	6280.140	1069.779		5.871
	Rainfall	13.931	.773	.801	18.027
	Temp	-32.427	38.090	-.038	-.851

a. Dependent Variable: Malaria_cases

Figure 4: Analysis of variance of Bida

The regression coefficients reveal that rainfall has a positive and strong significant influence on malaria incidence in Bida, with a coefficient ($B = 13.931$, $p = 0.001$), indicating that increased rainfall is associated with a rise in cases of

malaria. On the other hand, temperature is not statistically significant predictor of malaria cases ($B = -32.427$, $p = 0.396$).

This suggests that while rainfall may contribute to increased mosquito breeding and subsequent malaria transmission, temperature variations within the observed range and weakly affect malaria incidence in this context.

Correlation between Temperature, Rainfall and Most Prevalent Disease for Minna

Correlation Analysis of Minna

In malaria cases and rainfall, the analysis reveals that there is a weak positive coefficient (r) which is 0.178. This shows that although the relationship is weak, malaria cases tend to increase slightly as rainfall increases. This finding aligns with the understanding that increased rainfall provides breeding sites for mosquitoes, particularly stagnant water pools that form during the rainy season. However, it is important to note that while the relationship is statistically significant, the correlation is relatively weak, suggesting that rainfall alone does not strongly predict malaria cases and that other environmental and social factors may also contribute.

Correlations				
		Rainfall	Malaria_cases	Temp
Rainfall	Pearson Correlation	1	.178*	-.110
	Sig. (2-tailed)		.014	.128
	N	192	192	192
Malaria_cases	Pearson Correlation	.178*	1	-.210**
	Sig. (2-tailed)	.014		.003
	N	192	192	192
Temp	Pearson Correlation	-.110	-.210**	1
	Sig. (2-tailed)	.128	.003	
	N	192	192	192

*. Correlation is significant at the 0.05 level (2-tailed).
 **. Correlation is significant at the 0.01 level (2-tailed).

Figure 5: Pearson Correlation Coefficient of Minna

In contrast, it is observed that there is a weak negative relationship between malaria cases and temperature due to the correlation efficient (r) = -0.210 with a p-value of 0.003. This implies that higher temperatures reduce mosquito survival or parasite development. Lastly, the correlation between temperature and rainfall was also weak and not statistically significant ($r = -0.110$, $p = 0.128$). This implies that there is no clear linear relationship between these two climatic variables during the study period.

Regression Analysis for Minna

The R value of 0.262 suggests a weak positive correlation between the observed and predicted values of malaria cases while the $R^2 = 0.068$ means that only 6.8% of the variation in malaria cases is explained by rainfall and temperature combined. The Adjusted $R^2 = 0.059$ accounts for the number of predictors in the model and confirms that the model explains very little of the variance. The standard error of the estimate (1730.124) indicates the average deviation of observed malaria cases from the predicted values is a relatively large number, suggesting a poor fit.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.262 ^a	.068	.059	1730.124
a. Predictors: (Constant), Rainfall, Temp				

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	41597255.79	2	20798627.90	6.948	.001 ^b
	Residual	565739146.2	189	2993328.816		
	Total	607336402.0	191			
a. Dependent Variable: Malaria_cases						
b. Predictors: (Constant), Rainfall, Temp						

Figure 6: Regression analysis of Minna

The ANOVA test showed the F-statistic = 6.948 tests whether the regression model as a whole is significantly better than a model with no predictors. The p-value = 0.001 is less than 0.05, indicating that the model is statistically significant at the 5% level. The regression model does significantly predict malaria cases using rainfall and

temperature as predictors. In other words, these two variables, in combination, provide a statistically reliable model for predicting malaria incidence in Minna.

Coefficients ^a					
Model		Unstandardized Coefficients		Standardized Coefficients	
		B	Std. Error	Beta	t
1	(Constant)	9820.263	1736.349		5.656
	Temp	-175.557	64.242	-.193	-2.733
	Rainfall	2.804	1.264	.157	2.219

a. Dependent Variable: Malaria_cases

Figure 7: Analysis of variance of Bida

The regression coefficients reveal that rainfall has a positive and marginally significant influence on malaria incidence in Minna, with a coefficient ($B = 2.80$, $p = 0.028$), indicating that increased rainfall is associated with a rise in malaria cases and it is a good predictor of malaria cases. On the other hand, temperature exhibited a weak, negative, and statistically non-significant relationship with malaria cases ($B = -175.76$, $p = 0.007$).

This suggests that rainfall may contribute to increased mosquito breeding and subsequent malaria transmission, temperature variations within the observed range do not significantly affect malaria incidence in this context. These findings are consistent with the earlier correlation results and support the notion that rainfall is a more influential climatic factor in malaria transmission than temperature in Minna.

SUMMARY

This analysis objective confirms that climate variability directly determines disease prevalence across the study area. Rainfall is a key factor influencing malaria cases likely to the mosquitos breeding condition. Temperature alone does not significantly predict malaria incidence in the study. The presence of statistically significant associations between climate trends and illness rates underscores the urgency of climate smart public health planning.

CONCLUSION

This study examines the role of climate variability on common diseases in two urban centers: Bida and Minna in Niger State, Nigeria. The research team analyzed over 16 years of meteorological data (2009–2024) alongside primary survey responses from 384 residents and hospital health records to identify how climatic factors influence disease patterns. The analysis focused on vector borne disease (malaria) out of the four major health conditions found in the study area: heat related illness (Heatstroke), waterborne illness (diarrhea), respiratory illness (pneumonia), and vector borne disease (malaria).

In Bida, temperatures rose to an average of 28°C. These thermal extremes resulted in 60percent of surveyed residents reporting heatstroke, and 69percent reporting pneumonia during the dry season. Questionnaires confirmed high admissions for heat exhaustion especially between March and May. In contrast, Minna experienced slightly lower thermal stress but reported higher incidence of diarrhea (61percent) during the rainy season, especially in areas with poor drainage and stagnant water. Malaria prevalence remained high in both towns, with Bida at 79percent and Minna at 68percent, largely due to standing water after rainfall and weak vector control.

Statistical analysis suggests rainfall and temperature are relevant climatic factor in influencing disease transmission in Bida and Minna. The findings showed a weak but significant relationship between temperature and the most prevalent disease in the study area probably due to relatively stable thermal conditions that remain within the optimal threshold for mosquito and parasite development year-round. The regression analysis further revealed that rainfall and temperature together explain only a large portion of malaria variation, pointing to the presence of other influential variables such as humidity, vegetation, sanitation, and socio-economic factors which were not included in the current model [9].

The data clearly demonstrated that climate variability through rising temperatures, inconsistent rainfall, and prolonged dry seasons directly influences health outcomes. Both primary field data and hospital records confirmed this relationship, validating the survey's credibility and strengthening the need for climate informed health planning.

The findings from this research highlight a clear and urgent link between climate variability and diseases in Bida and Minna. The research team established that climate dynamics do not affect all regions equally. Bida, with its higher heat index, experiences more extreme health consequences from heat stress and air pollution. Minna, while less thermally intense, suffers from the health impacts of seasonal flooding, poor sanitation, and prolonged rainy seasons. By combining survey data with hospital records, the research team confirmed that climate variability acts as a multiplier of health risks, especially in low income and poorly planned neighborhoods. This conclusion demands a decisive shift in public health planning from reactive responses to proactive, climate sensitive health governance. Health systems must start tracking climate parameters, preparing for seasonal health spikes, and building structural resilience in vulnerable zones.

RECOMMENDATIONS

Based on the evidence from this study, the following policies should be recommended:

- i. Government agencies should establish localized early warning systems in Bida to prepare residents and health workers for heatwaves and temperature spikes.
- ii. Urban planners and local authorities in Minna should prioritize modern drainage and sanitation upgrades to prevent outbreaks of waterborne illnesses during flood seasons.
- iii. Public health departments need to implement targeted mosquito control programs including larviciding and net distribution before and during the rainy season.
- iv. Primary healthcare centers should receive seasonal stockpiles of asthma kits, inhalers, and dust masks to help residents manage respiratory illnesses during the Harmattan period.
- v. Health and environment ministries must collaborate to develop integrated climate health surveillance systems that detect and respond to disease trends linked to changing weather patterns.

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Assessment of Activities of Crime Prevention Agencies in the Residential Neighbourhoods of Minna, Nigeria

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ABSTRACT

Urbanization in Nigerian cities has accelerated in recent decades, accompanied by socio-spatial inequalities that affect security and crime prevention. This study examines the spatial distribution of crime prevention agencies and the extent of community engagement in Minna, Niger State. Using a mixed- methods approach, data were collected from 1,474 residents, 27 agencies, and spatial imagery, covering nine neighbourhoods categorized into high-, medium-, and low-density areas. Geographic Information Systems (GIS) were used to map agency locations, while surveys measured awareness and utilization of security services. Findings reveal significant spatial inequities in security infrastructure distribution: low-density neighbourhoods host 60% of formal crime prevention agencies while housing only 20% of the population, compared to 30% in high-density areas that contain 65% of the city's population. Although awareness of agencies such as the Nigeria Police Force and Vigilante Corps exceeded 90%, utilization patterns varied by neighbourhood density. High-density areas showed 23% points lower utilization rates of formal agencies (65% vs. 88% in low-density areas) but demonstrated stronger reliance on vigilante corps (78% vs. 71%). Crime incidence analysis revealed rates 4.6 times higher in high- density areas (131.4 per 1000 population) compared to low-density neighbourhoods (28.3 per 1000 population). Response time disparities were equally pronounced, with formal agencies taking 35-45 minutes to respond in high-density areas versus 8-15 minutes in low-density areas. However, the data shows encouraging crime reduction trends, with both high-density (45% reduction) and medium-density (46% reduction) neighbourhoods experiencing significant decreases from 2020-2024. The study recommends equitable distribution of security infrastructure, improved trust-building initiatives, and integration of formal and informal crime prevention systems. These measures can enhance urban safety and strengthen social cohesion in Minna and similar rapidly urbanizing Nigerian cities.

Keywords: Crime prevention, urban security, spatial distribution, community policing, Minna, GIS

INTRODUCTION

Urbanization is a transformative global phenomenon, and Nigeria, particularly cities like Minna, reflects this trend. The rapid migration from rural to urban areas offers economic opportunities but also brings significant challenges, among which urban insecurity and crime are prominent. Socio-economic disparities, population density, and the anonymity of urban life create conditions where criminal activities such as armed robbery, kidnappings, and cult-related violence can thrive (Ojo and Ojewale, 2019). Globally, urban crime is a pressing concern, affecting both developed and developing nations (Ghani, 2019; Muggah, 2015). In developing countries, the pace of urban growth often outstrips the capacity of infrastructure and institutions to manage safety and security (Bako *et al.*, 2018). In Minna, the uneven distribution of resources and infrastructure across neighbourhoods has created stark differences in crime incidence and perceptions of safety. Recent years have seen a shift toward proactive crime prevention, including environmental design, community policing, and integration of informal systems such as vigilante groups (Tilley, 2008; Abrahansen and Williams, 2019). This study focuses on Minna, Niger State, as a case study to examine how spatial distribution and community engagement shape crime prevention outcomes.

In order to assess the effectiveness and efficiencies of the activities of crime prevention agencies in residential neighbourhoods of Minna, the research; mapped out the spatial distribution of crime prevention agencies across neighbourhoods in Minna using GIS; assessed residents' awareness and utilization of available crime prevention services; and, evaluated the relationship between neighbourhood characteristics and the effectiveness of crime prevention strategies.

Crime prevention strategies have evolved globally over the past decades, moving from purely reactive measures toward integrated, proactive approaches (Tilley, 2008). The spatial distribution of security infrastructure plays a critical role in determining the speed of response and the deterrence effect of security agencies (Weisburd *et al.*, 2016). Studies in developed countries such as the United States and the UK have demonstrated that clustering police resources in high-crime areas also known as "hot spot policing" can significantly reduce crime rates without merely displacing crime to other areas (Braga *et al.*, 2014).

In developing country contexts, however, institutional weaknesses, and infrastructural gaps often limit the effectiveness of these agencies and many strategies often fail in the peculiar African scenario (Abrahansen and Williams, 2019). In Nigeria, research shows that urban crime is influenced by poor planning, socio-economic inequality, and inadequate security infrastructure (Oyinloye *et al.*, 2023). As a result, community-based interventions such as vigilante groups, neighbourhood watches, and civil defence corps have emerged as significant actors in urban safety. In Minna, these informal structures often fill gaps left by formal policing, especially in high-density, low-income areas where police presence is minimal ((Alemika and Chukwuma, 2020; Shariati, 2022). However, these groups face their own challenges, including lack of training, limited resources, and occasional abuse of power.

Meanwhile, from the spatial planning perspective, literatures have shown that urban design and environmental management can contribute to crime prevention through the principles of Crime Prevention Through Environmental Design (CPTED), which emphasize visibility, access control, and territorial reinforcement (Cozens and Love, 2015). When integrated with community engagements, these spatial strategies are known to produce more sustainable

security outcomes (Morakinyo, Ayede, Abdulquadri, & Yusuf, 2024; F. Umar, 2017; Yusuf, 2019). However, less is known in the aspects of the different contributions of crime prevention agencies in the fast-growing Niger State's administrative capital. The gap has the tendency of depriving policy makers adequate understanding of existing crime prevention mechanisms, those that need assistance, and the manner and aspects of interventions for those that require collaborations.

METHODS

The Study Area

Minna, which has been serving as the administrative capital city of Niger State since 1976, is located in the North-Central region of Nigeria between Latitudes 9°30'N and 9°45'N and Longitudes 6°30'E and 6°45'E (Figure 1). The city covers an approximate area of 88 square kilometres and is strategically positioned along major transportation corridors connecting northern and southern Nigeria. The distance from Minna to the capital of Nigeria, Abuja, is approximately 121 km, making it a significant hub for regional administration and commerce. Recent studies indicate that there was over 2000% increase in the built-up area of Minna within the period from 1972 to 2015, demonstrating the city's rapid expansion and urbanization trajectory (Adamu *et al.*, 2020). Multiple administrative functions have also drawn high population into the city of Minna of recent. For example, besides being a regional administrative capital of the largest agrarian state in Nigeria, it is also the headquarters of Chanchaga Local Government Area – the only wholly urban LGA in the state (Kawu, 2025; Umar and Kawu, 2011; Bako *et al.*, 2018; NGSG, 2024) and only to be surrounded by largely rural based LGAs like Bosso to the North, Shiroro to the South, Munya to the East, and, Paikoro to the West.



Figure 1: The Location of Minna in the context of Nigeria

After: Kawu (2016:16)

In 2006, Minna had a population of 304,113 inhabitants which current estimates put at 500,000 mainly due to rural-urban migration (Bako *et al.*, 2018; NGSG, 2024; World Bank, 2023) that exhibits significant cultural diversities where the indigenous Gbagyi people now line along with Nupe, Hausa, Fulani, Yoruba, Igbo ethnic groups (Usman and Garba, 2022). This diversity, while contributing to the city's cultural richness, has also been shown to present unique security challenges (Adebakin and Raimi, 2012; Aradau and Mc Cluskey, 2022; Breeze, 2024; Woods and Berker, 2022). The Urban structure of Minna reflects the colonial planning legacy combined with post- independence rapid growth leading to the categorization of the city into three distinct density zones of low-, medium-, and, high-density residential areas. This is based on levels of planning administration and or standards, infrastructure quality, and socio-economic characteristics. Coincidentally, the low-density areas are known to house high-income groups, while the high-density areas are primary locations for the low-income earners (Abubakar and Omotoriogun, 2022; Kawu, 2016, 2025). The low-density Areas have planned layouts, good infrastructure, spacious plots, and predominantly occupied by government officials, academics, business elites, and also has fewer than 150 persons per hectare coupled with better access to public services (Mohammed and Suleiman, 2021). The high-density areas are shown to house over 300 persons per hectare, being dominated by informal settlements - often developed through informal processes with limited planning control, poor infrastructure, and predominantly low-income residents (Abubakar *et al.*, 2020). See Figure 2.

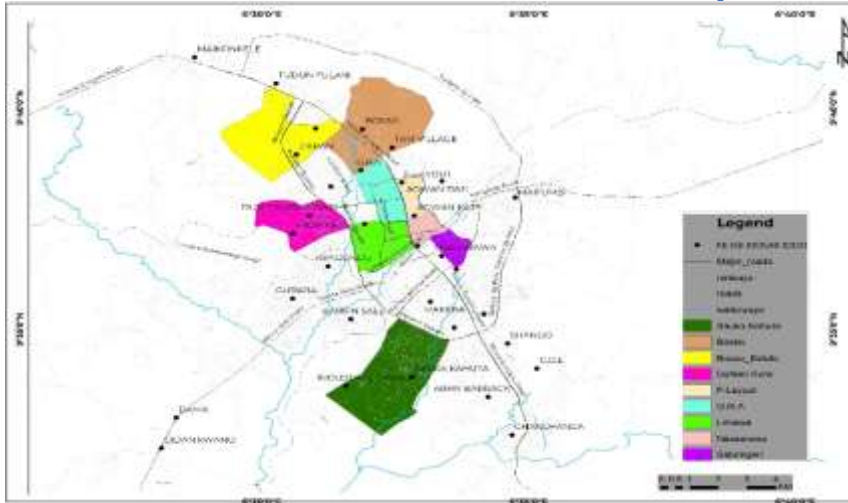


Figure 2: Main Residential Areas in Minna

Socioeconomic activities in Minna are primarily driven by government institutions, small-scale and home-based manufacturing, and, commerce. The Federal University of Technology, and the Abdulkadir Kure University amidst government ministries and agencies in the fast-growing city contributes significantly to the city's educational and economic profile (Bako *et al.*, 2018; NGSG, 2024; Hassan and Umar, 2021). However, high levels of youth unemployment, have contributed to various forms of urban crime like armed gangs, burglary, cultism, and drug trafficking. This is more sever in the high-density areas where communal conflicts are also known to take place. The inputs of crime prevention agencies are, in this scenario, necessary to study in order to understand its outcomes in the different residential areas and neighbourhoods within the city.

Study Population and Sampling

The study sample was determined using a proportional sampling method based on 5% of the estimated 2024 population for sampled residential areas (Table 1), thereby classifying the areas into high-, medium-, and low-densities. This approach ensured that areas with large populations receive higher representation. For example, Sabon Gari a high-density neighbourhood with estimated population of 65,349 had a sample size of 395 – given 1,474 respondents from estimated population of 244,065 persons. A total of 50 institutional respondents were also interviewed across the two main security agencies operating within the study area - the Nigeria Police Force (NPF) and Niger State Vigilante Corps (NSVC) comprising 20 and 30 respondents respectively. The Nigeria Police Force, though the formal state agency, maintains fewer posts concentrated in low-density areas, while the Vigilante Corps operate more extensively across medium- and high-density neighbourhoods - reflecting their broader coverage and community-level involvement in crime prevention activities within the study area.

Table 1: Estimated Household Size and Sample Size of the Study

SN	Name	Neighbourhoods Classification	Population (2006)	Projected Population	Estimated Household Size	Sample Size
1	Sabon Gari	High	47354	65349	7892	395
2	Limawa	High	38197	52712	6366	318
3	Nasarawa	High	37674	51990	6279	314
4	Bosso	Medium	13343	18413	2224	111
5	Dutsen Kura Gwari	Medium	12820	17692	2137	107
6	Sauka Kahuta	Medium	9942	13720	1657	83
7	F- Layout	Low	6802	9387	1132	57
8	Bosso Estate	Low	5755	7942	959	48
9	GRA	Low	4971	6860	829	41
Total Population			176858	244065	29475	1474

After: Usman et al (2022:32)

Data collection was through a mixed-method approach - quantitative and qualitative data, surveys, interviews, and spatial analysis. Structured questionnaires were used to capture socio-demographic data, crime experiences, awareness, and utilisation of security agency personnel and facilities. Spatial data were gathered through satellite imageries to identify agencies' facilities as input to quantitative data analysed using descriptive statistics and spatial analysis, while qualitative data were thematically examined to identify patterns of community engagement and institutional response.

Data Analysis

The Spatial Distribution of Crime Prevention Agency

GIS data revealed imbalance in the distribution of crime prevention agencies across the city. The formally planned, low-density areas enjoy privileged access to formal and private security personnel and facilities. For example, Bosso Estate houses full-fledged Nigeria Police Station, ensuring dedicated coverage; F- Layout and GRA, although lacking separate stations, are covered by patrols and operational jurisdiction of the nearby Police Headquarters (Figure 3). GRA further benefits from the Niger State Government House, which attracts a permanent, high-level security presence, with armed personnel stationed there. These neighbourhoods also feature widespread use of private security guards, electrified fences, and other forms of environmental design that enhance territorial demarcations and discourages unwarranted intrusions. In stark contrast, medium- and high-density areas rely solely on single vigilante corps posts which is understaffed, poorly equipped, and reactive in approach. Personnel in these areas report feeling overwhelmed by the high population and crime incidences, with minimal institutional support. Residents also lack access to private security services or advanced residential security facilities and infrastructures like duty posts, surveillance equipment, regular patrols; thereby making them more vulnerable.

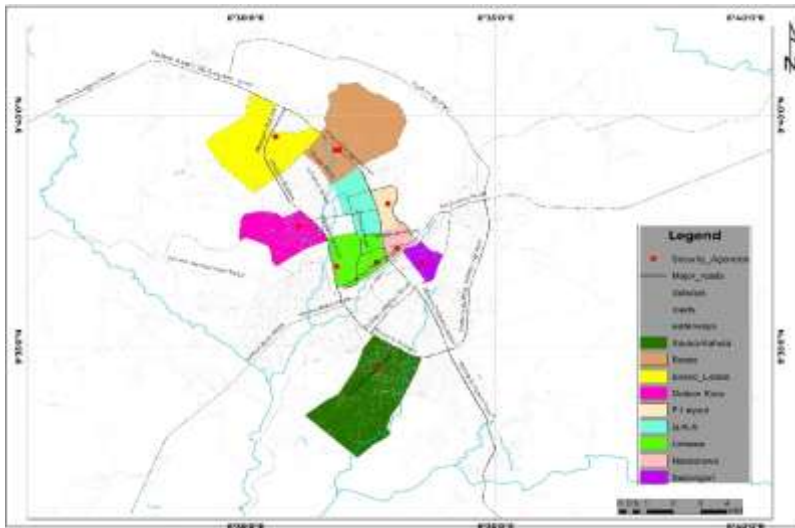


Figure 3: Spatial distribution of crime prevention agencies in Minna

Crime Incidence by Neighbourhood Density

From Table 2, Crime analysis showed clear spatial disparities across Minna. High-density neighbourhoods recorded the highest overall crime rate (124.8 per 1,000 population), five times higher than low-density areas (22.5). Burglary was the most common offence, followed by domestic violence, drug-related crimes, and cultism and gang violence, all of which were concentrated in high-density zones. This shows that residential density, socio-economic conditions, and uneven security infrastructure strongly influence crime patterns, highlighting the need for targeted, density-specific prevention strategies. Furthermore, this indicates that formal or planned areas, by virtue of their design and affluence, attract more attention from state agencies and are able to supplement adequate public policing with private security arrangements. Less planned areas or informal settlements generally, remain marginalized and underserved, and hotspots for crimes. This imbalance, as pointed out by many studies (Umar, 2017; Bako et al., 2018; Yusuf, 2019b; Morakinyo et al., 2024), reflects the socio-political reality in many Nigerian cities, where planned areas inhabited by the elite attract more government attention and infrastructural investment while the resulting clustering of police and security services in these places inadvertently signal serious neglect in high-density neighbourhoods.

Table 2: Reported Crime Incidence in Minna

Crime Type	High-Density	Medium-Density	Low-Density	City Average
Burglary	42.5	21.0	6.8	23.4
Armed Robbery	13.2	5.8	1.5	6.8
Cultism/Gang Violence	17.9	7.6	0.9	8.8
Drug-related	21.5	10.9	3.1	11.8
Domestic Violence	29.7	18.5	10.2	19.5
Total Crime Rate	124.8	63.8	22.5	70.3

Source: Field survey, 2025

Crime Pattern Analysis

Crime hotspot analysis revealed a clustering of crime incidents in high-density neighbourhoods such as Sabon Gari, Limawa, and parts of Sauka-Kahuta, with relatively fewer hotspots in medium- and low-density areas like Bosso Estate and GRA. This spatial pattern further reflects uneven security infrastructure distribution. Further analysis revealed significant variations where high-density areas consistently report higher incidences of various crime types

compared to their low-density counterparts. The pattern aligns with theories of environmental criminology, which suggest that densely populated, socio-economically disadvantaged areas often have higher crime rates due to anonymity, weaker community ties, and limited surveillance (Braga *et al.*, 2014). The lack of formal security presence in these areas further exacerbates the situation. However, the temporal analysis shows encouraging trends, with both high-density and medium-density neighbourhoods experiencing significant crime reductions of 45% and 46% respectively between 2020 and 2024, suggesting that existing interventions and community-based strategies are having positive impacts. See Figure 4.

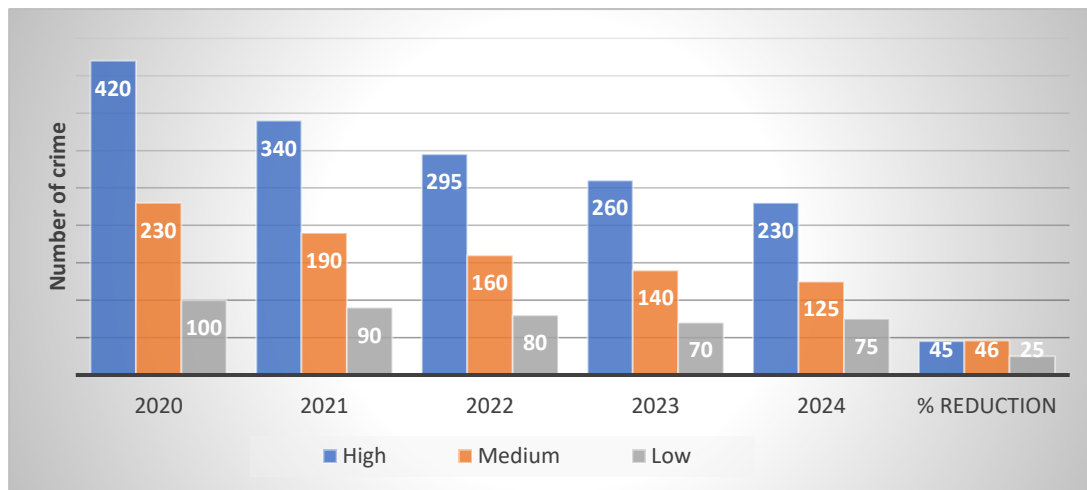


Figure 4: Crime Incidence Assessments in Neighbourhoods of Minna (2020–2024)

Source: Field survey, 2025

Awareness and Utilization of crime prevention agencies

There is awareness of major crime prevention agencies among residents of Minna with the Nigeria Police Force and Vigilante Corps been the most popular. However, there are notable discrepancies in the actual utilization of their services, particularly when disaggregated by neighbourhood densities (Figure 5). Low-density neighbourhoods are considerably higher utilizing formal agencies such as the Nigeria Police Force compared to their high-density counterparts which shows higher reliance on vigilante corps, reflecting the limited availability of formal security services in these areas. Several interrelated factors contribute to this utilization gap in high-density residential neighbourhoods. Firstly, pervasive mistrust towards formal security agencies rooted in documented allegations of corruption, inefficiency, and lack of accountability undermines community willingness to seek assistance from these bodies as also observed by Alemika and Chukwuma (2020). Such mistrust discourages residents from reporting crimes, thereby limiting the agencies' effectiveness in these areas. Secondly, spatial and infrastructural challenges exacerbate this divide – as high-density areas frequently face longer distances to police stations and other formal security facilities, coupled with inadequate transportation infrastructure.

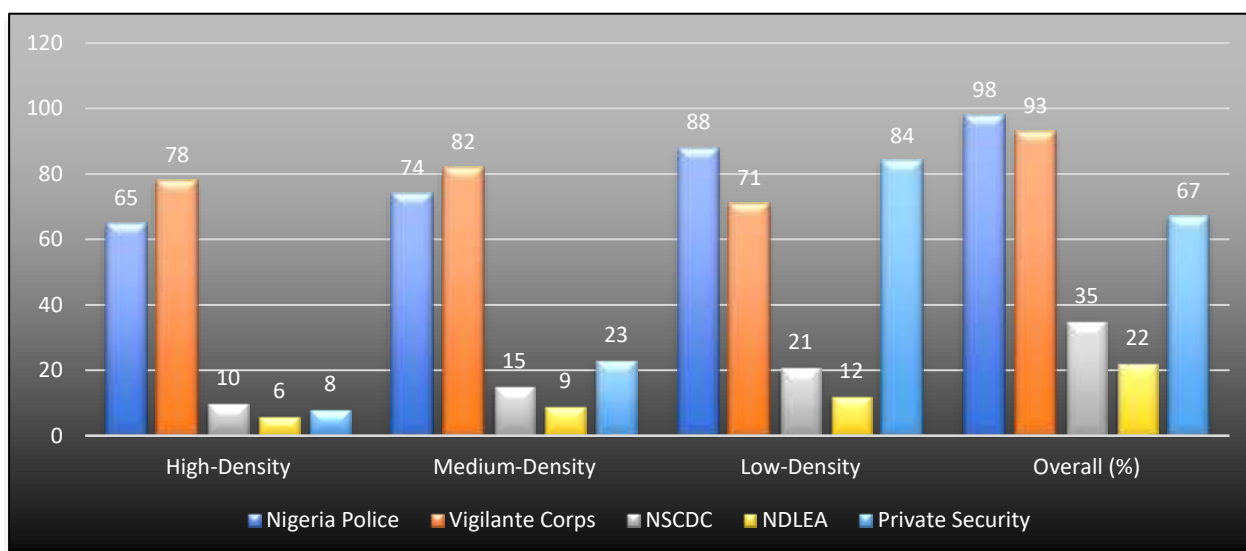


Figure 5: Awareness and Utilization of Crime Prevention Services by Density

Source: Field survey, 2025

These logistical barriers increase response times and reduce the perceived reliability of formal agencies during emergencies, reinforcing community reliance on more immediate and accessible informal mechanisms. This exhibited scenario aligns with the theoretical framework proposed by Olajide and Lizam (2017), who emphasize that physical proximity to law enforcement infrastructure is insufficient in isolation to ensure effective utilization. Instead, trust in institutional efficacy, perceived responsiveness, and community engagement are crucial mediators influencing whether residents utilize formal crime prevention services.

Furthermore, response time analysis revealed significant disparities in emergency response across different neighbourhood also and is directly correlating with the spatial distribution of security infrastructure. Field assessment shows (Table 3) that while vigilante corps provide the fastest response times in high-density areas (5-10 minutes), their capacity to handle serious crimes is limited. Formal agencies take 3-4 times longer to respond to emergencies in high-density areas compared to low-density neighbourhoods, significantly affecting their deterrent effect and community confidence in the most peopled residential areas of Minna.

Table 3: Response Times (mins) by crime prevention agencies in Minna

Agency	High-Density	Medium-Density	Low-Density
Nigeria Police	35–45	20–30	8–15
NSCDC	40–50	25–35	12–20
Vigilante Corps	5–10	5–8	10–15
Private Security	N/A	15–20	3–8

Source: Field survey, 2025

CONCLUSION AND RECOMMENDATIONS

The research revealed significant inequality between planned and less planned or high-density areas. Planned, low-density neighbourhoods (GRA, Bosso Estate, F-Layout) demonstrated superior security presence and outcomes with better infrastructure, higher agency presence, proactive policing, and greater outcome of interventions. High-density areas (Sabon Gari, Limawa, Nasarawa) experienced higher crime rates, lower outcome of interventions, and minimal institutional support. The Niger State Vigilante Corps, for example, played a crucial role in bridging security gaps in underserved neighbourhoods, contributing to measurable crime reductions between 2020-2024 through deep community integration, cultural familiarity, and responsiveness to local security challenges. This intervention effectively mitigated weaknesses in formal policing institutions.

Similar trends have been observed in other Nigerian cities such as Ibadan, Jos, and Enugu, where high crime neighbourhoods are often those with poor infrastructure and minimal police presence (Oyinloye *et al.*, 2023). In Lagos, a combination of formal and informal policing has moderately reduced crime hotspots in some areas (Shariati, 2022); whereas, Minna still holds on to integration between state and community actors and have remained inconsistent further limiting her potential to improve safety in underserved zones. The scenario at play in the city of Minna is such that high-density residential areas are poorly treated in terms of facilities and infrastructure including security services that are necessary for productive livelihood activities. As shown in Table 4, low-density neighbourhoods are by far favoured and continue to receive attention of the urban authorities when it comes to the issues of security and safety of persons and properties. For example, personnel are not only limited in the high-density areas, their remuneration is also not satisfactory; the low-density areas still enjoy adequate coverage in terms of surveillance, patrols, facility presence and higher supports from the urban authorities that the high-density areas that house most of the city residents.

Table 4: Summary of findings

Aspect	High-Density Areas	Medium-Density Areas	Low-Density Areas
Agency Coverage	Sparse, inadequate posts	Moderate, partial coverage	Comprehensive, well-distributed
Infrastructure Quality	Poor facilities, often dilapidated	Basic but functional facilities	Good, well-maintained buildings
Personnel Training	Mostly informal, limited	Some formal, occasional	Regular, structured, formal
Response Time	Slow, often >30 minutes	Moderate, ~20 minutes	Quick, usually <15 minutes
Community Cooperation	Low, with mistrust and tension	Moderate, mixed cooperation	High, supportive and trusting
Remuneration and Morale	Very low, leading to frustration	Modest, with some dissatisfaction	Higher, generally satisfactory
Challenges Reported	Severe understaffing, lack of equipment, security risks	Understaffing, inadequate vehicles	Minor logistical issues, manageable
Crime Patterns Observed	Burglary, assault, drug use, cultism, armed robbery	Burglary, assault, drug use	Mostly petty theft, minimal violent crime

Source: Field survey, 2024

The findings demonstrate that effective crime prevention requires more than security agency presence alone. It demands deliberate, inclusive strategies integrating community-based approaches, strengthened institutional capacities, and equitable spatial resource distribution. Addressing structural disparities in urban design and

institutional presence is fundamental to achieving sustainable safety and security across all neighbourhood in our fast-growing cities.

RECOMMENDATIONS

There should be immediate short-term intervention within a period of 24 months to introduce police presence in high-density neighbourhoods with adequate working equipment – where training will also be provided for the vigilante corps. Medium-term intervention (2-4 years) should be directed towards fostering trust via community engagements, integrating Crime Prevention Through Environmental Design (CPTED) approaches into urban projects, and establishing neighbourhood security committees to enhance coordination. The long-term intervention (5 years and more) should concentrate on deploying GIS-based crime mapping for adaptive resource allocation, create integrated security information system, and conduct regular security audits to ensure effectiveness of strategies and the adequacy of equipment and facilities.

The current approach of concentrating security resources in affluent areas and neglecting high-density neighbourhoods perpetuates spatial inequality and undermines overall urban safety. A more equitable distribution of these facilities, combined with recognition and support for community-based security mechanisms, could significantly improve safety outcomes while strengthening social cohesion. Findings exhibited here on crime reduction trends (45-46% decrease in medium and high-density areas from 2020-2024) demonstrate that targeted interventions can be effective even in resource-constrained environments. However, the persistent disparities in agency activity frequencies with community meetings occurring at only 18% frequency in high-density versus 45% in low-density areas indicate that proactive engagement strategies need significant improvement. Policy makers should recognize that the 78% utilization rate of vigilante corps in high-density areas reflects both a service gap and an opportunity. These informal security actors provide crucial services with response times of 5-10 minutes compared to 35-45 minutes for formal agencies in the same areas. This calls for a focus on integration and capacity building between these agencies to deliver efficient and equitable services across cities.

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Architectural Resilience in Primary Healthcare Centres: Enhancing Community Health Through Sustainable Design in the Face of Climate and Crisis

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ABSTRACT

Primary healthcare facilities serve as the backbone of community health systems, yet their architectural design frequently overlooks the growing challenges posed by climate change, natural disasters, and health emergencies. This study examines how sustainable and resilient design principles can transform these critical facilities into adaptable, crisis-resistant infrastructure that maintains continuous healthcare delivery while minimizing environmental impact. Through comprehensive analysis of design strategies that enhance operational continuity during pandemics, extreme weather events, and other crises, this research explores the relationship between architectural resilience and public health outcomes. Key focus areas include climate-responsive building envelopes, water security systems, renewable energy integration, adaptable spatial configurations, and passive environmental control strategies. Case studies of innovative primary healthcare facilities across diverse geographic and climatic contexts reveal crucial design interventions that enhance both daily operational efficiency and crisis response capabilities. Results demonstrate that architecturally resilient primary healthcare facilities exhibit significantly improved performance metrics during crisis periods, including reduced service interruptions, lower energy consumption, and enhanced patient outcomes. This research contributes to the expanding body of knowledge on resilient healthcare infrastructure and provides practical guidance for creating primary healthcare facilities that support community resilience and global sustainability goals.

Keywords: architectural resilience; healthcare delivery; community health; climate-responsive building; environmental sustainability

INTRODUCTION

As communities around the world deal with growing environmental problems and health crises, the relationship between climate change, public health, and architectural design has become more important (Das et al., 2024). Since PHCs serve as the initial point of contact between the public and official healthcare systems, they need architectural solutions that guarantee uninterrupted service delivery in the face of outside pressures (Malatji et al., 2023).

Due to their critical service needs and vulnerable populations, healthcare facilities have been disproportionately affected by the 70% increase in climate-related disasters over the past 20 years (Siegel & Mallow 2021). The COVID-19 pandemic also brought to light how traditional healthcare facility designs are inadequate for adjusting to quickly shifting operational needs while upholding safety regulations (Filip et al., 2022).

This study tackles the crucial discrepancy between the design of conventional healthcare facilities and the growing demand for sustainable, resilient infrastructure that can support everyday operational excellence while effectively responding to a variety of crisis situations (AIDulijand et al., 2023).

LITERATURE REVIEW

Architectural Resilience in Healthcare Context

A building's ability to continue operating in the face of disruptions, adjust to shifting circumstances, and bounce back swiftly from setbacks is referred to as architectural resilience (Attia et al., 2021). This goes beyond structural integrity in healthcare settings to encompass resource independence, operational continuity, and infection control adaptability.

Climate Change Impacts on Healthcare Infrastructure

The operations of healthcare facilities are directly impacted by changing disease patterns, rising global temperatures, and an increase in the frequency of extreme weather events (Ebi et al., 2021). In times of crisis, traditional design methodologies that mainly rely on mechanical systems and external resource dependencies are insufficient.

Sustainable Design Integration

When sustainability and resilience are combined in healthcare architecture, opportunities are created for facilities that function well in everyday situations and in emergency situations (Emami et al., 2024). Locally produced materials, renewable energy sources, and passive design techniques all improve operational independence and environmental performance (Reddy et al., 2024).

METHODOLOGY

This study uses a mixed-approaches strategy that combines: *Systematic Literature Review*: Examination of more than 150 peer-reviewed publications published between 2015 and 2024 on crisis response architecture, sustainable design, and healthcare facility resilience. *Analysis of a Case Study*: a thorough analysis of 3 model primary healthcare facilities in various economic and climatic contexts, with an emphasis on design approaches and performance results. *Evaluation of Performance Metrics*: quantitative evaluation of operational data, such as energy usage, rates of service interruption, and patient outcomes in both routine and emergency situations. *Interviews with experts*: 25 healthcare architects, facility managers, and public health representatives participated in semi-structured interviews to confirm results and pinpoint implementation issues.

CONCEPTUAL FRAMEWORK

The research is grounded in three interconnected theoretical frameworks:

Resilience Theory

Recognising healthcare facilities as intricate adaptive systems that need modularity, diversity, and redundancy to continue operating under pressure.

Bioclimatic Design Principles

Minimising energy reliance while preserving ideal healing environments by utilising natural environmental conditions.

Community-Centred Design

Acknowledging primary healthcare facilities as valuable community resources in need of stakeholder engagement and locally relevant solutions.

Design Strategies

Advanced building envelope strategies: features that adjust to environmental conditions while preserving interior comfort, such as adaptive shading, thermal mass optimisation, natural ventilation, and moisture management.

Comprehensive water strategies: collecting rainwater and using treatment systems. recycling of greywater for non-potable uses. Water storage for emergencies with quality control procedures. Decentralised wastewater treatment lessens reliance on outside sources.

Renewable energy systems designed for reliability and adaptability: solar photovoltaic systems that can operate independently for 72 hours thanks to battery storage. Techniques for passive cooling lower the need for electrical load. energy-efficient placement and selection of medical equipment. Energy resilience in communities is supported by grid-interactive systems.

Design strategies enabling rapid reconfiguration for changing healthcare needs: Multiple care delivery models are supported by modular spatial arrangements. spaces that can be converted for emergency surge capacity. distinct circulation routes to prevent infections. Culturally appropriate and pandemic response outdoor treatment areas.

CASE STUDY ANALYSIS

Gando School Health Center, Burkina Faso

By using local materials, double roofs, and natural ventilation systems, this building exemplifies passive cooling, which keeps temperatures comfortable without the need for mechanical cooling (Ashtari *et al.*, 2021). In comparison to traditional facilities, the design reduced energy use by 40% while increasing patient comfort by 35%.

Butaro Hospital, Rwanda

A facility with 95% energy independence and no service interruptions during the 2018 regional drought was made possible by the integration of solar power, natural ventilation, and rainwater harvesting (Wekesa, 2022). The biophilic design features helped patients recover 25% more quickly.

Maggie's Oldham, United Kingdom

Convertible treatment areas that were quickly rearranged during COVID-19 are an example of adaptive spatial design that maintains full-service capacity while putting improved infection control measures in place (Changi, *et al.*, 2024).

PERFORMANCE OUTCOMES

Analysis of case study facilities during crisis periods reveals

About 78% fewer service outages than traditional facilities. Reduce the use of emergency generators during power outages by 45%. 60% quicker post-crisis return to regular operations (Mutuku & Raveendran, 2024).

Daily operational benefits include

Between 35–50% less energy is used. Reduce water use by 25% by using conservation techniques. 20% operational cost reduction over ten years (Wang *et al.*, 2024).

Patient and community health impacts demonstrate

Patient satisfaction ratings increased by 15%. 30% fewer infections linked to healthcare. higher rates of employee retention as a result of better working conditions (Alanazi *et al.*, 2023).

CHALLENGES AND LIMITATIONS

Resilient systems require higher upfront costs and long-term financial modelling that shows lifecycle value. Green bonds are one example of an innovative financing mechanism. partnerships between the public and private sectors that use a variety of funding sources. Several systems must be integrated, which requires: Limited availability of specialised design expertise. sophisticated maintenance and commissioning procedures. Performance monitoring systems for optimization. Community involvement throughout the design process is necessary for local appropriateness. blending with conventional medical procedures. Respect for cultural ideas about healing environments and health.

RECOMMENDATIONS

Architects and Designers: The project intends to establish standardised resilience assessment instruments, develop passive design techniques, and incorporate climate risk assessment into healthcare facility projects. Healthcare

Planners and Policymakers: The strategy calls for incorporating resilience requirements into standards for healthcare facilities, allocating funds for sustainable infrastructure, developing facility manager training programs, and setting up regional networks for technical assistance and information exchange. Research Community: The study aims to enhance healthcare facility performance during crises, develop standardized architectural resilience metrics, explore innovative materials and technologies, and examine the community health impacts of resilient healthcare design.

CONCLUSION

Architectural resilience in primary healthcare centres represents a critical intersection of sustainable design, public health, and community development (Alfowzan, et al., 2024). This study shows that well-planned healthcare facilities can lower operating costs and their environmental impact while improving daily operational performance and crisis response capabilities. The transition toward resilient healthcare infrastructure requires coordinated action among architects, healthcare professionals, policymakers, and communities (Okyere, et al., 2024). Increased investment in architectural resilience is a cost-effective way to enhance community health outcomes and develop adaptive capacity for an uncertain climate future, according to the evidence presented.

In order to further improve healthcare facility resilience, future research should concentrate on creating standardised assessment instruments, growing case study databases, and examining cutting-edge technologies. Transforming primary healthcare infrastructure into community assets that can effectively respond to multiple challenges while supporting optimal health outcomes is imperative given the urgency of climate change and the rising frequency of health crises (Okyere et al., 2024). The design of primary healthcare facilities needs to change to become more resilient, sustainable, and adaptive as we face an uncertain future characterised by climatic variability and possible health emergencies. In an increasingly unstable world, this transition is not only an architectural challenge but also a basic necessity for guaranteeing fair access to healthcare services.

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Incorporation of Restorative Landscape Design Features in the Design of Paediatric Hospital in Makurdi, Benue State, Nigeria

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Abstract

The design of hospital facilities significantly influences the health and well-being of patients. Accordingly, incorporating specific design strategies such as well-structured walkways, increased vegetation, and unobstructed views and access to natural features is essential for enhancing patients' satisfaction and fostering a supportive environment. This paper investigates the incorporation of restorative landscape features in the architectural design of a pediatric hospital located in Makurdi, Benue State, Nigeria with the objective of fostering a restorative environment that supports the psychological and emotional recovery of patients. Primary data were obtained through structured surveys administered to hospital staff, patients, their relatives and other hospital users. The quantitative data gathered provided insight into the effectiveness of existing hospital designs and the potential value of incorporating restorative landscape components. Comparative case studies of select healthcare facilities were conducted to examine successfully implemented restorative landscape strategies. Data analysis was performed using the Statistical Package for the Social Sciences (SPSS), with reliability confirmed via Cronbach's alpha. Additionally, the Relative Importance Index (RII) was utilized to rank landscape features based on their perceived importance and impact on patient health outcomes. The study's results underscore the importance of incorporating natural elements into hospital design. Key features such as access to natural daylight with RII:0.8758, respondent's frequency of 44 and a percentage of 21.67%, views of green environments with RII:0.8640, respondent's frequency of 58 and a percentage of 28.57%, and outdoor seating areas with RII: 0.8788, respondent's frequency of 66 and a percentage of 32.52% were shown to significantly enhance patient well-being. Ultimately, the research highlights the critical role of landscape incorporation in creating healing environments within hospital settings. It concludes by advocating for the deliberate inclusion of restorative landscapes, green spaces, and nature-based features from the earliest stages of hospital planning and design, thereby fostering improved treatment outcomes and higher levels of patient satisfaction.

Keywords: Restorative landscape, Hospital design, Pediatric healthcare, Restorative environment, Patient well-being, Nature-based features.

INTRODUCTION

The design of healthcare facilities extends beyond clinical functionality; it shapes patients' psychological experiences and recovery outcomes. Research demonstrates that natural environments reduce stress, improve mood, and foster healing (Brambilla *et al.*, 2019). For children, whose hospital experiences are often marked by fear and anxiety, access to restorative spaces can be particularly transformative (Wilson, 2015).

Globally, hospitals have increasingly incorporated biophilic and therapeutic design strategies, such as gardens, natural lighting, and interactive spaces, into healthcare architecture (Joye & van den Berg, 2018). These features promote restoration from mental fatigue and enhance overall satisfaction. However, in Nigeria, most hospitals neglect outdoor landscapes and fail to prioritise therapeutic design (Adebayo *et al.*, 2022; Barau *et al.*, 2022). Consequently, hospital environments often exacerbate stress rather than alleviate it.

Paediatric hospitals require special attention because of their distinct user groups—children, families, staff, and visitors—whose needs extend beyond clinical care to psychological and emotional support. Yet, there is little research on how restorative landscapes can be systematically applied in Nigerian paediatric healthcare facilities.

This study addresses this gap by investigating how restorative landscape features can be incorporated into the design of a proposed paediatric hospital in Makurdi, Benue State. It aims to (1) identify patient and staff needs regarding outdoor spaces; (2) assess user perceptions of landscape features; and (3) propose design strategies that integrate healing gardens, natural light, and accessible green spaces into paediatric healthcare design.

LITERATURE REVIEW

Restorative Environments in Healthcare

Hospital environments significantly influence patient outcomes by affecting stress, anxiety, recovery rates, and satisfaction (Douglas & Douglas, 2004). Key factors include noise levels, lighting, air quality, and spatial organisation (Jamshidi *et al.*, 2020). Paediatric hospitals must go further, incorporating playful, interactive, and family-friendly features (Neilson *et al.*, 2019). Restorative spaces—defined as environments that replenish cognitive resources and reduce stress—are essential for supporting recovery (Berto & Barbiero, 2017).

Healing Gardens and Therapeutic Landscapes

Gesler (1992) introduced the concept of therapeutic landscapes, highlighting the role of physical, social, and symbolic environments in healing. Healing gardens, a subset of therapeutic landscapes, have deep historical roots—from Egyptian temple gardens to medieval monastic courtyards (Dinu Roman Szabo *et al.*, 2023). Modern healing gardens are guided by theories of Biophilia (Wilson, 1984), Attention Restoration Theory (ART) (Kaplan & Kaplan, 1989), and Stress Reduction Theory (SRT) (Ulrich, 1991).

Healing gardens provide; Psychological benefits: reduced stress and cognitive restoration (Cordoza *et al.*, 2018); Physiological benefits: faster recovery and reduced pain perception (Ulrich, 1984); and, social benefits in enhanced support and community-building (Kim, 2021). It is also known to have environmental benefits through air purification, biodiversity, and sustainable cooling (Andriani *et al.*, 2021).

Evidence of Health Outcomes are abounds and numerous studies demonstrate that access to nature improves medical outcomes. Ulrich (1984) found that post-surgical patients with window views of trees recovered faster and required less pain medication than those facing a wall. Whitehouse *et al.* (2001) observed that hospital gardens reduced anxiety in children and increased family satisfaction. Staff also benefit; access to gardens reduces burnout and supports retention (Sadler, 2001). Conversely, poorly designed environments dominated by hardscape or ambiguous art can worsen stress (Ulrich, 1999).

Landscape Design Strategies in Healthcare

Effective restorative landscapes follow principles of richness, compatibility, and attractiveness (Liu *et al.*, 2023). Strategies include multisensory engagement (sight, sound, scent, touch), accessible pathways, shaded seating, and flexible use areas (Mahmood, 2018). Indoor plants also contribute through phytoremediation, removing pollutants such as benzene and formaldehyde (Susanto *et al.*, 2021; Han *et al.*, 2022). Outdoor design must accommodate diverse users—children, elderly, and disabled—while ensuring safety and sustainability (Paraskevopoulou & Kamperi, 2018).

Theoretical Framework and Application to Paediatric Hospitals

Three theories frame this study: the Attention Restoration Theory (ART) – that Nature restores depleted cognitive resources (Ohly *et al.*, 2016); the Stress Reduction Theory (SRT) - Natural environments lower stress and improve well-being (Ulrich *et al.*, 1991); and, the Prospect-Refuge Theory: Spaces combining visibility with security promote comfort and healing (Dosen & Ostwald, 2016). In paediatric hospitals, these frameworks support incorporation of playful landscapes, family gardens, and staff wellness areas to foster holistic healing (Allahyar & Kazemi, 2021).

METHODOLOGY

Research Design, Study Population and Sampling

A mixed-method approach was adopted to capture both statistical trends and in-depth insights. This combination strengthens validity by integrating quantitative surveys with qualitative case studies (Creswell & Creswell, 2018). The study population included patients, parents, visitors, and staff in hospitals across Benue State. A stratified random sampling method ensured diverse representation. The sample size was determined using standard statistical guidelines for social research, balancing accuracy and feasibility.

Data Collection Methods

Primary data: Surveys, structured interviews, and observational studies of hospital landscapes. Secondary data: Literature reviews, architectural drawings, and hospital records. Questionnaires were pre-tested for clarity and consistency. Reliability was confirmed through Cronbach's alpha, while expert review ensured content validity (Denscombe, 2014). On data Analysis and Ethics, survey responses were analysed using descriptive statistics and the Relative Importance Index (RII) to rank user preferences. Case studies were evaluated through comparative analysis. Ethical approval was obtained, and participants gave informed consent, with anonymity guaranteed.

RESULTS AND ANALYSIS

Demographic Profile

Respondents included healthcare staff, parents, and visitors, representing a broad range of ages and professional backgrounds, reflecting the diversity of hospital users.

Perceptions of Restorative Features

Survey results indicated strong support for incorporating gardens, walkways, natural lighting, and child-friendly play areas. Respondents associated these features with stress reduction and comfort, aligning with findings by Whitehouse *et al.* (2001).

Relative Importance Index (RII) Ranked preferences included

- a) Architectural features (RII = 0.87).
- b) Colour-coded signage (0.85).
- c) Digital navigation aids (0.84).
- d) Spatial organisation and layout (0.81).

Case Studies

National Hospital Abuja: Demonstrated integration of gardens and defined walkways.

Benue State University Teaching Hospital: Highlighted gaps in outdoor space utilisation.

Nelson Mandela Children's Hospital (South Africa): Incorporated sit-out gardens and interactive spaces.

Boston Children's Hospital (USA): Featured rooftop healing gardens and multisensory design.

Design Application

Insights from these case studies informed the proposed hospital in Makurdi, which integrates courtyards, therapeutic gardens, child-focused play areas, and staff wellness facilities.

DISCUSSION AND RECOMMENDATION

Healing Benefits

Restorative landscapes support psychological recovery, reduce medication use, and enhance satisfaction for patients and families (Cordoza *et al.*, 2018).

Design Implications

Hospitals should adopt biophilic design principles, integrating vegetation, water, and natural ventilation. Multisensory features should be prioritised to stimulate children's curiosity and comfort (Mahmood, 2018).

Policy Recommendations

Nigerian healthcare design standards should mandate the inclusion of therapeutic landscapes in hospital projects. Policies must prioritise child-centred care environments (Zeisel & Buchman, 2018).

Professional Collaboration

Designing restorative hospitals requires collaboration between architects, healthcare providers, landscape architects, and policymakers to ensure both functional and therapeutic goals are met (Paraskevopoulou & Kamperi, 2018).

Future Research

Further studies should explore long-term impacts of healing gardens on clinical outcomes in Nigerian paediatric hospitals. Comparative studies across different regions would strengthen evidence and inform national policy.

CONCLUSION

This study demonstrates that restorative landscape features significantly improve hospital experiences for children, families, and staff. By integrating healing gardens, accessible pathways, multisensory features, and staff wellness spaces, paediatric hospitals in Nigeria can move beyond functionality to foster holistic healing environments. The proposed design for Makurdi illustrates how global best practices can be adapted to local contexts. Incorporating these principles into national healthcare policy and architectural standards will bridge current gaps, enhance patient care, and promote sustainable healthcare environments.

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Evaluation of the perceptions of patients, staff, and visitors on the therapeutic benefits of landscape design in teaching hospitals in Abuja

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ABSTRACT

Rapid urbanization and the expansion of healthcare infrastructure in Abuja have often prioritized clinical functionality over the integration of natural and therapeutic environmental features. This trend raises questions about how landscape design can influence healing, well-being, and overall hospital experience for patients. Therapeutic landscapes defined by elements such as greenery, water features, natural light, and spatial arrangements are increasingly recognized for their potential to foster emotional, psychological, and physiological recovery. This study aims to evaluate the perceptions of patients, hospital staff, and visitors regarding the therapeutic benefits of landscape design in teaching hospitals within Abuja. Using a mixed-methods approach, the research combines structured surveys with qualitative interviews to capture diverse user perspectives across demographic and professional backgrounds. Participants were asked to reflect on their experiences with hospital landscapes, focusing on natural elements such as vegetation, water features, and natural light, as well as spatial configurations that evoke organic forms and patterns. The analysis revealed significant patterns indicating that landscape features which promote tranquility, connection with nature, and restorative environments are highly valued by users. The findings suggest that integrating user-preferred landscape elements can enhance healing environments, improve staff morale, and enrich visitor experiences. This underscores the importance of adopting a human-centered approach in hospital landscape design, emphasizing sustainable and culturally sensitive practices that align with users' needs. In conclusion, this research advocates for the strategic integration of therapeutic landscape elements in Abuja's teaching hospitals. By prioritizing natural features that resonate with users' perceptions, hospital environments can be transformed into holistic spaces that support health, wellbeing, and long-term satisfaction, contributing to sustainable healthcare architecture.

Keywords: Therapeutic Landscape, Teaching Hospital, Patient well-being, Sustainable design, Visitor experience, Natural elements

INTRODUCTION

The design of healthcare facilities plays a pivotal role in shaping the health and well-being of patients. Beyond clinical care, the physical environment significantly influences recovery, stress reduction, and overall satisfaction (Brown & Corry, 2020). Research has consistently demonstrated that thoughtfully integrated natural features such as vegetation, gardens, and outdoor seating areas that support physical and mental health by providing restorative experiences (Kaplan *et al.*, 2004; Ellis *et al.*, 2006; Ward Thompson & Aspinall, 2011). Hadavi *et al.* (2017) further emphasized that features such as well-designed sidewalks, enhanced vegetation, and unobstructed access to natural elements are essential not only for environmental quality but also for user satisfaction within local communities.

In the Nigerian context, Barau *et al.* (2022) assessed the role of outdoor green areas in ATBU Teaching Hospital, Bauchi, and reported that gardens reduced stress, promoted healing, and improved the quality of life for both patients and staff. However, many existing healthcare facilities across the country still lack the deliberate incorporation of therapeutic landscape features, often limiting greenery to aesthetics or shade rather than embedding it as part of holistic patient care (Sholanke & Oke, 2020; Manga *et al.*, 2023). These gaps reflect missed opportunities to align hospital design with global best practices, which emphasize healing environments that merge clinical efficiency with restorative landscapes (Marcus & Sachs, 2014).

Teaching hospitals provide a particularly strategic platform for integrating therapeutic landscapes, as they serve patients, healthcare professionals, and medical students simultaneously. Evidence from Lagos University Teaching Hospital demonstrates that architectural design strongly influences patient experiences and underscores the importance of human-centered spaces in advancing healing outcomes (Akinluyi, 2021). In Abuja, Nigeria's rapidly urbanizing capital, the growing demand for quality healthcare highlights the urgency of embedding green and therapeutic landscapes into hospital design to counterbalance stress-inducing urban conditions and promote sustainable health infrastructure.

The study focuses on the impacts of blue and green spaces for older adults and asserting that, access to nature can have a positive impact on physical health, mental health, and social wellbeing. Building on these insights, Barau *et al.* (2022) examine the therapeutic benefits of hospital gardens and outdoor green spaces, offering design recommendations based on their findings. Their study evaluates these landscapes within the ATBU Teaching Hospital in Bauchi, Nigeria, and considers the integration of landscape elements into pediatric and women's hospitals in Maiduguri, Borno State (Usman & Muhammad, 2023).

This study investigates the integration of therapeutic landscapes into the design of a teaching hospital in Abuja, Nigeria. Using structured surveys, case studies, and statistical analysis (SPSS, Cronbach's alpha, and Relative Importance Index), the research identifies and prioritizes key landscape elements with the potential to enhance patient recovery, reduce stress among healthcare workers, and provide supportive environments for medical education. By framing hospital design through both healing and sustainability lenses, this study aligns with the global agenda for resilient, regenerative, and patient-centered healthcare architecture (ASLA, 2017).

The findings aim to contribute to the discourse on sustainable healthcare environments in Nigeria by demonstrating how therapeutic landscape integration can foster improved treatment outcomes, environmental performance, and user satisfaction. Ultimately, the study provides evidence-based recommendations for embedding green, restorative, and sustainable landscapes

from the inception of hospital design, positioning Abuja's teaching hospital as a model for future healthcare facilities in Nigeria and beyond.

In Abuja, hospitals reflect this pattern, lacking frameworks or guidelines to integrate therapeutic landscapes that suit local climatic and cultural contexts. This gap risks undermining patient recovery, prolonging hospital stays, and diminishing staff resilience. The key challenge is determining how to effectively incorporate natural elements and culturally relevant features into hospital design, while also addressing stakeholder perceptions and potential barriers.

This research therefore seeks to develop a context-specific framework for integrating therapeutic landscapes into Abuja's teaching hospitals, aligning with global best practices while addressing Nigeria's unique realities.

LITERATURE REVIEW

The Concept of Therapeutic Landscapes

Introduced by Gesler (1992), emphasizes the capacity of places to contribute to healing through physical, social and symbolic dimensions. In healthcare design, therapeutic landscapes are expressed through natural features such as greenery, water, open space, light, and their integration with patient pathways and staff facilities. Later refinements extend the concept to urban parks, gardens, and hospital courtyards, highlighting both environmental affordances and cultural meanings (Bell *et al.*, 2018). This perspective frames hospital landscapes not as decorative amenities, but as active components of the healing environment. Therapeutic landscapes research synthesizes psychological, physiological and place-theory perspectives. The effectiveness of therapeutic landscapes is underpinned by several key theoretical frameworks:

Place Attachment Theory

Theory emphasizes the emotional bonds between people and places, where strong connections to the environment foster a sense of belonging and enhanced well-being (Hidalgo & Hernandez, 2001; Scannell & Gifford, 2010). It highlights the cognitive, emotional, and social dimensions that intertwine with the physical attributes of a place, shaping human experiences and perceptions (Shumaker & Taylor, 1983; Lewicka, 2011).

Stress Reduction Theory (SRT)

Proposed by Ulrich (1983, 1984), SRT posits that exposure to natural environments triggers physiological and psychological mechanisms that effectively reduce stress levels and promote relaxation. Chronic stress is linked to various non-communicable diseases, and restorative environments such as serene forests or well-designed urban green spaces that provide rejuvenation and revitalization, leading to improved stress recovery and mental fatigue restoration (Townsend *et al.*, 2018; Lee *et al.*, 2021).

Attention Restoration Theory (ART)

Developed by Rachel and Stephen Kaplan (1983), ART suggests that interacting with natural environments can restore depleted directed attention and improve cognitive functioning. Nature provides "soft fascination," allowing the brain to recover from mental fatigue by engaging effortlessly, thereby enhancing focus and overall well-being (Kaplan & Kaplan, 1989; Ohly *et al.*, 2016).

Biophilia Hypothesis

Wilson (1984) and Kellert & Wilson (1993) introduced the biophilia hypothesis, which posits an inherent human affinity for nature, suggesting that contact with natural elements is vital for overall health and well-being. This innate emotional affiliation is seen as a "learning rule" that helps understand nature and has deep evolutionary roots, influencing emotional reactions and adaptive responses (Wilson, 1993; Joye & de Block, 2011). Empirical evidence supports this, with systematic reviews confirming that exposure to green environments consistently reduces blood pressure and heart rate (Van den Berg *et al.*, 2017; Lee *et al.*, 2022).

Healing Garden

A healing garden is a purposefully designed outdoor space that incorporates natural elements such as plants, water, sunlight, and sensory features to promote holistic health. In teaching hospitals, these gardens function as therapeutic landscapes that support patient recovery, reduce staff stress, and provide learning and research opportunities for medical students. Characterized by accessibility, inclusivity, and sensory richness, they foster resilience and well-being for patients, families, and healthcare providers. Drawing on biophilic design principles, healing gardens integrate therapeutic, social, and educational components, thereby enhancing the overall healthcare environment (Ulrich *et al.*, 2020; Peters *et al.*, 2020; Chaudhary *et al.*, 2022).

Design Principles and Strategies for Therapeutic Landscapes

Effective therapeutic landscape design integrates thoughtful strategies tailored to user needs and site characteristics:

Patient-Centered and Evidence-Supported Design (PCD/EBD): These principles prioritize patient needs and comfort, grounding design decisions in empirical research (Ulrich *et al.*, 2020; Hamilton *et al.*, 2022). EBD advocates for spaces that reduce anxiety, pain, and hospital stay durations through features like healing gardens and natural light, fostering feelings of control and comfort (Ulrich *et al.*, 2021).

User-Centered Design (UCD): UCD involves engaging all stakeholders' patients, staff, visitors, students directly in the design process to create accessible, meaningful, safe, and engaging environments (Lawson, 1980; Norman, 2013). Participatory design approaches in hospital gardens have been shown to increase user satisfaction and usage rates (Liu *et al.*, 2022).

Biophilic Design: This approach integrates natural elements and patterns into the built environment to enhance human connection with nature (Kellert, 2008; Browning *et al.*, 2014). Strategies include visual connection with nature (natural views),

presence of natural light and daylight optimization, natural ventilation, use of natural materials, integration of water features, access to outdoor gardens, nature-themed imagery, and spatial diversity (Park *et al.*, 2020; Liu *et al.*, 2022; Ulrich *et al.*, 2019; Zhang & Wang, 2021; Kellert *et al.*, 2020; Oh *et al.*, 2021).

Sustainable Design: In teaching hospitals, sustainability reduces ecological footprint and enhances occupant well-being and operational efficiency (Van der Ryn & Cowan, 2007). This involves energy efficiency (high-performance insulation, renewable energy), water conservation (low-flow fixtures, rainwater harvesting), improved Indoor Environmental Quality (IEQ), and integrated waste management (Liu *et al.*, 2022; Zhou *et al.*, 2023; Kim *et al.*, 2022).

Specific Design Strategies for Teaching Hospitals

To maximize the healing potential of therapeutic landscapes in teaching hospitals, specific design strategies must be adopted that integrate natural, social, and cultural dimensions of the healthcare environment.

One of the most fundamental approaches is maximizing contact with nature. This can be achieved by incorporating gardens, green roofs, and outdoor healing spaces into the hospital fabric, as well as by maximizing natural daylight, introducing indoor plants, and ensuring patient rooms and waiting areas have direct views of natural landscapes. Biophilic interior design elements—such as natural materials, patterns, and textures combined with accessible therapeutic gardens and courtyards, further strengthen the restorative connection between users and nature (Annerstedt van den Bosch & Ode Sang, 2017; Wang *et al.*, 2022; Kellert *et al.*, 2021; Ulrich *et al.*, 2020). Equally important is the creation of restorative zones. These include quiet, nature-inspired areas such as shaded courtyards, green roofs, and healing gardens that offer patients, families, and staff places of respite and stress reduction. Indoor restorative environments are also essential, with design considerations such as ample natural light, acoustic control, and the use of calming natural forms to promote mental recovery and relaxation (Ulrich *et al.*, 2008; Hartig *et al.*, 2003; Kellert & Calabrese, 2015).

Teaching hospitals also benefit from encouraging social connections through design. Inclusive gathering spaces such as lounges, cafés, and landscaped gardens can foster interaction, build community, and promote peer support among patients. Dedicated family rooms and visitor-friendly environments strengthen family engagement, while shared spaces for staff and students encourage interprofessional collaboration, which is central to the teaching hospital model (Francis *et al.*, 2012; Ulrich *et al.*, 2020).

In addition to natural and social elements, the integration of art and music into hospital design enriches the therapeutic environment. Art installations, music therapy programs, and other creative mediums have been shown to reduce stress, uplift mood, and enhance the overall healing experience (Stuckey & Nobel, 2010; Nilsson, 2009). To ensure these environments remain supportive and safe, careful attention must also be given to safety and security measures, including proper lighting, clear sightlines, and unobstructed circulation routes, which together help create environments that feel welcoming yet secure (Painter, 1996).

Benefits of Therapeutic Landscapes in Teaching Hospitals

The integration of therapeutic landscapes in the design of a teaching hospital in Abuja offers multidimensional benefits that extend across patients, staff, families, and the broader healthcare system. First, therapeutic landscapes contribute directly to improved patient recovery and well-being. Exposure to natural settings has been shown to reduce psychological distress, accelerate physical recovery, lower blood pressure, and strengthen immune function, thereby supporting faster recuperation and enhancing overall health outcomes (Nieberler-Walker *et al.*, 2023; Ulrich *et al.*, 2020).

Beyond physical recovery, therapeutic environments play a critical role in promoting mental and emotional well-being. The presence of natural elements such as gardens, water features, and greenery alleviates psychological stress, improves mood, and reduces anxiety levels, which is particularly vital for patients undergoing long-term treatment and recovery (Lee *et al.*, 2021).

The benefits extend to healthcare professionals as well. The integration of green spaces helps in reducing stress and burnout among hospital staff. Research has shown that staff who regularly utilize hospital gardens experience lowered stress levels, improved job satisfaction, and enhanced concentration, which translates into better quality of care for patients (Ulrich *et al.*, 2022).

For patients and their families, therapeutic landscapes foster enhanced satisfaction and engagement. Green spaces within hospital environments provide peaceful retreats that support family bonding, improve the hospital experience, and promote a more patient-centered approach to care (Kearns *et al.*, 2021).

Therapeutic landscapes also support holistic and integrative healthcare approaches. They can function as outdoor classrooms for therapeutic interventions such as horticultural therapy, mindfulness practices, and health education programs, thereby reinforcing preventive and complementary care strategies within the hospital environment (Lee *et al.*, 2022).

Additionally, these spaces provide research and educational opportunities. As real-world laboratories, they enable studies on the environmental impacts of healthcare design, while also fostering interdisciplinary collaboration among medical, environmental, and social science researchers (Smith *et al.*, 2023).

Finally, therapeutic landscapes contribute to sustainability goals. Incorporating native plantings, rain gardens, and green roofs not only reduces the hospital's environmental footprint but also lowers operational costs through improved energy efficiency and water management (Moore *et al.*, 2023).

EVIDENCE FROM HEALTHCARE DESIGN

Subsequent research has reinforced these findings. Marcus and Barnes (1999) established that healing gardens support stress reduction, social interaction, and emotional resilience among hospital users. Harris *et al.* (2016) conducted a systematic review linking hospital interior and landscape design to improved patient and staff outcomes. Moreover, exposure to natural elements has been shown to reduce blood pressure, enhance mood, and shorten hospital stays (Ulrich *et al.*, 1991; Bowler *et al.*, 2010).

STAFF AND VISITOR PERSPECTIVES

Much of the literature has focused on patient outcomes, but recent studies highlight the equally important needs of hospital staff and visitors. Nejati *et al.* (2016) identified restorative design features such as access to natural light and outdoor break areas as critical to staff well-being. Visitors, often dealing with stress and anxiety, also benefit from calming environments that provide respite during long waiting periods (Whitehouse *et al.*, 2001).

AFRICAN AND NIGERIAN CONTEXT

In the African context, the integration of landscape design in hospitals remains limited. Adegun (2017) argues that Nigeria's built environment often prioritises rapid urban expansion over environmental quality. Yet, culturally appropriate design such as the use of indigenous plants and climate-sensitive layouts can enhance both sustainability and user satisfaction. The Abuja context presents a unique opportunity to examine how therapeutic landscapes might be adapted to local cultural and environmental realities.

Gaps and context-specific needs for Abuja/Nigeria

While international evidence is robust, Nigerian teaching hospitals often treat landscapes as aesthetic rather than therapeutic. Local needs include drought and heat-adaptive species, maintenance capacity, cultural relevance, and clear institutional support.

METHODOLOGY

This study adopts a mixed-methods approach to comprehensively investigate the integration of therapeutic landscapes in the design of a teaching hospital in Abuja, Nigeria. This methodology combines qualitative and quantitative data collection and analysis to provide a holistic understanding of stakeholder perceptions, empirical evidence of benefits, and spatial design elements. This approach aligns with recent studies that advocate for integrating personal narratives with empirical data for effective healing environment design (Ulrich *et al.*, 2021; Zhang & Liu, 2023). The study was conducted in the Federal Capital Territory (F.C.T.), Abuja, Nigeria, a rapidly expanding urban center with an estimated population of over 4.5 million residents by 2023 (based on growth rates from the 2006 census of 1.4 million). The study population encompasses prospective users of a teaching hospital in Abuja, including patients, caregivers, hospital staff, and visitors, reflecting the diverse demographic served by such a facility.

A mixed-method design combined (a) literature and design-document review; (b) comparative case studies (local and international hospitals); (c) structured electronic questionnaires distributed to patients, hospital staff and visitors; (d) observational surveys of existing hospital landscapes; and (e) semi- structured interviews with stakeholders (designers, facility managers, clinicians and administrators). Ethical approval and informed consent procedures were followed during fieldwork. Employed to recruit readily accessible and willing participants (patients, staff, visitors) within existing hospital premises to gather broad, representative data.

To determine the sample size for the quantitative survey, the Krejcie and Morgan (1970) table was adopted. For a large and known population exceeding one million (such as Abuja's FCT), a minimum of 200 questionnaires structured into two both patient and staff; distributed to the patients and staff within the Teaching Hospital. Ensuring data reliability, a minimum of 60% of distributed questionnaires were required to be valid and completely filled, thus targeting at least 115 valid responses for analysis for the patients and 50 valid responses for the staffs.

Sample and instruments

Reliability

Assessed using Cronbach's Alpha to measure internal consistency of questionnaire items. A Cronbach's Alpha value of 0.589 for the landscape elements scale was considered moderate, indicating a reasonable level of consistency (George & Mallery, 2000).

Table 1: Reliability Test Outputs

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Item	No of Items
0.564	0.589	4

Validity

Ensured by comparing study findings with existing literature and established theoretical frameworks. Consultation with a project supervisor further reinforced the appropriateness and accuracy of the measurement tools. Hypothesis testing using cross- tabulation and Chi-square tests was employed to validate relationships between variables.

Table 2: Question Validity

Cronbachs Alpha	Mean	Standard	N
Garden and Green Spaces	4.0810	0.79924	111
Outdoor seating areas	4.0360	0.83040	111
Natural Lighting and views of nature	4.2613	0.68372	111
Art and Sculptures	3.1351	1.04869	111

Instruments

Structured questionnaire (5-point Likert items), observation checklist, and interview guide. The questionnaire captured awareness, access, perceptions of benefit, constraints, and priorities for specific landscape elements. Reliability was assessed using Cronbach's alpha; the study reports a moderate internal consistency (Cronbach's $\alpha \approx 0.59$), adequate for exploratory analysis.

RESULTS AND ANALYSIS

The data were analyzed using appropriate statistical methods to identify significant relationships between the variables whilst the discussions provide an in-depth interpretation of the survey results, relating them to the research objectives and the existing literature on the topic. The discussion also highlights the implications of the survey findings for the design of Teaching hospitals, emphasizing the importance of integrating landscape elements to create healing environments between the staff and the patients as it relates to how integration of therapeutic landscape in the design Hospitals can improve the overall perception of the patient and staff

The patient population was largely youthful to middle-aged, with most aged 26–35 years (48.6%) and a balanced gender distribution (55.1% male, 44.9% female). Educational levels were high, as over 70% held bachelor's or master's degrees, indicating an informed group capable of providing valuable perspectives on therapeutic environments while the Staff were mostly within the 26–45 age group, representing diverse roles such as technical (28.3%) and administrative (18.9%), with the majority having less than 10 years of experience. This diversity enriched perspectives on how therapeutic landscapes influence staff well-being and productivity.

Environmental Comfort Ratings

More than half of the patients rated natural lighting (56.1%) and ventilation (51.4%) as good or very good. However, 37.3% and 44.8% rated noise levels and privacy, respectively, as poor, or very poor. This suggests that while certain comfort elements are well implemented, others, like noise control and privacy need improvement as shown in Table 3.

Table 3: Environmental Comfort Ratings

Variable	Positive (Good + Very Good) - % -	Neutral (%)	Negative (Poor + Very Poor) - % -
Natural lighting	56.1	26.2	17.8
Ventilation / Air	51.4	33.6	14.9
Noise levels	27.1	35.5	37.3
Room temperature	38.3	38.3	23.4
Cleanliness	52.3	21.5	26.2
Proximity	49.5	33.6	16.9
Views of nature	46.7	29.0	24.3
Accessibility	55.7	29.0	24.3
Bed comfort	44.8	28.0	27.1
Privacy	27.1	28.0	44.8

Staff Access to Landscape Features

Natural light (71.7%) and outdoor gardens (49.1%) were the most accessed features, while only 5.7% of staff reported no access. About half accessed features occasionally, but regular daily access was rare. These results underscore the need to improve frequency and ease of access.

Table 4: Landscape access

Variable	Frequency	Percentage (%)
Indoor potted plants	21	39.6
Natural light	38	71.7
Central indoor courtyards	25	47.2
Outdoor gardens	26	49.1
Rooftop gardens	3	5.7
Green walls	5	9.4
Natural-themed interior décor	15	28.2
Water feature	7	13.2
Trees or shaded walking paths	19	35.8

Presence of Indoor Landscape Elements

High presence was reported for natural light (63.6%) and resting benches (73.8%). Moderate presence was seen for indoor gardens (46.7%) and potted plants (55.1%). Features like vertical gardens and water features were less common. Exposure to indoor greenery is uneven. Key features exist but are not uniformly accessible, suggesting room for environmental design improvements.

Table 5: Presence of Indoor Landscape Elements

Variables	Category	Frequency	Percentage
Potted plants or greenery in hallways/lobbies	Yes	59	55.1
	No	34	31.8
	Not sure	14	13.1
Indoor therapeutic garden or courtyard	Yes	50	46.7
	No	43	40.2
	Not sure	14	13.1
Vertical garden / green wall	Yes	28	26.2
	No	67	62.6
	Not sure	12	11.2
Natural light through atriums/skylights	Yes	68	63.6
	No	27	25.2
	Not sure	12	11.2
Water features (indoor fountain, pool)	Yes	22	20.6
	No	73	68.2
	Not sure	12	11.2
Use of natural materials (wood, stone) in interiors	Yes	49	45.8
	No	42	39.3
	Not sure	16	15.0
Garden-themed waiting lounges	Yes	31	29.0
	No	57	53.3
	Not sure	19	17.8
Interior art or murals of nature	Yes	41	38.3
	No	49	45.8
	Not sure	17	15.9
Scented plants or sensory design features	Yes	30	28.0
	No	59	55.1
	Not sure	18	16.8
Resting benches near indoor greenery	Yes	79	73.8
	No	21	19.6
	Not sure	7	6.5

Healing Perception by Gender

Chi-square tests revealed no significant gender differences in agreement levels regarding stress reduction, improved emotional well-being, or faster healing associated with greenery. This implies a consistent perception of healing benefits across genders.

Table 6: Contingency tables of gender against Healing perception

Variables	Dependent variables	Male	Female	Hi-square (p-value)
Indoor greenery reduced stress	Agree	50	38	0.564 (0.453)
	Disagree	9	10	
Natural features improved emotional wellbeing	Agree	52	41	0.172(0.678)
	Disagree	7	7	
Green areas supported faster healing	Agree	50	38	0.564(0.453)
	Disagree	9	10	

Constraints and enabling strategies

Top institutional constraints reported were budget limitations (73.6%), a prevailing functional- over-healing design culture (77.3%), and limited local expertise in therapeutic landscape design (≈83%). Usage constraints included limited staff time and proximity of green spaces to work areas. The most frequently suggested enabling strategies were formation of interdisciplinary design teams (72.9%), dedicated design and maintenance budgets (64.5%), and staff maintenance training (61.7%).

Access and usage

Staff access to landscape features was uneven. Natural light was the most- accessed feature (71.7% of staff reported access); outdoor gardens were accessed by ~49.1%; rooftop gardens and green walls were accessed only by a small minority (rooftop gardens 5.7%; green walls 9.4%). Indoor potted plants were present but not universally accessed (≈39.6%). This access patterns point to high value placed on simple, daylight and courtyard-based elements but limited diffusion of more complex features.

Perceptions of benefit

Large majorities believed green design reduced stress (71.1%) and that healing gardens support recovery (77.5%). Staff reported strong perceived gains in morale, productivity and stress reduction: over 84% reported feeling refreshed by environments with landscape features and a similar proportion associated landscape features with reduced burnout. Chi-square tests showed no significant gender differences in healing perceptions, indicating broadly shared views

across demographic groups.

Top institutional constraints reported were budget limitations (73.6%), a prevailing functional- over-healing design culture (77.3%), and limited local expertise in therapeutic landscape design ($\approx 83\%$). Usage constraints included limited staff time and proximity of green spaces to work areas. The most frequently suggested enabling strategies were formation of interdisciplinary design teams (72.9%), dedicated design and maintenance budgets (64.5%), and staff maintenance training (61.7%).

Analysis

Quantitative data were analyzed with descriptive statistics, chi-square tests for subgroup differences, and Relative Importance Index (RII) to rank landscape elements according to perceived importance. Qualitative interviews were coded thematically to identify barriers, enabling conditions, and design preferences.

Relative Importance Index (RII) priority elements

The RII ranking highlighted the highest priority items as simple, high-visibility, and low-cost interventions:

Table 6 Relative Importance Index (RII) of Landscape Elements to be Integrated

Landscape Element	Rating (w)	Positive %	A*N (w*f)	RII	Decision
Resting benches near Greenery	5	74	370	30.74	5
Natural light through skylights	5	64	320	0.64	5
Indoor potted plants in hallways / lobbies	4	55	220	0.44	4
Outdoor gardens	4	49	196	0.392	4
Use of natural materials	4	46	184	0.368	3
Garden-themed waiting lounges	3	29	87	0.174	3
Interior art/murals of nature	3	38	144	0.228	3
Scented plants or sensory features	3	28	84	0.168	2
Natural-themed interior décor	3	28	84	0.168	2
Water features (indoor fountain, pool)	2	21	42	0.084	2
Water feature (staff access)	2	13	26	0.052	2
Trees or shaded walking paths	3	36	108	0.216	2
Rooftop gardens	1	6	6	0.012	1
Green walls	1	9	9	0.018	1

The RII analysis provides a ranked prioritization of landscape elements:

High Priority

Resting benches near greenery (RII = 0.74), Natural light through skylights (RII = 0.64). These are seen as most crucial for immediate therapeutic impact.

Medium-High Priority

Indoor potted plants in hallways/lobbies (RII = 0.44), Outdoor gardens (RII = 0.392). These are important but slightly less critical than the top two.

Medium Priority

Use of natural materials (RII = 0.368), Interior art/murals of nature (RII = 0.228), Trees or shaded walking paths (RII = 0.216), Garden-themed waiting lounges (RII = 0.174), Scented plants or sensory features (RII = 0.168), Natural-themed interior décor (RII = 0.168). These contribute significantly to the therapeutic atmosphere.

Low Priority

Water features (indoor fountain, pool) (RII = 0.084), Water feature (staff access) (RII = 0.052). While beneficial, these are perceived as less critical than other elements.

Very Low Priority

Rooftop gardens (RII = 0.012), Green walls (RII = 0.018). While innovative, these might be perceived as less immediately impactful or practical given current contexts.

This ranking provides a practical guide for designers and policymakers on which elements to prioritize during the planning and implementation of therapeutic landscapes in Abuja's teaching hospitals.

DISCUSSION AND RECOMMENDATIONS

The empirical results align with international evidence that access to natural elements in healthcare settings contributes to psychological restoration and improved staff wellbeing (Ulrich, 1984; Kaplan & Kaplan, 1989; Berman et al., 2008). However, the Abuja context shows distinctive operational constraints: compressed budgets, spatial limitations, and institutional priorities centered on function. These contextual realities shape pragmatic implementation choices.

Two implications stand out. First, prioritize high-impact, low-cost interventions (daylight optimization, benches and shaded courtyards, indoor plants), these scored highest by users and are achievable within constrained budgets. Demonstrable small pilots can provide quick wins and build institutional support. Second, institutional reform (policy, budgets, interdisciplinary teams and training) is essential for scaling beyond isolated pilots. The paper proposes a phased, evidence-driven rollout that begins with high-RII interventions, evaluates impact (user surveys, stress indicators), and then expands interventions as evidence and budgets permit.

Future research

Further studies should explore comparative research across different Nigerian regions and hospital types (primary,

secondary, tertiary) is also recommended.

CONCLUSION

The study affirms that therapeutic landscapes are essential for enhancing patient recovery, staff well-being, and overall healthcare delivery in Abuja's teaching hospitals. While natural lighting and ventilation are strengths, deficiencies in noise control, privacy, and uneven integration of landscape features limit their full potential. Both patients and staff reported significant psychological and physical benefits from exposure to natural elements, yet systemic barriers such as limited funding, functional design priorities, lack of awareness, and inadequate expertise hinder widespread adoption. The study emphasizes that therapeutic landscapes should be treated as core design priorities rather than optional additions, calling for policy support, institutional investment, and interdisciplinary collaboration. It further provides practical design guidelines and pilot proposals to guide implementation and future research. Adopt an evidence-based checklist (RII-informed) for hospital briefs: daylighting, accessible seating near greenery, accessible courtyards, indoor plants, and natural materials.

Institutionalize dedicated landscape design and maintenance budgets to avoid ad-hoc provision and degradation.

Require interdisciplinary project teams that include landscape architects, clinicians and facilities managers in hospital projects.

Start with pilot projects (staff break courtyards, paediatric play garden) with before/after evaluation of psychological and use outcomes. Embed therapeutic landscape modules into medical and facility-management training to increase uptake and long-term stewardship.

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Examining Urban Environmental Quality in Shaping Sustainable Human Behaviour for Long-Term Development in Nigeria: Revitalising Urban Landscapes

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Abstract

*This study looks at the basic elements of urban environmental quality and how they affect human behaviour in given circumstances of Keffi, Nasarawa State, Nigeria's urban environments. The study aims to develop improvements that promote environmentally conscious living and increase community levels of life by rejuvenating urban areas through more stringent environmental regulations. The study takes a mixed-methods strategy, combining quantitative evaluations of environmental quality (EQLTY) variables, including water quality (WQLTY), Urban green spaces (UGS), and garbage disposal/refuse disposal (REFD), with qualitative observations gleaned from focus-group discussions and interviews with local inhabitants, and city planners. The Cronbach's alpha of 0.950 and Cronbach's alpha based on standardised items of 0.951 demonstrated 100% validity and 95% reliability, respectively. The coefficient of determination for the study variable EQLTY 0.877**, WQLTY 0.870**, UGS 0.833**, and REFD 0.846 at <0.001 significant levels indicate a strong correlation. The results demonstrate the relationship between environmental quality and human behaviour, emphasising the role of functional urban surroundings in fostering green habits, minimising pollution, and facilitating community engagement in sustainability programs. The study emphasises the crucial function of government policy and civic involvement in promoting urban regeneration activities. By taking a holistic approach, the study makes practical suggestions for enhancing urban environmental quality in order to meet the criteria for sustainable development. The findings of this study are anticipated to assist decision-makers, urban planners, and stakeholders in developing resilient, liveable, and responsible urban environments in Keffi, Nasarawa State, Nigeria. This study adds to the larger discussion on urban sustainability by illustrating how improved environmental quality might contribute to beneficial behavioural adjustments, which in turn improve long-term growth and wellness of urban residents.*

Keywords: Green space, garbage disposal, sustainable environment, behavioural adjustment, and community engagement.

INTRODUCTION

The loss of green spaces as a late concept in climate change mitigation attributed to several causes, urban environmental quality in shaping human behaviour including urbanisation, destruction of streetscapes, and unsustainable urban land use practices. In a usual traditional context, the majority of the greenery in cities and towns that are legally protected is imperiled. To enhance the effectiveness of safety in those locations and create conservation approaches that are responsive to the unique characteristics of the various sites, it is essential to understand the threatening elements.

Human behaviour towards sustaining the environment in Nigeria is complex and influenced by various factors such as cultural practices, economic development, and education. However, there is a need for awareness campaigns and educational programs to promote the importance of environmental conservation and the long-term benefits of sustainable practices. Environmental quality related to human nature is critical for long-term development, influencing city sustainability, accessibility of resources, and social well-being (Akanwa et al., 2019). The importance of environmental sustainability and restoration is a fundamental imperative that extends beyond live human nature to include both biotic and abiotic components (Njar et al., 2019).

Human-nature's interconnections have been extensively investigated in recent decades as a result of rising environmental pressures caused by urban expansion and globalisation (Simangele, 2021). Nevertheless, behaviour needs to accommodate natural characteristics consistently to ensure the environment is concurrently economically socially, politically functional, and maintained as well as eco-friendly to optimise human satisfaction. Moreover, their support for environmentally friendly activities might motivate local populations to embrace more sustainable practices (Patway, 2022). However, environmental managers continue to face difficulties in reconciling environment and preservation goals environmental quality and its influence on long-term urban development as a result of human conduct are today major global concerns, especially in nations that are developing, such as Nigeria (ALEHILE, 2024). However, the growing number of ecological problems of today are the result of human behaviour, individual consumer choices, and the operations of both small and major corporations (Akintunde, 2017).

To address these challenges, it is crucial to focus on awareness campaigns, policy reforms, and capacity building initiatives. However, by promoting education and incentivising sustainable practices, Nigeria can begin to foster a culture of sustaining urban environmental quality as well as environmental responsibility, ultimately leading to positive changes in human behaviour and the sustainable preservation of the environment. This study provides an insight on how urban environmental quality shape human behaviour and affects the quality of the environment and, ultimately, contribute to sustainable development.

LITERATURE REVIEW

In a situation where community understand the dynamic nature of landscapes, they stop seeing landscapes as a static scene (Aftab et al., 2023). Environmental principles and pro-environmental behaviour ease the relationship between green human resources control and environmental achievement in the production firm of developing nations (Aftab et al., 2023). However, greening implies the change directed to sustainability in which sustainable best practices focus in the change's trends performance engagement, opinions, and activities within the ecosystem (Eya et al., 2022). Cumulative global emissions have been dominated by industrialisation procedures throughout the Global North, leaving little atmospheric space for similar processes in the Global South if atmospheric concentrations are to be kept below levels that would result in a 1.5- or two-degrees Celsius increase in global average temperature (Klinsky & Mavrogianni, 2020).

The green human resource management incorporate environmental sustainability approaches in to human resource (Resource & Green, 2024). Human resource management researchers currently exploring the green human resource management (GHRM) viewpoint and examine its performance to meet up with present sustainable development goal agenda (Aftab et al., 2023). However, green human resource management secure environmental achievement and protect institutions long term programme of sustainability goal. Green human resource management in conjunction with human resource management furnished environmental challenges, policies, strategies and performance guidelines directly connected to the organisational goal (Anwar et al., 2020). Currently, the global practice of human behaviour viewed environmental challenges as a contemporary Industrialisation on human financial capability (Aftab et al., 2023). This study is underexplored but the available literature shows access to hygiene water, public convenient, sound gardens, places of relaxation within green spaces is mostly influenced by human behaviour.

Theories of Urban Environmental Quality Behaviour in Shaping Human Behaviour

Primitive theory

Primitive theory is a conventional human nature on environmental responsibility behaviour based on several presumptions extrapolated from earlier research (Hungerford & Volk, 2013). These models were created with the presumption that changing public awareness of diverse ecological and environmental challenges will change people's behaviour. This line of thinking was closely linked to the theory that more knowledge would make people more conscious of matters about the environment and, as a result, encourage them to act in a way that is sustainable and ecologically responsible (Hargreaves, 2011)(Journal & Management, 2020)(Campbell et al., 2021).

Planned Behavioural Theory

Planned Behaviour Theory, views the desire to act and objective situational elements as direct predictors of pro-environmental behaviour. However, theory took into account cognitive characteristics such as knowledge, action methods and challenges associated with urban environment (Fuentes, 2017). The response abilities, and individual variables. Behavioural Planning is based on three major constructs: thoughts about consequences; and anticipation of unanticipated situations that may support behaviour (Sulaiman et al., 2019). A key assumption of the theory is that, at the conceptual level, linkages among influences on behaviour and their consequences are incorporated in one of the model's variables or relationships in the mode (Akintunde, 2017).

The model is appropriate for this research because it gives further insights into the relationship between knowledge, attitude, behavioural intention, and actual behaviour as they impact urban green space and waste management methods in which information is not a separate component of the paradigm; rather, "attitudes are an outcome of belief (Alcock et al., 2020), where beliefs relate to information about a given behaviour.

Human environmental safety and well-being

Growing concern about the nature and extent of socio-spatial inequities in urban environmental quality and human well-being has refocused worldwide study on the problems of living in a modern city (Foster et al., 2022). The identification of quantifiable landscape aspects that impact health is viewed as a vital step in planning future landscape designs that promote human health. Sustainable development, among other things, requires that growth initiatives do not deplete natural resources utilised for outdoor recreation.

The external environment's impact on our health and well-being is being increasingly recognised. Keeping a bright future for the earth and the generations to come is the main objective of environmentally conscious repercussions to other PEBs sustainability, which is accomplished by increasing global knowledge of the concept (Foster et al., 2022). Environmental consciousness positively affects PEB among active sports club members in Germany (Thormann & Wicker, 2021). According to (Zientara & Zamojska, 2016) a positive correlation between environmental awareness and PEB however, those having pro-environmental attitudes had greater levels of awareness of the environment. Other perspectives on the environment and the perceived value of environmental consequences can enhance the perception of environmental knowledge (Thormann & Wicker, 2021).

Green Area Suitability and Environmental Suitability

According to (Binder & Blankenberg, 2017) observed that those who practise environmentally beneficial behaviours, such as recycling and saving water, had higher self-esteem. In general, self-efficacy belief is low if a person feels they are competent in just a few specific circumstances and actions. (Corso, 2022), despite a lack of awareness of this

phenomenon. (Mouazen & Hernández-Lara, 2020) and utilising eco-friendly shopping bags. Despite a lack of awareness of this phenomenon, those who have higher levels of self-efficacy would be motivated by PEBs to exert greater effort in maintaining the behaviours (Corso, 2022).

Factors Associated with Human Nature for Sustainable Development

Water quality

Water quality refers to the physical, chemical, and biological qualities of water, typically in relation to its fitness for a specific activity, such as drinking, recreation, or aquatic life preservation. Poor water quality, aggravated by direct discharges from factories, wastewater treatment facilities, or runoff water, restricts the consumption of water for food production, drinking, and enjoyment.

Green Space Availability

Green spaces are places with plants in cities, such as parks, gardens, and nature preserves. Improve air quality by filtering pollutants, provide possibilities for inhabitants, and encourage both mental and physical wellness. Integrating green spaces into built environments helps to mitigate the impact of urban heat islands, regulate runoff, and boost biodiversity. Green places that are easily accessible increase community involvement and encourage environmentally conscious living habits.

Waste management

Waste management refers to the collection, transportation, processing, reuse, recycling, and dumping of waste materials. Proper handling of trash is crucial for maintaining environmental quality. Solid waste consists of household garbage, hazardous waste such as chemical substances and batteries, organic waste from kitchen leftovers, park debris, and recyclable items such as plastics, paper, and metals. There are insufficient landfilling ideas, reusing, composting, incineration, and the concept of waste to conversion. Inadequate waste management led to soil and water degradation, air pollution, and safety risks. However, sound waste-management practices, such as recycling and reuse, can assist to reduce environmental damage and save resources

Goal 6 of Sustainable Development Agendas

It designed to ensure availability and sustainable management of water and sanitation for all

- Achieve universal and equitable access to safe and affordable drinking water for all by 2030.
- Improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally by 2023.
- Substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity by 2030.
- By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.
- By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.
- By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.

Research Gap. The study area is far off track from urban environmental quality on achieving the Sustainable Development Goals towards the ending point on the 2030 Agenda. But it is possible to actively improve future prospects for action and progress and beyond. Leveraging research knowledge, strengthening community participation in handling environmental challenges for the Goals and benefit, the full potential of the Sustainable Development Goals framework for promoting sustainable development can be enhancing in the study area. Nigeria as a benefactor of SDG interlinkages, and international spillovers and dependencies must be systematically adhering to all backlogs.

METHODOLOGY

This study used the Theory of Planned Behaviour (TPB) to investigate the structural linkages and intensities of various human nature interaction attributes. The theory has widespread use in fields such as planning for towns and cities, geography of people, environmental management, and sustainability development and design. The previous studies aligned with planned behaviour theory is that human nature, positively influence the state of the environmental quality on urban landscape.

Planned Behaviour Theory, views the desire to act and objective situational elements as direct predictors of pro-environmental behaviour (Stern, 2000b). The intention took into account cognitive characteristics such as knowledge, action methods and challenges (Fuentes, 2017). The response abilities, and individual variables. Behavioural Planning is based on three major constructs: thoughts about consequences; and anticipation of unanticipated situations that may support behaviour (Sulaiman et al., 2019). A key assumption of the theory is that, at the conceptual level, linkages among influences on behaviour and their consequences are incorporated in one of the model's variables or relationships in the mode (Akintunde, 2017). The model is appropriate for this research because it gives further insights into the relationship between knowledge, attitude, behavioural intention, and actual behaviour as they impact

waste management methods. information is not a separate component of the paradigm; rather, "attitudes are an outcome of belief (Alcock et al., 2020), where beliefs relate to information about a given behaviour.

Urban Environmental Quality (UEQ) can be seen as a generic indicator that objectively represents the physical and socio-economic condition of the urban and built environment Kamil Faisal (2017) used Principal Component Analysis (PCA) and Geographically-Weighted Regression (GWR) techniques to integrate various parameters and estimate the urban environmental quality.

Hypothesis Testing

H₀: Does urban environmental quality influence human behaviour for long-term development?

H₀: Do public awareness campaigns influencing human behaviour towards environmental sustainability?

H₀: Does adoption of sustainable environmental quality on human behaviours impact loss of green space?

H₀: Do sustainable environmental quality on human behaviour impact urban landscape?

Table 1. Five Likert Scale Variable Statement

S/No	Variable Statement	5	4	3	2	1
1	Engaging communities in the process of achieving urban environmental sustainability is vital for long-term success.	*				
2	Recognizing and incorporating indigenous knowledge of landscapes can contribute to sustainable urban development.	*				
3	Integrating electric mobility solutions to reduce emissions will promote sustainable urban transportation.		*			
4	Urban landscapes offer opportunities for innovative sustainable development initiatives.		*			
5	Implementing educational programs to raise awareness about sustainable urban living and environmental conservation.		*			
6	Building urban infrastructure that is resilient to climate change impacts and extreme weather promote long-term development.	*				
7	Encouraging the adoption of sustainable trees planting practices and behaviours will reduce the impact of green loss.	*				
8	Access to clean environments influence urban environmental policies on vulnerable communities.		*			

Source: Survey, 2025 N.B: Strongly agree =5, Agree =4, Neither agree/Nor disagree =3, Disagree =2, Strongly disagree =1

Non-Parametric Analysis

Reliability Test

Table 2. All Variables Test

		N	%
Cases	Valid	50	100.0
	Excluded ^a	0	.0
	Total	50	100.0

a. Listwise deletion based on all variables in the procedure.

This study included 50 respondents who answered every question, resulting in 50 cases. The four modified data variables validate a test or instrument, ensuring reliable measurement of objectives. Content validity demonstrates that the assessment captures every pertinent element of the notion in question. The instruments used to assess each variable represent the whole study issue in question.

The study variables or measuring elements evaluated the data, including dependent and independent variables. However, in this test, all variables were input with no values missing. Validity and reliability ensure accurate measurement results. The structures improve the reliability of study results and boost confidence in the technique. This broad methodology enables researchers to make stronger inferences from their results. As a result, researchers can reliably adapt the study's findings to everyday situations, increasing their practical value.

Table 3. Table Reliability Statistics

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.950	.951	4

Spearman's rho results show significant positive relationships between urban environmental and human behaviour. The low p-values (< 0.001) for all correlations, along with an average Spearman's rho of 0.950, imply statistical

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significance. These results highlight the impact of urban environmental quality on water, urban green space and refused disposal especially along waterways which explicitly affects urban environment.

Table 4. Item Statistics

Item Statistics			
	Mean	Std. Deviation	N
EQLTY	3.4240	.22728	50
WQLTY	3.4440	.23313	50
UGS	3.4320	.22627	50
REFD	3.4200	.24328	50

Table 5. Table Inter-Item Correlation Matrix

Inter-Item Correlation Matrix				
	EQLTY	WQLTY	UGS	REFD
EQLTY	1.000	.904	.890	.715
WQLTY	.904	1.000	.886	.761
UGS	.890	.886	1.000	.819
REFD	.715	.761	.819	1.000

Table 6. Scale Statistics

Scale Statistics			
Mean	Variance	Std. Deviation	N of Items
13.7200	.753	.86756	4

Table 7. Test of Normality

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
EQLTY	.222	50	<.001	.885	50	<.001
WQLTY	.195	50	<.001	.893	50	<.001
UGS	.176	50	<.001	.897	50	<.001
REFD	.193	50	<.001	.900	50	<.001

a. Lilliefors Significance Correction

Table 8. Hypothesis Summary

Item	Null Hypothesis	Statistics Test	Sign ^a	Decision
1	The categories of Predicted Response Category occur with equal probabilities.	One-Sample Chi-Square Test	<0.001	Reject the null hypothesis.
2	The distribution of EQLTY is normal with mean 3.42 and standard deviation .22728.	One-Sample Kolmogorov-Smirnov Test	<0.001 ^b	Reject the null hypothesis.
3	The distribution of WQLTY is normal with mean 3.44 and standard deviation .23313.	One-Sample Kolmogorov-Smirnov Test	<0.001 ^b	Reject the null hypothesis.
4	The distribution of UGS is normal with mean 3.43 and standard deviation .22627.	One-Sample Kolmogorov-Smirnov Test	<0.001 ^b	Reject the null hypothesis.
5	The distribution of REFD is normal with mean 3.42 and standard deviation .24328.	One-Sample Kolmogorov-Smirnov Test	<0.001 ^b	Reject the null hypothesis.
6	The distribution of Estimated Cell Probability for Response Category: 2.80 is normal with mean .02 and standard deviation .14140.	One-Sample Kolmogorov-Smirnov Test	<0.001 ^b	Reject the null hypothesis.
7	The distribution of Estimated Cell Probability for Response Category: 3.20 is normal with mean .32 and standard deviation .39467.	One-Sample Kolmogorov-Smirnov Test	<0.001 ^b	Reject the null hypothesis.
8	The distribution of Estimated Cell Probability for Response Category: 3.40 is normal with mean .34 and standard deviation .33248.	One-Sample Kolmogorov-Smirnov Test	<0.001 ^b	Reject the null hypothesis.
9	The distribution of Estimated Cell Probability for Response Category: 3.60 is normal with mean .16 and standard deviation .28029.	One-Sample Kolmogorov-Smirnov Test	<0.001 ^b	Reject the null hypothesis.
10	The distribution of Estimated Cell Probability for Response Category: 3.80 is normal with mean .16 and standard deviation .37028.	One-Sample Kolmogorov-Smirnov Test	<0.001 ^b	Reject the null hypothesis.
11	The distribution of Estimated Classification Probability for the Predicted Category is normal with mean .84 and standard deviation .13472.	One-Sample Kolmogorov-Smirnov Test	<0.001 ^b	Reject the null hypothesis.
12	The distribution of Estimated Classification Probability for the Actual Category is normal with mean .81 and standard deviation .21364.	One-Sample Kolmogorov-Smirnov Test	<0.001 ^b	Reject the null hypothesis.

a. The significance level is .050.

Corrected. Asymptotic significance is displayed.

b. Lilliefors

Table 9. Non-Parametric Correlations

		Correlations				
			EQLTY	WQLTY	UGS	REFD
Spearman's rho	EQLTY	Correlation Coefficient	1.000	.877**	.863**	.762**
		Sig. (2-tailed)	.	<.001	<.001	<.001
		N	50	50	50	50
	WQLTY	Correlation Coefficient	.877**	1.000	.870**	.833**
		Sig. (2-tailed)	<.001	.	<.001	<.001
		N	50	50	50	50
	UGS	Correlation Coefficient	.863**	.870**	1.000	.846**
		Sig. (2-tailed)	<.001	<.001	.	<.001
		N	50	50	50	50
	REFD	Correlation Coefficient	.762**	.833**	.846**	1.000
		Sig. (2-tailed)	<.001	<.001	<.001	.
		N	50	50	50	50

** . Correlation is significant at the 0.01 level (2-tailed).

Spearman's Coefficient of Correlation

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Where:

r is the sample correlation coefficient

n is the sample size

x is the value of the independent variable

y is the value of the dependent variable

Nonparametric correlation coefficients, such as Spearman's rank correlation, evaluate the strength and direction of the association between two ranked variables without assuming a normal distribution. The significance level (p-value) indicates the probability of observing the link as a result of random chance. A p-value under <0.001 signifies a highly significant correlation.

The estimation is based on Fisher's, Hartley, and Pearson r-to-z transformation.

$$Z = \frac{1}{2} \ln \left(\frac{1 + r}{1 - r} \right)$$

The correlation coefficient of 0.877** indicates a strong positive relationship between illegal vending and street quality. As dependent variables spread, the quality of urban environment rapidly polluted. A p-value < 0.001 suggests a very significant relationship with a chance of less than 0.1%. This provides compelling evidence that urban environment impairs variability of human natures. The correlation coefficient of 0.833** suggests a strong positive relationship between urban environmental quality and human behaviour.

The rate of human interference of environment is linked to a decrease in quality of water and loss of green space. At a significance level of less than < 0.05, the correlation is very significant, indicating that the probability of this association occurring by chance is minimal. This is substantial evidence that urban environment intensifies sustainable challenges.

A correlation coefficient of 0.877**, 0.863**, 0.762**, 0.870**, 0.846**, and 0.833** suggests a significant positive association between urban environmental quality and human behaviour. The rate of human behaviour affects aesthetic nature of the living environment. A significance level of <0.001 indicates that this association is highly significant and has a very high probability of arising by chance. This gives strong evidence that environmental quality impacts significantly on human behaviour in shaping urban landscape. To transform the correlated coefficients, the researchers employed Fisher's r-to-z transformation formula. A higher z-score indicates a more significant association between the variables. All of the relationships are highly significant (p-value < 0.001), demonstrating that the uncovered interactions were not a coincidence.



Figure 1. Garbage and refuse disposal



Figure 2. Water quality and urban green space

Solid waste accumulation feeds disease vectors such as rodents, flies, and mosquitoes, that transmit diseases like cholera, typhoid, and dysentery. Waste products from the decaying garbage soaks through the ground's pores and damages groundwater. Stagnant water frequently interacts with garbage and sewage, contaminating surrounding water bodies and lowering water quality for urban usage. However, rubbish piles and stagnant bodies of water diminish the visual appeal of urban areas. Garbage jams drainage systems, causing waterlogging during rains. Stagnant water from clogged drains exacerbates flooding in town, devastating facilities and upsetting normal life.

Urban green and blue spaces are public spaces such as nature parks, water bodies or open spaces that offer various recreational and ecological benefits. Sustainable Development Goal 11 recommends for a universal access to safe, inclusive and accessible green and public spaces however, human behaviour attributed a lot of uncoordinated activities that di-shape.

Table 10. Inter-Item Correlation Matrix

Inter-Item Correlation Matrix				
	EQLTY	WQLTY	UGS	REFD
EQLTY	1.000	.904	.890	.715
WQLTY	.904	1.000	.886	.761
UGS	.890	.886	1.000	.819
REFD	.715	.761	.819	1.000



Figure 3. Refuse disposal opposite Yoruba Community central Masjid Keffi, Nigeria



Figure 4. Figure Indiscriminate open defecation water channel

Human faeces frequently find in streams, and groundwater as a result of rainfall or closeness to water sources. Open defecation allows infections to propagate more easily, resulting in diarrhoea outbreaks. However, devote funds to public restrooms and cleanliness facilities. Support instruction in sanitation to help change cultural norms. Provide exposure to clean water for efficient restroom upkeep.

Pollution-prone habitats drive away native species while attracting invasive species, resulting in reduced urban biodiversity. Runoff from waste and slow-moving water present a risk to life on the water in adjacent waterways. Adverse environmental quality decreases productivity, raises healthcare expenditures, and lowers general quality of life. Informal garbage management methods frequently target vulnerable populations, resulting in unhealthy workplaces.

Strategies to Address Garbage and Stagnant Water in Urban Areas

Municipal garbage is collected and disposed of on a daily basis, following carefully established paths and times of day. Push people and firms to differentiate between recyclable, organic, and harmful garbage. Recycling and composting efforts aim to reduce landfill burden and foster a circular economy. Improve the drainage infrastructure to avoid obstructions and maintain appropriate water flow. Drain, tunnels and runoff channels are routinely maintained. Collection of rainwater helps to prevent surface runoff and sluggish ponds. Neighbourhood initiatives highlight the health dangers of inadequate hygiene and the positive effects of clean settings. School programs to promote ecological consciousness at a young age. Behavioural nudges include warnings and incentives for safe garbage disposal.

To discourage illegal dumping, designated garbage areas and collection points may be built. Green landscapes and permeable pavement can help drain rainwater and decrease stagnation. Sustainable urban planning incorporates sanitation into housing and transportation development. Strict penalties for unauthorised dumping and littering. Monitoring systems use drones or sensors to identify problem areas. Sanitation initiatives are funded and managed through public-private partnerships. Neighbourhood clean-ups and garbage watch groups. Support for informal garbage workers through training, safety equipment, and fair pay. Citizen reporting platforms for identifying rubbish hotspots or stagnant water. Mobile apps for making rubbish disposal orders and noting sanitary issues. Innovative and environmentally friendly water treatment solutions. Smart containers inform officials when they are full.

Challenges in Implementing Urban Sanitation Strategies

Municipal finances may not be sufficient to cover infrastructure changes, garbage truck automobiles, or outreach programs. Operating costs for water drainage and garbage disposal facilities can be substantial and frequently underestimated.

Inconsistent enforcement of sanitation legislation results in unlawful garbage and insufficient adherence. Unethical behaviour or the absence of openness in garbage disposal contracts might jeopardise effectiveness. A community like Keffi is expanding rapidly, frequently topping the development of wastewater systems. Haphazard neighbourhoods may have limited access to basic amenities, rendering water and garbage management challenging. Communities may not be aware of health perils or ecological effects of poor sanitation. Cultural habits and unwillingness to change might impede the widespread acceptance of novel techniques such as trash segmentation.



Figure 5. Open grazing on garbage environment



Figure 6. Environmental view and street quality

Table 11. Confidence Intervals of Spearman's rho

Confidence Intervals of Spearman's rho				
	Spearman's rho	Significance(2-tailed)	95% Confidence Intervals (2-tailed) ^{a, b}	
			Lower	Upper
EQLTY - WQLTY	.877	<.001	.788	.930
EQLTY - UGS	.863	<.001	.766	.922
EQLTY - REFD	.762	<.001	.609	.861
WQLTY - UGS	.870	<.001	.777	.925
WQLTY - REFD	.833	<.001	.717	.903
UGS - REFD	.846	<.001	.739	.912

a. Estimation is based on Fisher's r-to-z transformation.

b. Estimation of standard error is based on the formula proposed by Fieller, Hartley, and Pearson.

The table above shows the intraclass correlation coefficient for single and mean variables. A two-way mixed impact model is used, with unpredictable impacts for people and fixed effects for measurements. The limit that is lower reduces as the upper bound increases. The confidence interval of 95% indicates a high association with measurement variables.

Table 12. Weighted Kappa Based on Quadratic Weight

Ratings	Cohen's Weighted Kappa				95% Asymptotic Confidence Interval	
	Weighted Kappa ^b	Std. Error ^c	Asymptotic z ^d	Sig.	Lower Bound	Upper Bound
EQLTY - WQLTY ^a	.891	.052	6.331	<.001	.790	.993
EQLTY - UGS ^a	.889	.045	6.290	<.001	.801	.977
EQLTY - REFD ^a	.750	.135	5.307	<.001	.485	1.015
WQLTY - UGS ^a	.884	.051	6.263	<.001	.785	.984
WQLTY - REFD ^a	.798	.125	5.664	<.001	.552	1.043
UGS - REFD ^a	.815	.112	5.788	<.001	.596	1.035

- a. Categories are determined by observed values and values for which value labels are defined.
b. The estimation of the weighted kappa uses quadratic weights.
c. Value does not depend on either null or alternative hypotheses.
d. Estimates the asymptotic standard error assuming the null hypothesis that weighted kappa is zero.

Weighted Kappa based on quadratic weight is a statistic that assesses inter-rater reliability for qualitative (categorical) variables by factoring in chance consensus and using linear weighting.

Table 13. Weighted Kappa Based on Linear Weight

Ratings	Cohen's Weighted Kappa				95% Asymptotic Confidence Interval	
	Weighted Kappa ^b	Std. Error ^c	Asymptotic z ^d	Sig.	Lower Bound	Upper Bound
EQLTY - WQLTY ^a	.851	.058	8.779	<.001	.737	.964
EQLTY - UGS ^a	.804	.060	8.561	<.001	.686	.922
EQLTY - REFD ^a	.801	.084	8.361	<.001	.636	.966
WQLTY - UGS ^a	.824	.060	8.719	<.001	.705	.942
WQLTY - REFD ^a	.821	.075	8.562	<.001	.674	.968
UGS - REFD ^a	.795	.073	8.631	<.001	.652	.938

- a. Categories are determined by observed values and values for which value labels are defined.
b. The estimation of the weighted kappa uses linear weights.
c. Value does not depend on either null or alternative hypotheses.
d. Estimates the asymptotic standard error assuming the null hypothesis that weighted kappa is zero.

The latest application of Cohen's Weighted Kappa provides evidence of statistical relationship amongst the dependent and independent variables.

Table 14. Autocorrelation

Autocorrelations						
Series: EQLTY						
Lag	Autocorrelation	Std. Error ^a	Value	df	Box-Ljung Statistic	
1	-.646	.139	21.713	1	1	<.001
2	.261	.137	25.321	2	2	<.001
3	-.130	.136	26.242	3	3	<.001
4	-.087	.134	26.664	4	4	<.001
5	.131	.133	27.634	5	5	<.001
6	-.056	.131	27.814	6	6	<.001
7	-.100	.130	28.403	7	7	<.001
8	-.025	.128	28.440	8	8	<.001

- a. The underlying process assumed is independence (white noise).
b. Based on the asymptotic chi-square approximation.

Table 15. Agreement on Individual Categories^a

Agreement on Individual Categories ^a						
Rating Category	Conditional Probability	Kappa	Standard Error	Asymptotic z	Sig.	Asymptotic 95% Confidence Interval
2.80	.800	.795	.058	13.768	<.001	.682 .908
3.20	.908	.870	.058	15.077	<.001	.757 .984
3.40	.818	.729	.058	12.620	<.001	.615 .842
3.60	.701	.628	.058	10.884	<.001	.515 .742
3.80	.896	.876	.058	15.173	<.001	.763 .989

- a. Sample data contains 50 effective subjects and 4 raters.

DISCUSSION OF RESULTS

The Spearman's correlation coefficient, which describes the intensity and direction of correlations between the study variables. We tested the variable measurements, and the data were 100% valid. We also tested the device to ensure dependability, and the results were accurate. All variables were input correctly, with no items missing or excluded. Every variable was entered accurately.

The Cronbach's alpha of 0.950 and Cronbach's alpha based on standardised items of 0.951 demonstrated 100% validity and 95% reliability, respectively. The model fitting data yielded 95% at the 0.001 significance level. The results indicate that the model was appropriate for the comparison.

We utilised descriptive statistics to calculate the mean, lowest, and highest values, as well as the standard deviation, skewness, and kurtosis. As the number drops, the lowest and maximum values rise. The environmental quality value is biased to the right, indicating that water quality, urban green spaces are the principal's motivator for human behaviour that shape urban landscape. We performed nonparametric tests to test our research hypothesis. The converted variables include both the dependent variable, water quality (WQLTY), urban green spaces and garbage (refuse disposal) and one independent variable. According to the test report, the both Kolmogorov-Smirnov and Shapiro-Wilk test of normality yielded results of 0.001. However, respectively this led us to reject the null hypothesis. WQLTY, UGS and RED (garbage) indicate a significant positive relationship (EQLTY value < 1.000). The coefficients 0.877**, 0.863**, and 0.762 are statistically significant at 0.001** for all dependent variables. EQLTY (0.877**, $p < 0.001$) is significantly positively correlated with WQLTY (0.877**, $p < 0.001$), UGS (0.863**, $p < 0.001$), REFD (0.762**, $p < 0.001$). The WQLT 0.877 correlation coefficients of 0.870**, 0.833**, and 0.846 at <0.001 significant levels indicate that the model is fit. Environmental quality explains 98% of the total variation in dependent variables. The Spearman's correlation score for environmental quality is 1.000, indicating that putting all the variables together account for 98% of the change. This also shows that the model is a good fit. The ordinal regression statistic indicates that the autocorrelation relationship between the three variables is substantial, however Shapiro-Wilk states that environmental quality challenge is statistically significant at the 0.05 level of determination. As a result, the fitted Spearman line demonstrated positive autocorrelations, as indicated by the Shapiro Wilts test.

FINDINGS

This section contains the data analysis, findings, and results interpretation. Numerous challenges were identified and discussed including water quality, greenspaces, and waste management under human nature while, public awareness, sociocultural practice, economic activities, and government policy were characterised as policy framework. The study revealed that adoption of sustainable environmental quality on human behaviours will improve water quality, urban green space, and sanitary condition of area.

Improvement Strategies

Reduce energy use and switch to LED bulbs, unplug devices when not in use, and use energy efficient appliances. Minimise waste by composing food scraps, recycle properly, and avoid single- use plastics. Conserve water by fix leaks, install low flow faucets and reuse water where possible especially for plants and other gardens. Support local green spaces through volunteer for clean-ups trees planting initiatives. Promote sustainable transport through walk, bike, or use public transit instead of driving. Educate and inspire through eco-friendly tips within friends or organised awareness events. Use paperless through the use of digital documents and reduce printing hard materials. Create a green workplace by encouraging recycling bins, reusable cups, and energy saving habits Nevertheless, the condition of green areas in cities, and garbage disposal constitute the three primary variables for this research. An intricate network of interrelated factors shapes the general state of the city's surroundings.

Water Quality

Poor water quality in urban areas is often a result of both untreated surface and underground sewage, industrial discharge, and runoff from impervious surfaces like roads and rooftops leading to contamination of drinking water sources, polluted streams, rivers and groundwater. Change in water colours to black may result to loss of aquatic biodiversity: Toxic pollutants can disrupt aquatic ecosystems, killing fish and other organisms as presented in the figures (plate 2&3). Therefore, dirty or foul-smelling water bodies degrade the liveability and attractiveness of urban spaces. In addition, blocked drainage systems from polluted runoff can cause urban flooding and damage infrastructure.

Urban Green Space

Urban green spaces such as gardens, playgrounds, and forests are critical to preserving the ecosystem and improving urban conditions. However, plants and forests absorb toxins and emit oxygen, which improves the cleanliness of the air. Landscaping helps to reduce heat islands in cities by lowering the surroundings with shade and evapotranspiration. Nonetheless, access to green places improves physical activity, decreases stress, and encourages social contact. Landscapes provide habitat for urban creatures, thereby preserving biodiversity in nature.

Garbage/Refuse Disposal

Sustainable collection of trash is critical to municipal aesthetics and public health. Inappropriate garbage disposal causes damage to the environment, while open dumps and burning of trash harm the air, land, and water. Nonetheless, accumulating garbage attracts pests and propagates diseases. Disorganised streets and full dumpsters detract from the appearance of cities. Unlawful disposal blocks waterways, which leads to flooded houses and a build-up of water.

Sustainable Strategies for Enhancing Urban Environmental Quality

Sustainability in Cities and ecologically sound Approaches

Using parks, urban vegetation, rooftop gardens, and porous surfaces to minimise heat, enhance the atmosphere, and control wastewater. Similarly, incorporating biological and constructed systems such as ponds and bioswales, into

conventional structures can improve climate resilience. Educating communities to co-design and maintain green areas promotes involvement and long-term viability, which should be seen as a new way of governing the built environment in cities.

Sustainable Waste Management

Employing cameras and statistical analysis to optimise collection routes and cut waste. However, by teaching and merging illegal garbage operators into official systems, municipal cleanliness will improve.

Water Quality and Management

Decentralised wastewater treatment as well as individual systems relieve demand on central infrastructure in locations whereby neighbourhood drinking is sourced from ponds and increase service in disadvantaged communities. Capturing rainwater for reuse will help to prevent disaster and a water crisis.

CONCLUSION

Improving access to these spaces and promoting their use can have direct and indirect benefits on health, social connections, mental health, well-being and the environment, in particular through physical activity, leisure, social interactions and exposure to nature. Waste practices, which impact health and wellbeing outcomes, are impacted by individual values, the social and cultural environment, as well as contextual factors like physical environments and convenience. Behavioural and cultural insights (BCI) offer a lens through which to see opportunities for and leverage positive behaviours through evidence-based and effective interventions (8,9). Positive behaviours for a sustainable future often have co-benefits for individual health. Such behaviours are influenced by physical and social environments, by cultural values and social norms, and by the policies, practices, information and infrastructure provided by companies, governmental organizations and leaders. The relationship between environment quality and human behaviour is bidirectional where the environment shapes human behaviour where as human behaviour in turn, shape the environment.

RECOMMENDATIONS

Urban environment and its associated attributes such as water, well define green spaces, and sanitation should not be seen as the only indicator, to monitor progress and organise planning. Individual, community, and youth leaders should have a responsibility for protecting waterways water, sanitation service provision which should not lie with the Local Authorities, State government and the Federal Government which all requires to provides the policy direction and framework for governance and full implementation urban and regional planning and environmental laws. The study suggests that with the current global information communication technology, community with higher awareness and better habit quality are more likely to engage in sustainable behaviour, especially when supported by strong social network.

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Incorporation of Afro-Centric Architecture in the Design of a Museum in Minna, Niger State, Nigeria

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ABSTRACT

There is a growing concern about the loss of indigenous identity in contemporary architectural practice, particularly in public institutions such as museums. This study investigated how Afro-centric architecture can be applied in museum design to reinforce cultural representation, preserve traditional knowledge, and celebrate the spatial heritage of Nigerian ethnic communities. In Nigeria, modern museums are often designed using Western architectural styles that do not reflect the traditional values, identities, or spatial characteristics of indigenous communities. This creates a disconnect between the museum as a cultural institution and the people it intends to represent. The lack of Afro-centric design approaches undermines the relevance of museums as spaces for cultural preservation, education, and identity formation. The study addressed this problem by integrating local architectural languages such as symbolic layouts, traditional forms, and climate-responsive materials into museum design, with a specific focus on selected ethnic groups in Niger State. This qualitative study used ethnographic tools including case studies, interviews with local artisans and cultural custodians, field observations, and surveys. Placing emphasis on traditional spatial principles drawn from the Nupe, Gbagyi, and Hausa communities. Museums such as the Slave History Museum and community heritage sites in Bida and Minna respectively were also reviewed. The study revealed that traditional architecture provides functional, symbolic, and environmentally responsive solutions. Key features such as courtyards, earth-based materials, and spatial zoning reflect deep socio-cultural values and serve as effective design tools for culturally grounded museum spaces. Integrating Afro-centric architectural principles into museum design promotes cultural education, decolonized space-making, and sustainable development. This approach encourages a reconnection with indigenous identities while creating immersive, contextually meaningful visitor experiences.

Keywords: Afro-centric Architecture, decolonized space-making, Museum, sustainable development, Traditional Building Techniques; Indigenous Architecture

INTRODUCTION

Museums play a vital role as custodians of cultural heritage, preserving the history, values, and identity of a society (Boylan, 2017). In Nigeria, institutions like the National Museum in Lagos have historically served this purpose. However, a significant issue persists: the architectural expression of these museums often fails to reflect the indigenous identities of the communities they represent (Isah, 2016). In regions like Niger State, contemporary public buildings frequently adopt Western design paradigms, leading to a built environment that is culturally alienating and disconnected from local traditions (Opaluwa Ejiga et al., 2012).

Afro-centric architecture emerges as a critical response to this problem. It is a design philosophy that seeks to centre African worldviews, materials, and spatial practices in the built environment (Uji, 2001; Nnamdi Elleh, 1996). This approach aligns with the broader "New Museology" movement, which advocates for museums as dynamic, community-centred spaces rather than static repositories of objects (Vergo, 1989; Macdonald, 2011). Therefore, this study proposes the design of a museum in Minna for Minna, Niger State, that incorporates Afro-centric architectural principles to enhance cultural identity and provide a culturally resonant civic landmark.

REVIEW OF BACKGROUND STUDIES AND THEORETICAL BASIS OF DESIGN STRATEGIES

Theoretical Frameworks

This study draws on two interrelated theoretical perspectives. First, Afrocentricity emphasizes placing African identity and culture at the centre of knowledge production and creative practice (Asante, 1991). Second, Critical Regionalism advocates for architecture that balances global modernist influences with local cultural and environmental conditions (Frampton, 2016). Together, these frameworks provide a basis for museum design that is simultaneously modern, sustainable, and rooted in African cultural realities.

The Concept of Afrocentric Architecture

The study is anchored on three interrelated theoretical pillars. First, Afrocentrism (Asante, 1991) provides the ideological basis for centring African experiences and aesthetics, challenging the Eurocentric bias in architectural design. Second, New Museology (Vergo, 1989) redefines the museum's role from an authoritative institution to a participatory platform for community engagement and storytelling. Third, Indigenous African Spatial Theory (Uji, 2001; Nnamdi Elleh, 1996) offers practical insights into traditional spatial organization, such as the use of courtyards as social and spiritual nuclei, and the symbolic significance of materials and ornamentation.

The literature confirms a gap in the application of these theories to contemporary public architecture in Nigeria. While scholars have extensively discussed Afro-centric theory and the evolution of museums, there is a scarcity of design projects that successfully translate these concepts into built form, especially within the specific cultural context of Niger State.

Afrocentric architecture is rooted in the philosophy that African worldviews, cultural values, and traditions should form the foundation of design (Asante, 1991; Asante, 2017). It seeks to challenge the dominance of Western paradigms

by re-centring Africa in the discourse of architecture, not as a nostalgic return to the past but as a progressive reinterpretation of heritage for contemporary needs (Nnamdi Elleh, 1996). Within this perspective, architecture becomes both a functional product and a cultural statement, symbolizing identity, memory, and continuity.

The Evolving Role of Museums: From Colonial Repositories to Community Hubs

The modern museum has undergone a significant transformation. Historically, museums in Nigeria, like the National Museum Lagos (1957), were established on a colonial model, functioning as institutions for the collection and display of artifacts often acquired through imperialist practices (Eboime, 1995; Kohol & Adeleke, 1994). This model positioned the museum as an authoritative, object-centred space. The late 20th century saw the rise of the '*New Museology*' movement, which critiqued this traditional model (Vergo, 1989). As articulated by Macdonald (2011), New Museology advocates for a shift towards museums that are socially responsive, audience-centred, and focused on dialogue and community participation. This paradigm aligns with global efforts to '*decolonize museum spaces*', returning narrative agency to source communities, a process evident in initiatives like the Benin Dialogue Group and the Museum of West African Art (MOWAA) (Sarr et al., 2018; (Hellman, 2023). In an Afro-centric context, the museum is reimagined as a "living monument" – a platform for cultural revival, healing, and the celebration of indigenous knowledge systems (Uji, 2001).

Afrocentricity as an Architectural Ideology

Pioneered by Molefi Kete Asante (1991), '*Afrocentrism*' is a cultural and intellectual paradigm that places African experiences, perspectives, and agency at the centre of analysis. In architecture, this translates to an ideology that consciously rejects the imposition of Western forms and instead seeks to express local identity, memory, and functionality. It is not merely a style but a philosophy of place-making (Elleh, 1996). Z. A. Uji (2001) defines Afro-centric architecture as a deliberate effort to revive indigenous knowledge systems, materials, and forms to foster spaces that are contextually appropriate and culturally meaningful. This framework challenges the symbolic legacy of colonial-era civic buildings and represents an act of cultural reclamation and sovereignty, allowing African nations to articulate their histories through their built environment.

Indigenous African Spatial Logic and Environmental Response

The practical application of Afro-centric principles is deeply rooted in the spatial intelligence of traditional African architecture. Scholars like Nnamdi Elleh (1996) and Uji (2001) articulate how African spatial traditions are guided by principles of communality, continuity, and ritual flow. Key elements relevant to this study include:

- i. **The Courtyard as a Social Nucleus:** The central courtyard, found in the compounds of the Nupe, Gwari, and other ethnic groups, is the heart of social and spiritual life. It facilitates communal interaction, provides a safe play area for children, and serves as a venue for ceremonies (Nadel, 2018).
- ii. **Climate-Responsive Design:** Traditional architectures in Niger State exhibit sophisticated responses to the tropical savanna climate. Thick mud walls provide thermal mass for temperature regulation, steeply pitched thatched roofs manage heavy rainfall, and strategic orientation of buildings maximizes natural ventilation (Opaluwa Ejiga et al., 2012).
- iii. **Symbolic Ornamentation:** Decorative elements, such as the geometric patterns on Nupe walls or the symbolic motifs on gateways, are not merely aesthetic but encode social narratives, cosmological beliefs, and community values.

The Cultural and Architectural Context of Niger State

Niger State is a culturally rich region, home to diverse ethnic groups including the Nupe, Gwari (Gbagyi), Gade, Gwandara, Kambari, and Kamuku. Each group possesses distinct but related architectural traditions. The Nupe, for example, are known for their compact, courtyard-centred compounds and renowned brass work, while the Gwari are celebrated for their pottery and spacious homesteads ((Adamu, 1984); (Yahaya, 2003)). Despite this diversity, common threads of earth-based construction, communal spatial planning, and climatic sensitivity bind these traditions together. This rich tapestry provides a vast repository of design intelligence that remains underutilized in contemporary public architecture in the state, highlighting the gap this research aims to address.

Synthesis: Towards an Afro-Centric Museum Architecture

The convergence of New Museology, Afrocentric theory, and Indigenous Spatial Logic provides a robust framework for this study. An Afro-centric museum in Minna must therefore be more than a building; it should be a ****cultural text**** written in the architectural language of its context. It should embrace the courtyard not just as a formal element but as a symbolic and functional core, use local materials authentically, facilitate community participation, and perform environmentally through passive design strategies. This synthesis moves the discourse from theoretical abstraction to a practicable model for cultural institution design in post-colonial Nigeria.

Museums globally have evolved as institutions that safeguard heritage and facilitate cultural continuity. Yet in Africa, many museums replicate colonial typologies, functioning more as neutral storage than as living cultural spaces (Uduku, 2006). Such models often fail to capture indigenous cosmologies and the communal nature of African societies. In this regard, an Afrocentric Museum in Minna could serve as both a repository of artifacts and an experiential environment that embodies cultural meaning.

Evolution and Key Principles

The evolution of Afrocentric architecture highlights recurring themes that distinguish it from Eurocentric

approaches. These include:

1. Symbolism and Narrative – Buildings act as cultural texts, embedding myths, motifs, and historical memory (Oliver, 1997).
2. Spatial Hierarchy and Communalism – Indigenous planning often reflects social structures, with courtyards, plazas, and thresholds reinforcing community bonds (Agboola, 2011).
3. Material Authenticity – Use of local materials such as laterite, mud, and timber, which not only affirm cultural rootedness but also promote sustainability (Okosun et al., 2023).
4. Environmental Responsiveness – Vernacular systems of shading, orientation, and ventilation demonstrate adaptive strategies to the tropical climate (Olgyay, 2015)

These principles underscore the importance of an architecture that is simultaneously context-sensitive and culturally expressive.

METHODOLOGY

This study employed a qualitative research approach designed to investigate Afrocentric architectural principles and their application in museum design for Minna, Niger State. The methodology consisted of three major stages: literature review, case study analysis, and site investigation.

LITERATURE REVIEW

The first stage involved an extensive review of literature on Afrocentric architecture, museum evolution, and sustainability in tropical regions. Scholarly works on Afrocentricity ((Asante, 1991; Nnamdi Elleh, 1996), vernacular and regionalist approaches (Oliver, 1997; Frampton, 2016), and sustainable building practices in Nigeria (Nwalusi & Okeke, 2021; (Agboola, 2011)) provided the theoretical foundation. This review helped establish the cultural and environmental gaps in existing architectural practices and identified principles relevant to Afrocentric Museum design.

Case Study Analysis

The case study analysis phase of the research involved ethnographic fieldwork based on ethnographic fieldwork and case study analysis. The population of the study included traditional builders, community elders, and residents in selected Local Government Areas of Niger State, focusing on the Nupe, Gwari, and Gade ethnic groups.

A purposive sampling technique was used to select four traditional compounds for in-depth case study analysis. The criteria for selection included the presence of intact traditional architectural elements, cultural significance, and accessibility. Primary data was collected through:

- i. Site visits and photographic documentation of building forms, materials, and spatial layouts.
- ii. Semi-structured interviews with local artisans and residents to understand construction techniques and cultural meanings.
- iii. Sketches and spatial mappings of compound layouts.

Data analysis involved thematic analysis to identify recurring patterns in spatial organization, material use, and cultural symbolism across the different ethnic groups. A comparative analysis was conducted to distil common Afrocentric principles applicable to the museum design.

Site Investigation

The study included a detailed examination of Minna's physical and socio-cultural context. Climatic data such as solar orientation, wind patterns, and rainfall were analysed to inform sustainable design strategies (Olgyay, 2015). Observations of local settlement patterns and building techniques, including the use of mud walls, courtyards, and shaded verandas, revealed indigenous strategies that align with Afrocentric and sustainable principles. The cultural composition of Niger State with its ethnic diversity, festivals, and craft traditions was also studied as a basis for embedding symbolism and cultural narratives into the museum design.

Analytical Framework

The findings from the literature, case studies, and site investigation were synthesized using Afrocentricity (Asante, 2017) and Critical Regionalism (Frampton, 2016) as guiding frameworks. Afrocentricity provided the lens for prioritizing cultural identity, while Critical Regionalism ensured responsiveness to local environmental conditions. Together, these frameworks formed the basis for identifying design strategies that balance cultural preservation with sustainability.

FINDINGS AND DISCUSSION

Afrocentric Elements Identified

The analysis of the case studies yielded several key findings critical for the museum design: A comparative analysis revealed consistent use of specific elements across the ethnic groups:

Spatial Organization

A strong preference for clustered compounds organized around a central courtyard ('soro' or 'zhempa'). This

courtyard acts as a multi-functional space for social gatherings, rituals, and climatic modulation.

Building Materials

Predominant use of locally sourced, sustainable materials: sun-dried mud bricks ('tuki') for walls, thatch ('zaure') for roofing, and timber for structural support and openings.

Construction Techniques

Traditional methods such as rammed earth flooring, mud-block masonry, and decorative plastering with symbolic motifs (e.g., embedded metal plates in Nupe architecture).

Response

Passive design strategies are inherent, including thick earth walls for thermal insulation, strategically placed openings for cross-ventilation, and shaded courtyards.

Design-Informing Principles

The findings suggest that an Afro-centric Museum design should be guided by the following principles derived from the vernacular:

Spatial Symbolism

The layout should tell a story, guiding visitors through a narrative sequence that reflects local cosmologies and rituals.

Material Honesty

The use of earth-based materials and traditional motifs should be expressed authentically, even when adapted with modern stabilizers for durability.

Community Centredness

The design should incorporate flexible, multi-functional spaces that encourage community participation and engagement, mirroring the communal life of traditional compounds.

Environmental Harmony

The building must respond to Minna's tropical savanna climate through passive cooling, natural ventilation, and rainwater management, as seen in the traditional case studies.

Integration of Sustainability

Afrocentric design principles inherently align with sustainable practices. Vernacular strategies such as natural ventilation, deep roof overhangs, and shaded courtyards are passive cooling mechanisms highly suited to Minna's tropical climate (Olgyay, 2015; Adenaike et al., 2024). The reliance on local materials reduces embodied energy and construction costs, while vegetation and water features can serve as bioclimatic regulators. These strategies demonstrate that cultural identity and environmental sustainability are not opposing goals but complementary imperatives in Afrocentric design.

Implications for Museum Design in Minna

The findings suggest that an Afrocentric Museum in Minna would serve as more than a repository of artifacts; it would itself be a cultural artifact, a built expression of identity. The integration of symbolism, courtyards, and indigenous materials would create a space that resonates with local communities while providing educational and tourism value. Such a design model also addresses the broader need to reposition Nigerian public architecture as a vehicle for cultural preservation, rather than mere functional infrastructure.

Discussion of Findings

The findings underscore the urgent need to reposition architecture in Minna as a medium for cultural preservation rather than a neutral backdrop for imported aesthetics. The current reliance on Western modernist forms, while functionally adequate, fails to resonate with the lived experiences and histories of the local community (Uduku, 2006; Nnamdi Elleh, 1996). This disconnection risks alienating users from their built environment and contributes to the erosion of cultural identity.

The identified Afrocentric elements—symbolism, courtyards, local materials, and spatial hierarchy—collectively point to a design paradigm where buildings act as cultural texts. In the context of museum design, these elements transform the building into an active participant in heritage preservation, enabling architecture itself to communicate history and meaning (Oliver, 1997). For instance, the courtyard typology not only supports communal gathering but also provides climatic comfort, aligning with indigenous knowledge systems that have evolved over centuries (Adenaike et al., 2024).

The alignment between Afrocentric principles and sustainable practices is particularly significant. Strategies such as passive ventilation, orientation for solar control, and the use of earth-based materials demonstrate that identity-driven design can simultaneously address environmental concerns (Olgyay, 2015). This challenges the perception that sustainability is a Western import; rather, it is embedded in African vernacular traditions that have long practiced ecological sensitivity.

This study has examined the application of Afrocentric architectural principles in the design of a museum for Minna, Niger State. The findings demonstrate that contemporary Nigerian public architecture, while functional, often lacks cultural resonance due to its dependence on imported forms and paradigms. Museums, as cultural institutions,

provide an opportunity to correct this imbalance by embedding identity directly into architectural expression.

The study identified Afrocentric elements such as symbolism, courtyard planning, material authenticity, and spatial hierarchy as critical to re-establishing cultural relevance in architecture. These elements not only affirm community identity but also align with sustainable practices suited to tropical environments. The integration of Afrocentric design and sustainability underscores the capacity of indigenous knowledge to address both cultural and environmental imperatives in contemporary architecture.

The proposed museum design is a direct application of the research findings. The design concept is inspired by the courtyard typology, a universal element in the traditional architecture of Niger State's ethnic groups.

Architectural Synthesis

Spatial Planning

The museum is conceived as a conglomeration of interlinked courtyards. Each courtyard represents a different functional zone (arrival, exhibition, performance, reflection), creating a journey that mimics the spatial progression of a traditional compound. This layout facilitates intuitive wayfinding and offers varied experiences, from communal gathering spots to quiet, contemplative areas.

Materiality and Form

The design employs a modern interpretation of traditional materials. Stabilized earth blocks form the primary wall system, evoking the texture and presence of mud architecture. The roofing system combines long-span aluminium sheets with synthetic thatch to recall the traditional thatched roof while ensuring longevity and fire resistance. Facades are articulated with recessed openings and carved motifs inspired by Nupe and Gwari decorative patterns.

Climate Response

The courtyard arrangement promotes natural cross-ventilation throughout the building. Deep overhangs, shaded walkways, and the thermal mass of earth-based walls work together to passively cool the interior spaces, reducing reliance on mechanical systems.

RECOMMENDATIONS

Based on this study, the following recommendations are proposed for culturally grounded architectural projects in Nigeria:

- i. Policy Integration: Development control regulations should be amended to incentivize the use of Afro-centric principles and local materials in public building designs.
- ii. Community Participation: The design process for cultural institutions must involve continuous engagement with local communities and traditional custodians to ensure cultural accuracy and ownership.
- iii. Educational Shift: Architectural education in Nigeria should place greater emphasis on indigenous design studies and fieldwork to equip future architects with the skills to design culturally responsive environments.

CONCLUSION

This study demonstrates that the rich architectural heritage of Niger State's ethnic groups provides a viable and meaningful foundation for contemporary museum design. By moving beyond superficial aesthetic references to deeply integrate indigenous spatial principles, materials, and symbolism, architecture can become a powerful tool for cultural preservation and identity reaffirmation. The proposed museum for Minna is not merely a container for artifacts but is itself an exhibit a spatial narrative of the region's diverse cultures. It stands as a model for how Afro-centric architecture can bridge the past and present, creating sustainable, meaningful, and culturally resonant public spaces in Nigeria.

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Evaluation of Biophilic Design Principles in the Design Proposal of A 5-Star Hotel in Minna, Niger State, Nigeria

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ABSTRACT

Over the years, hotels around the world have been a haven of relaxation and wholesomeness. But the growing concern for sustainability and occupant well-being has increased the adoption of biophilic design plans in hospitality architecture. Biophilic design which incorporates natural features like plants, water, and natural lighting into constructed spaces, highlight the relationship between humans and the natural world. The study's specific goal is to evaluate the integration of these biophilic principles (Terrapin 14 Patterns) into the design proposal of a 5-star hotel in Minna, Niger State, Nigeria, with the aim of identifying patterns suitable for the region's tropical savannah climate in order to create a healthier and more productive built environment. To attain the desired objective, a descriptive study design with a quantitative research approach was used. Following an intensive analysis of journals and books, as well as observations of existing five-star hotels, 100 questionnaires were distributed to guests of luxury hotels, yielding a total response of 94, which were examined using descriptive statistics. Case studies were used as primary sources of data, while a review on available literatures, online databases and books were used as secondary sources of data. The findings suggest that by evaluating biophilic design principles such as nature in the space, nature of the space and nature analogues suitable for Minna weather condition, luxury hotels can create health promoting environments that stand out in the competitive hospitality market, offering an immersive experience that is in line with the growing trend of wellness-centered travel and modern environmental consciousness. The study emphasizes the value of comprehensive biophilic evaluation tools in early design stages and gives practical insights and ideas for Architects who want to incorporate biophilic design concepts to create an aesthetically beautiful setting that links guests to nature and improves their overall well-being.

Keywords: Biophilic design; environmental sustainability; integrate natural elements; psychological well-being.

INTRODUCTION

With rising investments in upscale hotels to serve both business and leisure tourists, the hospitality sector of the Nigerian economy is now one of the fastest-growing. However, the design of these hotels often prioritises modern aesthetics and mechanical systems, with limited attention to environmental responsiveness and user well-being (Akinyemi *et al.*, 2024). This development raises questions regarding energy efficiency, client pleasure, and the sustainability of hotel facilities in fast-urbanizing areas like Minna, Niger State. Biophilic design, which integrates natural elements and patterns into the built environment, has gained recognition as a sustainable design approach that enhances human comfort, health, and psychological restoration (Abraham *et al.*, 2023). Biophilic design has emerged as a strategy to reconnect people with nature, improve comfort, and enhance sustainability outcomes (Hindley *et al.*, 2023).

Studies have shown that the application of biophilic principles in hotels improves mood, reduces stress, enhances thermal comfort, and creates memorable guest experiences (Ayejuyo *et al.*, 2025). Yet, despite its global adoption, the systematic integration of biophilic design into Nigerian hotel architecture remains limited, with most projects focusing on conventional building strategies (Kalu *et al.*, 2025). Recent research on Nigerian hospitality facilities has highlighted that although some biophilic features such as daylighting, shading devices, and greenery are present, they are often applied superficially and without reference to structured frameworks like Terrapin Bright Green's 14 Patterns of Biophilic Design (Yusuf *et al.*, 2025).

Additionally, Minna's hot, dry climate poses unique problems for air circulation, thermal regulation, and energy consumption, highlighting the need for climate-sensitive design approaches that also enhance human well-being. This study uses the 14 Patterns of Biophilic Design as an assessment framework to evaluate the proposed 5-star hotel in Minna considering these deficiencies.

The goal is to determine the extent to which biophilic concepts have been included into the design plan and which patterns are most suited to Niger State's sociocultural, ecological, and climatic setting. In addition to making recommendations for ecologically friendly hotel design in Minna, this study will contribute to the ongoing discussion in Nigeria about context-responsive architecture.

STATEMENT OF RESEARCH PROBLEM

Recent studies on Nigerian hospitality design emphasize the economic and environmental benefits of climate-adapted architecture (Eze *et al.*, 2023). Nevertheless, little research has been done expressly on how to incorporate biophilic principles into hotel design for Nigeria's various climate zones. By offering suggestions unique to Minna, this study helps close this gap. While numerous studies highlight the benefits of incorporating biophilic elements to enhance guest well-being and satisfaction (Uzoagulu, 2021), many hotels in Nigeria still adhere to conventional design practices that neglect natural integration.

Aim of the Study

The aim of this study is to evaluate biophilic design principles towards integrating it in the design proposal of a 5-star hotel in Minna, Niger State.

Concept of Biophilic Design

The term "biophilia", literally meaning "love of life or living systems", was popularized by biologist Edward O. Wilson (1984) in his book *Biophilia*. He proposed that the deep affiliations humans have with nature are rooted in our species' evolutionary history, where survival and well-being were intrinsically linked to the natural environment. Biophilic design, therefore, is a human-centered approach that integrates natural elements and processes into the built environment to enhance physical, psychological, and emotional well-being.

Akinyemi *et al.* (2024) highlighted that hotels adopting biophilic concepts achieve higher guest satisfaction levels, as natural lighting, greenery, and water features foster comfort and relaxation. Similarly, Kalu *et al.* (2025) demonstrated that combining passive and biophilic design strategies improves both energy efficiency and indoor environmental quality in Nigerian buildings. Biophilic design extends the idea of sustainability by highlighting human–nature interaction within built environments. Research shows that biophilic spaces reduce stress, improve cognitive performance, and create memorable experiences (Abraham *et al.*, 2023).

Biophilic Design in Hospitality Spaces

Hospitality facilities, particularly hotels, benefit significantly from biophilic interventions. Hotels increasingly integrate biophilia through landscaped courtyards, natural materials, daylighting, and vegetation. These features enhance guest satisfaction and sustainability outcomes (Yusuf *et al.*, 2024). However, hotels in hot climates must adapt strategies such as shading, ventilation, and drought-resistant planting (Akinyemi *et al.*, 2024). Abraham *et al.* (2023) evaluated resorts in Nigeria and found that features such as water, vegetation, and natural lighting improved mood, cognitive restoration, and guest satisfaction. Ayejuyo *et al.* (2025) further observed that landscaped courtyards and greenery in Southwestern Nigerian resorts enhanced relaxation and created memorable guest experiences, though they noted that many hotels implemented these features at a basic level. Ifebi (2024) confirmed that many Nigerian hotels incorporate natural elements such as greenery and daylight, but often without structured alignment to established frameworks like Terrapin Bright Green's 14 Patterns of Biophilic Design, leading to inconsistent guest outcomes.

Biophilic Design Principles (Terrapin 14 Patterns)

Terrapin Bright Green's "14 Patterns of Biophilic Design" provides a comprehensive framework for understanding and applying biophilic principles in practice. These patterns are categorized into three groups: Nature in the Space, Natural Analogues, and Nature of the Space (Browning *et al.*, 2014).

Nature in the Space

Visual Connection with Nature: The ability to see natural elements, living systems, and natural processes.

Non-Visual Connection with Nature: Auditory, tactile, olfactory, or gustatory stimuli from nature.

Non-Rhythmic Sensory Stimuli: Random and ephemeral connections with nature, such as breezes or rustling leaves.

Thermal & Airflow Variability: Subtle changes in air temperature, humidity, and airflow that mimic natural environments.

Presence of Water: A condition that enhances the experience of a place through seeing, hearing, or touching water.

Dynamic & Diffuse Light: Varied light intensities and shadows that change over time, mimicking natural light conditions.

Connection with Natural Systems: Awareness of natural processes, such as seasonal changes, weather, or cycles of life and death.

Natural Analogues

Biomorphic Forms & Patterns: Symbolic references to nature through shapes, patterns, and textures.

Material Connection with Nature: Use of natural materials that reflect the local ecology or geology.

Complexity & Order: Rich sensory information that is organized in a meaningful way, echoing patterns found in nature.

Nature of the Space

Prospect: An unimpeded view over a distance, providing a sense of openness and control.

Refuge: A place for withdrawal from environmental stimulation, where one feels protected from behind and overhead.

Mystery: The promise of more information gained through partially obscured views or intriguing pathways.

Risk/Peril: A discernible threat coupled with a reliable safeguard, creating an exhilarating and engaging experience.

Recent studies show that not all patterns apply equally across regions; contextual factors such as climate, resources, and culture must guide their application (Kalu *et al.*, 2025).

RESEARCH METHODOLOGY

The quantitative method uses a structured survey aligned with the study's aim via questionnaires which consists of 5-point Likert scale questions. This is used to measure the opinions of respondents on how much they feel the biophilic design principles in hotel buildings. The questionnaire form was administered to hotel users. The questionnaire forms were hand-delivered to respondents within the study area. Purposive Sampling was employed in the case study selection based on three criteria: (i) The hotels selected provide the necessary range of amenities for a typical luxury hotel to function effectively (ii) The hotels selected are tropical climate (iii) The selected hotels incorporates various biophilic design principles, and elements.

ANALYSIS AND DISCUSSION OF RESULTS

Survey Report

The quantitative data for this study was collected through the distribution of questionnaires and is presented using descriptive and statistical tables. Out of 100 questionnaires distributed, 94 were duly completed and returned, yielding a response rate of 94%. These 94 responses formed the basis for the valid data analysis.

Table 1: Participants' Response Rate

S/No	Location	Distributed (X)	Returned (Y)	Not Returned	Rate (%) (Y/X*100)
1	Transcorp Hilton, Abuja	25	24	1	96
2	Frasier Suites, Abuja	25	23	2	92
3	Guddel Hotel, Minna	25	22	3	88
4	Vagosh Hotel, Minna	25	25	0	100
Total		100	94	6	94

Source: Author's Fieldwork (2025)

Discussion of Results

Table 2 presents the analysis of the general information provided by users. As regards the location of the users, 50% lodged in hotels in Minna, while 50% lodged in hotels in Abuja. The findings on type of hotel lodged reveal that 36.2% of the users lodged in a 3-star hotel, 14.9% of the users lodged in a 4-star hotel, 14.9% of the users lodged in a luxury resort and 34% of the users lodged in a 5-star hotel. As regards the gender of the users, 67%, which accounted for the majority, were male, while 33% were female. The findings with respect to the age bracket reveal that 43.6% are between the ages of 18 and 29, 27.7% are between the ages of 30 and 39, 11.7% are between 40 and 49 years, 10.6% are 50 and 59 older, and the remaining 6.4% are between the ages of 60 and above years. As regards the frequency of visits by the users, 27.7% of them visited rarely, 18.1% frequently visited, 54.3% occasionally visited. Finally, the findings regarding the general purpose of the users' visits indicate that 22.3% visited for leisure, 23.4% for business, 30.9% for conferences, and 23.4% for events.

Table 2: General Information for Users and Professionals

Variable	Frequency	Percentage
Type of Hotel		
5-star	32	34
4-star	14	14.9
3-star	34	36.2
Luxury Resort	14	14.9
Total	94	100%
Location		
Abuja	47	50
Minna	47	50
Total	94	100%
Gender		
Male	63	67
Female	31	33
Total	94	100%
Age bracket		
18-29	41	43.6
30-39	26	27.7
40-49	11	11.7
50-59	10	10.6
60 and above	6	6.4
Total	94	100%
How often do you stay in hotel?		
Rarely	26	27.7
Occasionally	51	54.3
Frequently	17	18.1
Total	94	100%
What is your general purpose of stay in hotels?		
Business	22	23.4
Conferences	29	30.9
Events	22	23.4
Leisure	21	22.3
Total	94	100%

Source: Author's fieldwork (2025)

Identify the Relevant Biophilic Design Principles in a Hotel Design

Several survey questions shown on Table 3 were presented to the respondents to know biophilic elements they would prefer in a hotel. The survey questions were able to identify the biophilic elements such as natural lighting, natural ventilation, outdoor views and vistas, indoor plants/green wall, natural materials, courtyard and garden spaces, and organic/biomorphic forms and patterns which users would prefer in a hotel. From the analysis, 53.2% of the respondents felt it is very important to integrate natural elements in hotels, 28.7% of the respondents felt it is essential to integrate natural elements in hotels, and 18.1% of the respondents felt it is moderately important to integrate natural elements in hotels. The results of MIS, which was employed to rate the biophilic elements they would prefer in a hotel, are summarised in Table 3.

Table 3: Identify the Relevant Biophilic Design Principles in a Hotel Design

Variable	Frequency (percentage)	Mean value
In your opinion, how important is the integration of natural elements in hotel design?		4.106
Not important	0	
Slightly important	0	
Moderately important	17(18.1)	
Very important	50(53.2)	
Essential	27(28.7)	
Which of the following biophilic design elements do you consider most relevant to hotel architecture? (Select all that apply)		
Natural lighting	58(61.7)	
Use of indoor plants/green walls	60(63.8)	
Water features (e.g., fountains, ponds)	46(48.9)	
Use of natural materials (e.g., wood, stone)	51(54.3)	
Outdoor views and vistas	60(63.8)	
Courtyards and garden spaces	41(43.6)	
Natural ventilation	50(53.2)	
Organic/biomorphic forms and patterns i.e. forms and patterns mimicking nature like flower patterns, water waves	14(14.9)	

Source: Author's fieldwork (2025)

About 61.7% of the respondents would prefer natural lighting during their stay. 63.8% of the respondents would prefer indoor plants during their stay. 48.9% of the respondents would prefer water features during their stay. 54.3% of the respondents would prefer natural materials during their stay. 63.8% of the respondents would prefer outdoor views and vistas during their stay. 43.6% of the respondents would prefer courtyards and garden spaces during their stay. 53.2% of the respondents would prefer natural ventilation during their stay. 14.9% of the respondents would prefer organic/biomorphic forms and patterns during their stay.

Assess the biophilic design elements in hotels

Table 4 shows the perception of the respondents on the biophilic design elements in the hotel. From the analysis, 21.3% of the respondents agreed that the presence of natural lighting is very high in the hotel, 29.8% agreed that it is high, 39.4% agreed that it is moderate, 8.5% agreed that it is low, while 1.1% agreed that it is very low with a mean value of 3.617 which implies that the respondent agreed that the natural lighting in the hotel is moderately effective. 11.7% of the respondents agreed that the presence of indoor plants/green walls is very high in the hotel, 33% agreed that it is high, 36.2% agreed that it is moderate, 14.9% agreed that it is low, while 4.3% agreed that it is very low with a mean value of 3.329 which implies that the respondent agreed that the presence of indoor plants in the hotel is moderate. 14.9% of the respondents agreed that the presence of natural materials(wood, stone) is very high in the hotel, 34% agreed that it is high, 36.2% agreed that it is moderate, 10.6% agreed that it is low, while 4.3 % agreed that it is very low with a mean value of 3.446 which implies that the respondent agreed that the presence of natural materials in the hotel is moderate. 22.3% of the respondents agreed that the presence of outdoor views/ vistas is very high in the hotel, 25.5% agreed that it is high, 34% agreed that it is moderate, 12.8% agreed that it is low, while 5.3% agreed that it is very low with a mean value of 3.468 which implies that the respondent agreed that the presence of outdoor views and vistas in the hotel is moderate. 18.1% of the respondents agreed that the presence of natural ventilation is very high in the hotel, 34% agreed that it is high, 40.4% agreed that it is moderate, 7.4% agreed that it is low, while 0% agreed that it is very low with a mean value of 3.627 which implies that the respondent agreed that the presence of natural ventilation in the hotel is moderate.

Table 4: Perception of the respondents on the biophilic design element in the hotel

Variable	Frequency (percentage)	Mean value
How would you rate the presence of natural light in the hotel?		3.617
Very high	20(21.3)	
High	28(29.8)	
Moderate	37(39.4)	
Low	8(8.5)	
Very low	1(1.1)	
How would you rate the presence of indoor plants/green walls in the hotel?		3.329
Very high	11(11.7)	
High	31(33)	
Moderate	34(36.2)	
Low	14(14.9)	
Very low	4(4.3)	
How would you rate the presence of natural materials (wood, stone) in the hotel?		3.446
Very high	14(14.9)	
High	32(34)	
Moderate	34(36.2)	
Low	10(10.6)	
Very low	4(4.3)	
How would you rate the presence of outdoor views and vistas in the hotel?		3.468
Very high	21(22.3)	
High	24(25.5)	
Moderate	32(34)	
Low	12(12.8)	
Very low	5(5.3)	
How would you rate the presence of natural ventilation in the hotel?		3.627
Very high	17(18.1)	
High	32(34)	
Moderate	38(40.4)	
Low	7(7.4)	
Very low	0	
How would you rate the presence of water features in the hotel?		3.138
Very high	14(14.9)	
High	26(27.7)	
Moderate	25(26.6)	
Low	17(18.1)	
Very low	12(12.8)	
How would you rate the presence of natural patterns and form in the hotel?		2.872
Very high	8(8.5)	
High	21(22.3)	
Moderate	28(29.8)	
Low	25(26.6)	
Very low	12(12.8)	
How would you rate the presence of courtyards and garden spaces in the hotel?		3.202
Very high	22(23.4)	
High	20(21.3)	
Moderate	24(25.5)	
Low	11(11.7)	
Very low	17(18.1)	

Source: Author's fieldwork (2025)

14.9% of the respondents agreed that the presence of water features is very high in the hotel, 27.7% agreed that it is high, 26.6% agreed that it is moderate, 18.1% agreed that it is low, while 12.8% agreed that it is very low with a mean value of 3.138 which implies that the respondent agreed that the presence of water features in the hotel is moderate. 8.5% of the respondents agreed that the presence of natural patterns and forms is very high in the hotel, 22.3% agreed that it is high, 29.8% agreed that it is moderate, 26.6% agreed that it is low, while 12.8% agreed that it is very low with a mean value of 2.872 which implies that the respondent agreed that the presence of natural patterns and forms in the hotel is fair. 23.4% of the respondents agreed that the presence of courtyard and garden spaces is very high in the hotel, 21.3% agreed that it is high, 25.5% agreed that it is moderate, 11.7% agreed that it is low, while 18.1% agreed that it is very low with a mean value of 3.202 which implies that the respondents agreed that the presence of courtyards and garden spaces in the hotel is moderate.

Examine the relevant biophilic design features in the hotel

Table 5 shows the influence of biophilic design elements on user's perception. From the analysis, 21.3% of the respondents agreed that the nature lighting in the hotel is excellent in enhancing their comfort and experience, 37.2% agreed that it is very good, 33% agreed that it is good, while 8.5% agreed that it is fair and 0% agreed that it is poor with a mean value of 3.712 which implies that the respondents agreed that the natural lighting in the hotel is good in enhancing their comfort and experience. 12.8% of the respondents agreed that the water features in the hotel is excellent in enhancing their comfort and experience, 28.7% agreed that it is very good, 34% agreed that it is good, while 12.8% agreed that it is fair and 11.7% agreed that it is poor. 12.8% of the respondents agreed that the nature material in the hotel is excellent in enhancing their comfort and experience, 40.4% agreed that it is very good, 34%

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agreed that it is good, while 10.6% agreed that it is fair and 2.1% agreed that it is poor. 26.6% of the respondents agreed that the courtyards and garden spaces in the hotel is excellent in promoting relaxation and comfort, 25.5% agreed that it is very good, 26.6% agreed that it is good, while 9.6% agreed that it is fair and 11.7% agreed that it is poor. 24.5% of the respondents agreed that the nature-inspired colours in the hotel is excellent in bringing a sense of harmony to the users of the hotel, 41.5% agreed that it is very good, 26.6% agreed that it is good, while 5.3% agreed that it is fair and 2.1% agreed that it is poor. 14.9% of the respondents agreed that the indoor plants/green walls in the hotel is excellent in enhancing their comfort and experience, 42.6% agreed that it is very good, 31.9% agreed that it is good, while 8.5% agreed that it is fair and 2.1% agreed that it is poor.

Table 5: Effects of biophilic design elements on user's perception in hotel environment

Variable	Frequency (percentage)	Mean value
How would you rate the success of natural lighting in enhancing guest comfort and experience?		3.712
Excellent	20(21.3)	
Very good	35(37.2)	
Good	31(33)	
Fair	8(8.5)	
Poor	0	
How would you rate the success of water features (fountain, natural water body) in enhancing guest comfort and experience?		3.18
Excellent	12(12.8)	
Very good	27(28.7)	
Good	32(34)	
Fair	12(12.8)	
Poor	11(11.7)	
How would you rate the success of natural materials (wood, stone) in enhancing guest comfort and experience?		3.51
Excellent	12(12.8)	
Very good	38(40.4)	
Good	32(34)	
Fair	10(10.6)	
Poor	2(2.1)	
How would you rate the success of courtyards and garden spaces in promoting relaxation and comfort?		3.457
Excellent	25(26.6)	
Very good	24(25.5)	
Good	25(26.6)	
Fair	9(9.6)	
Poor	11(11.7)	
How would you rate the success of nature-inspired colors that bring a sense of harmony to the users of hotel?		3.808
Excellent	23(24.5)	
Very good	39(41.5)	
Good	25(26.6)	
Fair	5(5.3)	
Poor	2(2.1)	
How would you rate the success of indoor plants/ green walls in enhancing guest comfort and experience?		3.595
Excellent	14(14.9)	
Very good	40(42.6)	
Good	30(31.9)	
Fair	8(8.5)	
Poor	2(2.1)	
How would you rate the success of outdoor views and vistas in enhancing guest comfort and experience?		3.553
Excellent	28(29.8)	
Very good	23(24.5)	
Good	25(26.6)	
Fair	9(9.6)	
Poor	9(9.6)	
How would you rate the success of natural patterns and form in enhancing guest comfort and experience?		3.340
Excellent	12(12.8)	
Very good	27(28.7)	
Good	33(35.1)	
Fair	15(16)	
Poor	7(7.4)	

Source: Author's work (2025)

29.8% of the respondents agreed that the outdoor views and vistas in the hotel is excellent in enhancing their comfort and experience, 24.5% agreed that it is very good, 26.6% agreed that it is good, while 9.6% agreed that it is fair and 9.6% agreed that it is poor. 12.8% of the respondents agreed that the natural patterns and forms in the hotel is excellent

in enhancing their comfort and experience, 28.7% agreed that it is very good, 35.1% agreed that it is good, while 16% agreed that it is fair and 7.4% agreed that it is poor.

Questionnaire Data Analysis

The questionnaire results provided valuable insights into the preferences of potential hotel guests in Minna and Abuja regarding biophilic features. A significant majority of respondents expressed a strong desire for natural elements within the hotel environment.

Natural Lighting: 61.7% of respondents rated "abundant natural lighting with views to the outside" as either very important or extremely important. This highlights a clear preference for bright, naturally lit spaces.

Vegetation & Indoor Plants: 63.8% indicated a desire for indoor plants and well-landscaped outdoor areas. Many respondents specifically mentioned that greenery creates a calming and refreshing atmosphere.

Outdoor Views and vistas: 54.3% emphasized the importance of having views of nature, whether it be a garden, a distant landscape, or even a well-designed urban green space.

Natural Ventilation: Despite Minna's hot climate, 53.2% of respondents expressed a preference for natural ventilation and the ability to open windows, suggesting a desire for fresh air and connection to the outdoor environment.

Presence of Water: 48.9% of respondents appreciated water features, citing their soothing sounds and aesthetic appeal.

Use of Natural Materials: 54.3% of respondents preferred hotels that incorporate natural materials like wood and stone, suggesting an appreciation for authenticity and a connection to the local environment.

Organic/ Biomorphic forms: 14.9% of respondents expressed a preference for natural forms.

Courtyard and Garden Spaces: 63.8% of respondents preferred hotels that incorporate open spaces like the courtyard, atrium and garden.

These findings underscore a strong latent demand for biophilic elements within the hospitality sector in Minna.

DISCUSSION OF CASE STUDY FINDINGS

The analysis of case studies (e.g., [Transcorp Hilton, Abuja], [Frasier Suites, Abuja], [Guddel Hotel, Minna], [Vagosh Hotel, Minna],) revealed moderate successful climate-responsive biophilic strategies relevant to the hotels. The case studies demonstrated that biophilic design in hot climates is not merely about adding plants but about a holistic integration of natural elements and processes that enhance both human experience and environmental performance.

CONCLUSION

According to the research, incorporating biophilic design principles into the proposed five-star hotel in Minna, Niger State, has a lot of potential and is desirable. The advantages of this method for visitor well-being and market attractiveness are highlighted by the 14 Patterns' theoretical framework as well as the actual data from the questionnaire, which is backed by successful case studies. The study discovered that tangible biophilic elements including natural lighting, vegetation, outdoor views, and natural ventilation were clearly preferred by prospective hotel guests in Minna and Abuja. These choices show that even abstract biophilic ideas may be turned into appealing and intelligible design features, as they directly correspond with several of Terrapin's 14 Patterns.

Subsequent analysis showed that there are few biophilic elements in the hotels of the research region. The evaluation confirms that among the Terrapin 14 Patterns, some are highly suitable for a 5-star hotel design in Minna's climate. Visual Connection with Nature, Thermal & Airflow Variability, Natural Materials, Vegetation, Prospect & Refuge, and Diffuse & Dynamic Light emerge as the most effective and feasible. Patterns involving high water use, high maintenance, or less direct impact on thermal comfort are less feasible unless adapted. This suggests that design proposals for the hotel in Minna should prioritize passive climate strategies, local materials, window/greenery design, and designing spaces that offer refuge and prospect.

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Cultural Values and Sense of Place Amid Environmental Change in a Riverine Community of North Central Nigeria

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Abstract

This study investigates the complex relationship between riverine landscapes and community life through in-depth exploration of a riverine community situated along the River Niger in North Central Nigeria. The River Niger functions not only as an ecological corridor but also as a cultural lifeline, supporting biodiversity, traditional livelihoods, spiritual practices, and place-based identities. Built upon interdisciplinary perspectives on sense of place, the research examines how individuals and communities perceive, experience, and internalize their environment across spiritual, psychological, and visual dimensions. Using a qualitative methodology comprising semi-structured interviews, focus group discussions, and personal observation the study captured the community's lived experiences and cultural expressions. Findings reveal that environmental changes, such as depletion of river sands, altered water flows due to dam operations, and migration pressures, are closely tied to shifts in cultural identity, heritage practices, and local knowledge systems. Despite these transformations, the river remains a vital archive of collective memory and meaning. Based on emergent themes, the study further develops a grounded theory that explains how riverine communities negotiate cultural continuity and environmental change through traditional governance structures, oral histories, and adaptive livelihood practices. This theory provides a conceptual framework for understanding similar dynamics in other riverine contexts and offers a foundation for future empirical testing and comparative research. By bridging cultural geography, environmental change studies, and livelihood research, the study contributes to broader debates on place-making, landscape meanings, and the socio-ecological dimensions of resilience in human geography. Ultimately, the study underscores the importance of cultural resilience and environmental attachment in shaping adaptive responses to ecological transformations such as flooding, resource depletion, and climate variability.

Keywords: Sense of Place, Cultural Landscapes, Riverine Communities, Environment, Identity, Livelihood

INTRODUCTION

River landscapes offer unique opportunities to interpret and convey natural values, community histories, and cultural significance (Zhang & Li, 2024). These landscapes are not only ecological corridors but also key to understanding the complex relationships between people and the environments (Brumann & Gfeller, 2022; Sun et al., 2024). In regions such as North Central Nigeria, home to the Niger and Benue rivers, riverine communities have historically shaped and been shaped by their fluvial environments, creating distinct cultural landscapes deeply rooted in place-based identities (Salihu, 2025).

The Niger and Benue rivers, which traverse this geopolitical zone comprising Benue, Kogi, Kwara, Nasarawa, Niger, Plateau states, and the Federal Capital Territory Abuja, sustains both biodiversity and a wide range of cultural traditions (Effiong, et al., 2024). These rivers support agriculture, spiritual practices, and artistic expressions while providing crucial ecological services (Inkani, et al., 2024)

However, this unique relationship is increasingly threatened by environmental pressures such as urbanization, pollution, and climate change, which have begun to erode the cultural fabric and ecological integrity of riverine communities (Ojiegbe, 2023). The degradation of these landscapes raises questions about the preservation of cultural values and the continuity of sense of place, defined as the emotional, spiritual, and psychological connection individuals and communities have with specific environments (Leather & Thorsteinsson, 2021; Teeple & Kabachnik, 2023)

Despite the global recognition of cultural landscapes by the United Nations Educational Scientific and Cultural Organization (UNESCO) as the combined works of nature and man (Labadi, 2024). African riverine cultural heritage remains underrepresented in both scholarly literature and heritage registers (Jordaan, 2022). Cultural landscape studies have predominantly focused on Europe and Asia, neglecting African perspectives that offer rich traditional ecological knowledge and unique sociocultural narratives (Sinthumule, 2023).

Sense of place has emerged as a vital conceptual tool in landscape studies, underpinning efforts to design and manage environments that resonate with cultural meanings and foster stewardship (Chen, et al., 2021; Erfani, 2022). This study builds on emerging scholarship that recognizes sense of place not just as an emotional bond, but as a foundation for sustainable planning, resilience building, and the preservation of indigenous knowledge systems (Ciofalo, et al., 2022) By investigating the cultural values and lived experiences of riverine communities in North Central Nigeria, this research contributes to a growing global discourse on landscape justice and cultural sustainability (Clark & Miles, 2021; Schmitz & Herrero-Jáuregui, 2021). In doing so, it addresses a critical research gap, the need to integrate local cultural knowledge and environmental perceptions into planning frameworks that can respond to environmental change while safeguarding identity and heritage (Albuquerque et al., 2021).

LITERATURE REVIEW

Conceptual Foundations of Sense of Place

Sense of place encompasses a multifaceted understanding of how individuals and communities perceive, experience, and emotionally engage with their environment (Erfani, 2022). It is a concept that bridges psychology, geography,

architecture, and cultural studies (Domingues, et al., 2021). Sense of place have been identified to have different dimensions which include visual, psychological, and spiritual and that together define how people form attachments to places (Chen et al., 2021). This interplay between perception and experience highlights how landscape elements relate to cultural norms and values, ultimately shaping environmental behavior and identity (Peng, Liu, Hu, & He, 2023).

Many studies have shown the inextricable link between landscapes, places, and cultures, noting that these elements continuously shape and transform each other over time (Muhammad, et al., 2020; Okon, et al., 2024; Salawu & Muhammad, 2024). Building on this understanding, scholars have proposed the concept of “embodied emplacement” a process through which individuals internalize place through lived experiences. This idea has sparked growing interest in the notion of sense of place across disciplines such as geography, urban design, and sociology, as researchers explore how place-based relationships inform both personal identity and broader cultural structures (Pearson & Gorman, 2023)

Sense of place is therefore both individually constructed and collectively shared (Erfani, 2022). It is grounded in the subjective experiences of memory, tradition, history, and cultural practices, as well as the tangible characteristics of the physical environment, such as sounds, smells, and aesthetics (Bender, et al., 2024; Bowering, 2024). The interaction between internal perception and external environmental features fosters place meaning and identity, shaping how people emotionally and cognitively interpret their surroundings (Bernardo, et al., 2023). In another dimension, the physical characteristics of an environment such as scale, texture, noise, temperature, and aesthetics contribute significantly to how individuals perceive and engage with it. It therefore means that sense of place manifests across different scales of attachment, from simple recognition of a location to profound emotional and spiritual connection. In riverine cultural landscapes, a profound sense of place is integral to preserving traditional practices and cultural heritage. This connection fosters emotional and psychological bonds between local communities and their environments, establishing a collective responsibility towards the stewardship of cultural heritage sites and practices (Najafi & Shariff, 2011). As these communities form deep connections with their landscapes, they are motivated to engage in the active preservation of both tangible and intangible heritage, such as fishing and boat-building, which are essential for maintaining cultural identity in riverine environments (Bender, 2014). These place-based attachments not only reinforce a shared cultural identity but also exemplify how sense of place serves as a vital mechanism through which cultural landscapes are sustained, transformed, and passed down through generations.

Sense of Place in Riverine Cultural Landscapes

A deep sense of place is fundamental to how communities understand, engage with, and preserve their cultural environments. This emotional and symbolic attachment is not simply a result of proximity or routine, but rather of lived experiences, shared histories, and cultural practices that embed meaning into the landscape (Hu, et al., 2021). In riverine communities, especially in North Central Nigeria, these connections are not only profound but also essential to cultural continuity and environmental stewardship (Salihu, 2025).

Traditional ecological knowledge (TEK), passed down through generations, plays a central role in sustaining these landscapes. Rooted in localized experiences and long-term adaptations, TEK underpins sustainable practices and affirms cultural identity (Ossai, 2024). For example, the intergenerational transfer of fishing techniques in these riverine societies does more than support livelihoods; it preserves knowledge systems, reinforces family bonds, and affirms a collective identity tied to the river.

A strong sense of place, rooted in the emotional and symbolic connections people form with their surroundings, plays a vital role in shaping how riverine communities live and interact with their environments. Across many regions, various ethnic groups have developed distinct traditions that are deeply intertwined with their river ecosystems (Cartel, et al., 2022). Rituals, economic activities, and seasonal practices reflect shared values and collective histories embedded in the landscape (Cartel et al., 2022). However, despite their richness, these communities are often overlooked in academic research, which tends to prioritize ecological factors over cultural ones (Okeke-Ogbuafor, et al., 2017). Scholars have stressed that exploring these place-based relationships is crucial for safeguarding the intangible heritage connected to riverine environments (Goussous, 2022; He, et al., 2024; Wang, et al., 2024). The symbolic and affective ties to riverine spaces echo the broader understanding of cultural landscapes not merely physical locations, but living records of identity and community values (Okeke-Ogbuafor et al., 2017). Ultimately, examining these rich interconnections reveals how senses of place serve not only as anchors of cultural memory but also as vital lenses for preserving the lived experiences embedded in riverine environments.

Study Community

Badeggi is a riverine community located in Niger State, Central Nigeria. It is a village in the Katcha Local Government Area, with an estimated population of about 8,280 residents. Situated along the A124 highway in the western part of the area, Badeggi is one of the major towns in the local government. The village is located near other settlements such as Gbakogi and Kangi Tsuyanpa.

Badeggi is known for its rich agricultural lifestyle, with the majority of its residents engaged in rice farming and fishing, which are occupations well-suited to its riverine environment. The community's proximity to water bodies supports both irrigation for rice cultivation and a thriving fishing culture, making these activities central to the local economy and way of life (See Figure 1).



Figure 1: Satellite image of Badeggi

Source: Google Earth (2025)

RESEARCH METHODOLOGY

The research philosophy guiding this study is rooted in an understanding of how different paradigms shape the exploration of cultural values and sense of place amid environmental change in riverine communities. Mantula, et al., (2024) argue that paradigms help align the research process with the study's questions, methods, and objectives, enhancing its coherence and rigor. This study adopts an interpretivist paradigm, which emphasizes understanding the subjective meanings and experiences within riverine communities, thus allowing for deeper insights into how environmental changes affect local cultural landscapes.

Data Collection

This study employed a combination of qualitative methods to explore the intricate relationship between community life and the riverine landscape. Semi-structured interviews were conducted with individuals recognized for their deep-rooted knowledge of local traditions and environmental histories, including elders, traditional leaders, cultural practitioners, and long-term residents. These interviews allowed for open-ended dialogue that captured participants' reflections on environmental changes and their impacts on cultural identity, traditional practices, and daily life. As Bayeck, (2021) notes, such interviews are particularly effective in uncovering contextually rich and culturally embedded knowledge, enabling researchers to engage with the lived experiences of individuals in a respectful and flexible manner.

In other to complement the individual narratives, focus group discussions were organized to gather collective perspectives on environmental change and its influence on sense of place. These discussions brought together diverse groups within the community, including fishermen, women involved in traditional riverine crafts, youth, and other local residents. Through shared dialogue, participants articulated variations in their experiences across age, gender, and occupation. This method has been found to be especially useful in environmental and social research for highlighting group dynamics and surfacing collective memory (Shoko, et al., 2024)

Personal observation was also integral to the research process, offering a grounded perspective on both the tangible and symbolic dimensions of the riverine environment. The observations helped contextualize interview and focus group data, revealing how the landscape itself operates as a living archive of cultural meaning. Together, these methods provided a holistic understanding of how cultural knowledge, identity, and environmental change are deeply interwoven in the community's sense of place.

Data Analysis

The data collected from interviews, focus groups, and observations was analyzed using NVivo12, a qualitative data analysis software designed to streamline the organization and examination of qualitative data. NVivo12 served as an essential tool in managing the complex datasets, enabling researchers to efficiently code, categorize, and visualize emerging patterns and themes. While the software provided significant support in handling the data, the analytical process remained firmly under the control of the researchers, ensuring that the interpretation of findings was grounded in human insight and methodological rigor.

The analysis adhered to a grounded theory approach, which is well-suited for developing theories directly from qualitative data. The process began with initial coding, where open coding techniques were employed to break down the data into discrete categories. This stage involved identifying recurring patterns and concepts within the raw data,

allowing researchers to establish preliminary nodes that represented key ideas. Throughout this stage, NVivo facilitated the systematic organization of codes while enabling researchers to connect related concepts across different data sources.

Also, Memoing played a crucial role in capturing reflective insights during the analysis. Researchers documented their thoughts and observations in memos, which acted as a repository for emerging theoretical ideas and critical reflections on the data. These memos were instrumental in guiding subsequent stages of analysis, as they provided a space for iterative thinking and theory development.

The grounded theory approach also emphasized constant comparative analysis. As new categories emerged during coding, they were continually compared with incoming data to refine their definitions and relationships. This iterative process ensured that the evolving theory was deeply rooted in empirical evidence while remaining flexible enough to accommodate new insights. NVivo supported this dynamic process by enabling researchers to retrieve and compare coded segments efficiently, fostering an environment where theoretical saturation could be achieved.

Overall, NVivo12 proved invaluable in facilitating a transparent and systematic analysis of qualitative data. By combining technological efficiency with grounded theory principles, the research process maintained both methodological rigor and creative flexibility, ultimately leading to meaningful insights grounded in participants lived experiences.

RESULTS AND DISCUSSIONS

The River as a Living Identity of the Indigenous people of Badeggi

Badeggi is a riverine community in North Central Nigeria. The community is intricately connected to its environment, particularly the River Gbako, which is the major source of livelihood for the inhabitants of community. The river is more than just a water source; it defines the community's identity and the rhythms of daily life.



Plate 1: A section of river Gbako River utilized for irrigation farming

Source: Author's field work, 2024

This symbiotic relationship between the river and the community shapes how the people of Badeggi identify with the land, as well as how they organize their daily lives, social networks, and spiritual practices. As one farmer stated:

“We plant rice, maize, vegetables, and fish, all because of the presence of river Gbako.”

Such expressions illustrate what Tuan (1977) describes as *topophilia*, the emotional and symbolic bond between people and place. For the indigenous people of Badeggi, the river is both a source of livelihood and a cultural anchor that defines belonging and continuity. Similar findings have been documented across other riverine communities, where water bodies are central to local identity and economic survival (Udechukwu et. al., 2017; Okeke-Ogbuafor et. al., 2017). These parallels affirm that the meanings attached to rivers are neither exclusively environmental nor economic, but deeply cultural, which shapes the moral and social geographies of everyday life.

The surrounding lakes, such as Ewan and Ewanko, also contribute to Badeggi and her environmental landscape, offering both physical resources and institutional order. The community has developed traditional systems of governance to regulate access and usage, ensuring collective responsibility. One respondent explained:

“The community has different organizations & hierarchy for controlling these rivers.”

This local governance system exemplifies what Ostrom (1990) termed “*collective action in the commons*”, where shared resources are managed through social rules and moral accountability rather than external enforcement. These practices mirror community-based natural resource management models observed in other African and Asian riverine

societies (Jani et al., 2024; He et al., 2024). These situate Badeggi within a wider conversation on indigenous sustainability and environmental stewardship.

In addition, tangible resources which physically connects people to the surrounding environment is anchored by intangible heritage such as oral traditions, memory, and spirituality. The legend of *Nnaihaiba*, believed to be the first settler in Badeggi, remains a foundational narrative linking people to their ancestral land. As an elder recounted:

“According to the stories, a woman was the first person that settled in Badeggi, and her name was Nnaihaiba.”

These oral histories are more than folklore; they function as cultural archives that transmit values, stewardship ethics, and collective identity. This aligns with Najafi and Shariff's (2011) argument that storytelling in riverine societies embeds environmental knowledge within cultural meaning. The narratives sustain what Erfani (2022) term as *“experiential sense of place”* an embodied awareness that ties spiritual heritage to ecological continuity.

Traditional leadership further strengthens this environmental identity. The *Etsu Foma*, *Mayaki Foma*, and other leaders oversee the use of fishing rights and regulate access to the river. According to a respondent:

“The Etsu Foma, Mayaki Foma, Ndeji Foma, and Kpotun Foma control how fishing is done in the Ewanko.”

These practices reflect the coexistence of culture and governance. An indigenous model that unites environmental management with social cohesion. In Badeggi, leadership is not only administrative but moral, it legitimizes authority through guardianship of the river. This supports Ostrom's (1990) and Schmitz and Herrero-Jáuregui's (2021) arguments that enduring sustainability arises from locally grounded governance that integrates cultural norms with ecological control.

However, these deeply rooted systems are increasingly under pressure from environmental changes. One of the most visible transformations is the loss of river sands which was once essential for pottery and trade. As a female potter lamented:

“There used to be special kinds of sands in the river. Those sands were extracted and sold at high prices. But now, they are no longer there.”

This material loss has a symbolic weight as it disrupts a generational craft that once defined both livelihood and identity. Similarly, experiences of *cultural erosion through ecological degradation* have been recorded in neighboring African countries of Ghana and Zimbabwe (Adu-Boahen et al., 2023; Jani et al., 2024). This shows that the depletion of environmental resources often weakens cultural continuity. In Badeggi, the disappearance of these sands signifies a rupture in the collective memory that binds people to the river.

Another challenge arises from the irregular release of water from upstream dams, which alters local ecological rhythms. When dam gates open or close unexpectedly, fishing and pottery activities are suspended. As one of the respondents opined:

“When the dams are opened, we don't get our materials for making pots, so we wait till the water is moderate.”

This act of *waiting* is more than a pause in activity. Rather, it represents a form of **cultural adaptation**, where people recalibrate the practices around environmental uncertainty. It exemplifies researchers Schmitz and Herrero-Jáuregui (2021) argument on the call for *temporal resilience*, and also what Ingold (2000) referred to as *“dwelling within change”*. The adaptive approach with the environment rather than resistance to it. Badeggi response thus offers insight into how small communities enforce resilience without relying solely on technology, rather through patience, rhythm, and cultural continuity.

Furthermore, the shift in river patterns have also disrupted social routines and weakened the certainty that once anchored daily life of the people. The river used to be stable and cyclical, but changes around it is eroding the community's psychological and spiritual sense of control. As observed globally, environmental threats often translate into existential insecurity, transforming place attachment as opined by Teeple and Kabachnik (2023) term *precarious belonging*. Badeggi's experience echoes this: a redefinition of home in the interior the flux of ecological change.

Migration further reshapes Badeggi's geography. The influx of Hausa settlers seeking fertile land has diversified Badeggi's economy but also reconfigured its cultural composition. A resident noted:



Plate 2: Residential area of the Hausa settlers in Badeggi, separated from the Nupe main town by just a road

Source: Author's field work, 2024

“When you go down the village, you’ll see Hausa people all around. They have settled here because of farming.”

While this migration brings new skills and boosts economic activities, it simultaneously challenges the cultural equilibrium. The blending of Hausa and Nupe traditions produces hybrid social practices and reinterpreted rituals. As stated by Teeple and Kabachnik (2023) “the *semantic diffusion of place*”. This process parallels findings from multicultural landscapes by Labadi, 2024; Brumann & Gfeller, 2022, where intercultural encounters reshape rather than erase local identity.

In Badeggi community, these changes mark a **renegotiation of place identity** which balances the act between preserving indigenous values and embracing different cultures. As opined by Escobar (2001) culture lives in places yet constantly redefines itself through day-to-day interaction. Thus, the Badeggi evolving landscape mirrors global human geography debates about how localities negotiate identity with migration and modernization.

Integrating Sense of Place and Environmental Sustainability in Badeggi Settlement Planning

Badeggi faces intensified environmental challenges that demand a planning strategy rooted in both sustainability and cultural preservation. The River Gbako remains the lifeline of the community. It is an ecological system and cultural symbol that represents identity, livelihood, and spirituality. As one respondent emphasized:

“Everything we do depends on the river, our farms, fishing, and even our festivals.”

This recognition reinforces the argument that sustainability in riverine environments must reflect cultural ecosystem. The interaction between people and their environment which is influenced by traditions, memory, and social institutions. Integrating these values into planning is crucial for achieving “*authentic place-making*”. This ensures balance between physical development and cultural continuity (Relph 1976; Tuan 1977).

Also, proposed interventions in Badeggi must therefore align with traditional governance and local environmental ethics. Strengthening community-based natural resource management through the formalization of existing traditional structures such as the *Ewanko* river organizations into a River Management Committee that includes traditional leaders would ensure more sustainable and accountable management of river resources. This echoes Ostrom’s (1990) concept of *collective resource governance*, where shared responsibility promotes stewardship and resilience. Through the integration of indigenous authority systems into environmental planning, Badeggi community can sustain both ecological balance and cultural identity.

Protecting the sources of raw materials, particularly the clay and river sand essential for pottery, is an economic measure and also culturally imperative. As a potter explained:

“If the river sand finishes, our work finishes too; that is our heritage.”

Such testimonies highlight the intersection of livelihood and heritage, an idea increasingly recognized in contemporary cultural geography as heritage-based sustainability (Labadi, 2024). This entails introducing sustainable irrigation methods, regulating sand extraction, and improving dam operations which are vital for ecological stability and safeguarding the community’s sense of place.



Plate 3: Impact of flooding on the settlements within the town

Source: Author's field work, 2024

Climate change amplifies existing vulnerabilities in Badeggi, particularly flooding, erosion, and the loss of vegetation cover. Residents emotionally recall seasons when water submerged farms and homes, prompting temporary migration:

“When the floods come, we just move to the higher ground and wait for the river to go down.”

This local adaptation resonates with Schmitz and Herrero-Jáuregui's (2021) notion of adaptive cultural landscapes, where communities continuously reconfigure their relationship with nature to maintain social stability. Therefore, planning responses should thus focus on adaptive design strategies such as afforestation, floodplain zoning, and local flood response systems that are integrated into everyday settlement patterns.

Furthermore, environmental policies should be culturally informed. So also, documentation of oral histories and embedding heritage education in schools would foster ecological consciousness grounded in local identity. A Cultural Heritage Archive can institutionalize collective memory, while cooperative groups for pottery, fishing, and eco-tourism can translate cultural assets into sustainable livelihoods for the indigenous residents. Initiatives such as pottery workshops and river festivals would strengthen economic resilience and nurture intergenerational continuity which aligns with UNESCO's (2021) call for culture-driven sustainable development.

Migration and new settlements are steadily reshaping Badeggi and her social landscape. The arrival of Hausa farmers has boosted the economy of the community and also added a new layer of social interaction. As one resident shared:

“The Hausa people farm here now; they are part of us, but things are changing.”

This coexistence reflects what Teeple & Kabachnik (2023) refer to as negotiated *belonging*. This refers to the ongoing process through which communities redefine identity in diverse cultural settings. Planning efforts must therefore embrace this diversity while safeguarding Badeggi and her cultural roots.

Inclusive settlement planning would promote dialogue and cultural exchange between indigenous and migrant groups, ensuring that growth strengthens rather than divides the community. Approaches such as protection of traditional settlement cores, gathering spaces, and ritual sites will help sustain social cohesion. Also, incorporating heritage zones, traditional materials, and riverfront preservation can maintain Badeggi's distinctive sense of place.

Finally, integrating eco-friendly water transport, farmland protection, and green infrastructure will enhance both environmental resilience and local identity. These approaches align with global thinking on cultural landscape planning, which recognizes that culture and ecology evolve together rather than apart (Sun et al., 2024; Stephenson, 2008).

CONCLUSION

In conclusion, this study shows that cultural values and sense of place in riverine communities are inseparable from the natural environments, particularly the River Gbako, which functions both as a source of livelihood and as a cultural lifeline. Environmental changes such as resource depletion, altered flows, and climate variability are disrupting these connections, yet traditional governance, oral histories, and local knowledge continue to provide adaptive frameworks that sustain resilience.

The study proposes a grounded theory of **eco-cultural continuity**, suggesting that in riverine contexts, cultural practices and collective memory operate as adaptive systems that help preserve environmental identity amid ecological change.

Further comparative research across Nigeria and other river-dependent communities would be valuable to test and refine this theory and assess how broadly these dynamics apply. The findings also emphasize that sustainable environmental planning must move beyond technical interventions to integrate the cultural and social dimensions of

place. Through appropriate support of traditional governance, protection of heritage-based livelihoods, and embedded local knowledge, policy can reinforce both ecological resilience and cultural continuity.



Plate 4: Proposed grounded theory, Badeggi

Source: Author's field work, 2024

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Planning Compliance of Cereal Processing Mills in Bida, Nigeria

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Abstract

Studies on land-use planning and management have revealed that informal small- and medium-scale enterprises (SMEs) which include cereal processing mills, have largely influenced local and regional developments. This research investigates the physical planning attributes of cereal processing mills in Bida, Nigeria, with a focus on compliance with planning regulations on land-use location, setbacks and distance decay effect. A cross-sectional survey design guided by the sustainability concept was used to randomly select 60 cereal processing mills from 249 recorded mills in Bida. Structured questionnaires were used to collect data, while descriptive statistics were used for the analysis. Results showed that 43.2% of the mills were located less than 1 metre from access roads. Only 11.4% of the mills located at a distance of above 10 metres from the access road, indicating a low level of compliance. This is against the recommended minimum setbacks of 12-15 metres for access/collector street in commercial establishments. Furthermore, incongruous activities and encroachment on collector roads affected the aesthetic outlook of the city, as on-street parking dominated the space. Additionally, 40.9% were within 0-10 metres of residences. Residents living within 0-10 metres of the cereal mills were mostly affected by effluent generated by these mills. This was due to distance decay effect, leading to air pollution. Approximately 41.7% of respondents utilised 81-100% of their plots without considering space allocation for other uses. Only 36.67% of the mills had planning approval, while others complained of very high rent/lease charges on commercial buildings and land spaces in Niger state. Conclusively, the study highlights the need for compliance with planning standards. To this end, the study presents four recommendations of reviewing planning permits administrative fees to accommodate urban poor, educating the cereal owners on the importance of setbacks, adopting a feasible setback of 10.7 metres for collector street in the face of present urbanisation trends and introducing a uniform national physical planning standard. Consequently, various stakeholders, including cereal mill owners, planners, state and local government authorities, should collaborate to promote sustainable living in Bida and Nigeria.

Keywords: Cereal Processing Mills, Physical Planning Attributes, Compliance, Planning Regulations

INTRODUCTION

The informal small- and medium-sized enterprises (SMEs) are the vertebrae of innovation and monetary progress worldwide. More than 90% of businesses and employments in most countries are informal SMEs, and these establishments are largely responsible for the rapid expansion of both the labour force and the economy as a whole (Shields and Shelleman, 2015; Gandhi *et al.*, 2018). The cereal processing mills in many countries are categorised under informal SMEs because their characteristics align with informal SMEs.

Scholars affirmed that informal SMEs, which include cereal processing mills have largely influenced local and regional development (Pike *et al.*, 2007; Mrva, M. and Stachová, P. 2014). According to the ILO (2016), 72% of jobs are provided by informal SMEs in Sub-Saharan Africa (SSA), of which 41% is accrued to an average GDP growth, with South Africa having 30%, while Nigeria, Zimbabwe, and Tanzania have about 60%. The contribution of informal SMEs has, thus, led to higher production, increasing exports, delivering products and services to big businesses, as well as promoting creativity and entrepreneurial abilities (Rahman, 2001; Anuar and Yusuff, 2011; Eggers *et al.*, 2013; Mwanza and Benedict, 2018).

Many people are dependent on the informal economy to earn their livelihoods since the formal economy's employment opportunities are constantly shrinking (ILO, 2002; Chen *et al.*, 2006). Many of these informal SMEs are found in the urban settlements of the world, and their impacts are felt in the environment. Will (2008) stated that it is irrefutable that businesses affect both the social and natural surroundings. While the environmental impact of individual informal SMEs may be minimal, their aggregate actions have a significant effect on the economy, social environment, and natural environment (Lawrence *et al.*, 2006; Ayuso and Navarrete-Báez, 2017). One challenge of informal SMEs, as accentuated by Gunilla (2014), is being sustainable, continuing to be sustainable, and remaining sustainable.

Cereal processing mills are manufacturing facilities that modify hard cereals like maize, rice, guinea corn, millet, wheat and the likes into easily usable powdered form by grinding. The cereal processing mills used different machines to deshell their rice, maize, and other grains before proceeding to grind the required cereal into powder. The need to analyse the activities of the cereal processing mills, a dominant constituent of Bida's informal SMEs as related to physical planning compliance in the urban area is, therefore, necessary. This is because, Niger State Nigeria, traditionally largely engage in cereals, grains, legumes and vegetable farming as a result of the conducive climate.

STATEMENT OF THE RESEARCH PROBLEM

Majority of informal SMEs do not obey physical planning regulations when siting their enterprises. Aguilar (2016) posits that the small and medium-sized enterprises (MSMEs) in India that operate informally do not follow environmental regulations. This is because they do not have the financial resources, expertise, or flexibility to comply with them. They also have difficulty recruiting qualified personnel, little awareness about environmental issues, and less environmental pressure from stakeholders.

The European Commission (2012) stated that just 24% of SMEs are making concerted efforts to lessen their environmental impact by largely reducing their energy consumption. The reason for this negligible sustainable practice is attributed to the inaccessibility of the available academic framework to informal SMEs. Similarly, the framework is viewed as broad and not

supportive of informal SMEs (Arent *et al.*, 2015). Generally, because of their small size, most informal SMEs are not aware of their impact on the environment, and so their activities do not cover how to sustain the environment, unlike the big firms. Nevertheless, the informal SMEs that are conscious of the significance of the sustainability of the environment have no idea how to enhance their procedures and actions.

Most of the reviewed studies focused on the economic role of informal SMEs in local and regional development (Onugu, 2005; Anigbogu *et al.*, 2014; Kubičková *et al.*, 2017). Others focused on the importance of the role of the legal structure on informal SMEs activities and the effect of informal SMEs activities on land use. For example, investigations carried out by Aboelimged (2018), and Gandhi *et al.* (2018) only discovered the importance of high-tech upgrading of informal SMEs as a driver towards sustainable practices to enhance profits and operational efficiency. Adhitama *et al.* (2018), similarly, emphasised a decrease in agricultural land use for trade and service purposes. Asgary *et al.*'s (2020) work revealed that the main apprehensions of informal SMEs were universal economic risks and geopolitical risks, but importance was not attached to environmental risks. Furthermore, Dung-Gwom and Dung (2018), in their study on the urban planning effects of informal sector activities, only divulged challenges like encroachment on access roads, change of land use without planning authorisations, and incompatible land uses, while Ileanwa *et al.* (2020) only worked on land pollution in Minna.

As commendable as these research findings and recommendations are, a major knowledge gap is the absence of study on the compliance of cereal processing mills to physical planning legislation and planning approval in Bida and how environmentally sustainable their activities are on the adjoining land uses.

This research was carried out by examining the activities of the cereal processing mills in the study area and the level of their awareness and compliance with the Niger state domesticated urban planning standards on land-use location and zoning. In addition, environmental sustainability indicators were used to investigate the sustainability of the practices engaged in by the informal SMEs (a perspective that is rare to find in urban and regional planning literature). This is to make the academic framework of cereal processing mills available, accessible, and concise. This is done by providing information to help policymakers ensure effective planning of more sustainable mills' locations and to improve the well-being of the residents living around them.

AIM AND OBJECTIVES

The aim of the study is to assess the planning compliance of cereal processing mills in Bida.

The objectives are to: evaluate the conformity of the mills to extant physical planning standards of land use regulations, setbacks, distance decay effect and planning approval. These findings will contribute to the available concise academic framework for informal SMEs and planning compliance and provide insight into further research.

Literature Review and Conceptual Framework

The study herewith presents the literatures on related issues of informal SMEs (under which the cereal mills fall), and physical planning.

Characteristics of Informal SMEs (Cereal Processing Mills)

The several definitions of informal SMEs symbolised the diverse procedures and organisational settings in which they function, as well as their vast diversity. Informal SMEs always display firm-level, sector-level, and national-level diversity (OECD, 2017). At the firm level, they are defined by using known standards like the size, age, location, building, number of workers, size of transactions and yearly gross revenue. The worth of properties, rights through invention and equipment, commercial model, presentation, and the physiognomies and aims of businesspersons are also considered, among others (Rahman, 2001; Kotane, 2017; OECD, 2017). Likewise, some of the characteristics of informal SMEs in third-world countries as listed by Fisher and Reuber (2000) using comprehensive titles like labour characteristics, areas of activity, competence, and the sex of the proprietor. Nwokoye (1988), for instance, posited that a small or medium-sized firm employs 5 to 500 people and has an annual revenue of ₦400,000 or less.

The OECD (2019) reported that about 362 million youth are in informal employment. This represents more than three-quarters of youth worldwide, and over half of this populace lives in sub-Saharan Africa or southern Asia. Older workers also engage in informal employment, particularly after the statutory retirement age. The OECD (2019), similarly, stated that men constitute 63% of global informal employment, compared to 58.1% for women.

Globally, the highest percentage of businesses, personnel, and events that do not function within the authorised and supervisory frameworks is found in the agricultural sector, at 93.6%; followed by the industry sector, at 57.2%, and the service sector, at 47.2% (Angel-Urdinola, and Tanabe, 2012; ILO, 2018).

There are two stylised global realities about the fragmented informal sector (Alabi, 2015 ; Chen, 2007). The first is that there are huge income disparities in the informal sector. Employers typically make the most money, followed by employees and other "regular" informal wage workers, then those who operate their accounts, and finally the casual workers (Chen, 2007). Secondly, there is a global trend toward the under-representation of women in lower-level positions and an over-representation of males in upper-level positions. The proportions of men and women in middle-level positions, however, differ among industries and nations. Shown in Figure 1 is a visual representation of these two truths.



Figure 1: Segmentation of the Informal Economy
 Source: (Chen, 2007)

Many urban residents suffer from very tough socio-economic circumstances like congestion, joblessness, accommodation deficiencies, and ‘urbanisation of poverty’ (Tibajuka, 2009). They are, thus, compelled to ‘survive through other means’ (Magidi, 2018) by ‘inventing’ their economy, livelihoods, and occupations (De Soto, 2000). The usage of low machinery, little funds, and inexperienced expertise in informal SMEs activities, gives rise to survival-based strategies, low productivity, and low incomes (Meagher, 1995).

Ekot (2010) and Gulani et al. (2012) researches in Akwa Ibom State and Gombe State, Nigeria respectively, revealed that small enterprises generally face several challenges, including a lack of capital, a lack of enthusiasm among young and educated individuals to start their firms, and inadequate support from the government. There is a general belief that the environmental impact of informal SMEs is insignificant and has less destructive effects, unlike large firms (Sridhar *et al.*, 2018). In reality, however, their overall environmental impact is considerable.

Aguilar (2016) posited that the small and medium-sized enterprises (MSMEs) in India that operate informally do not follow environmental regulations because they do not have the financial resources, expertise, or flexibility to comply with them. They also have difficulty recruiting qualified personnel, little awareness about environmental issues, and less environmental pressure from stakeholders. The concept of sustainability, therefore, anchored this research work.

Concept of Sustainability

Sustainability is the idea of a more stable and equitable society in the present and future (UNESCO, 2017). Sustainability has four cornerstones of economic, social, environmental, and cultural components. Environmental sustainability, the study’s emphasis, involves preserving a steady supply of resources, not depleting the non-renewable resources to the point that insufficient alternatives are invested in, and preventing the over-exploitation of renewable resource systems or environmental sink functions. Ecosystem services such as atmospheric stability and biodiversity preservation are part of the process of environmental sustainability. The environment is an important factor of growth as the supplier and also the sink, so issues like irreversible environmental degradation need to be addressed along with the growth process (Gupta, 2014; Barkemeyer *et al.*, 2014).

SEKEM, a business organisation in Egypt, in 2008 translated its corporate purpose into four pillars of sustainability to form the SEKEM business model. This model served as the standard for managing the day-to-day operations of the firm, evaluating employee performance, and communicating the organisation’s strategic goals. Sustainability Flower, as shown in Figure 2, is the resultant accounting structure that has been applied to the business’s operational tasks since 2008.



Figure 2: The Sustainability Flower and the Four Fields of Life (Economic, Societal, Cultural and Natural Life)
 Source: SEKEM documents adapted from (Gianluca et al., 2019).

The SEKEM's sustainability flower, however, did not sufficiently represent the four pillars of sustainability, because the picture, especially, the physical/natural aspect is a bit complex to comprehend at a glance. The natural life pillar ought to be represented within the framework of the other three sustainability pillars. Nevertheless, the natural life or environment, represented by six components (energy, water, plants, animals, soil and air) are the outer petals, giving an impression that the sustainability flower has nine fields of life. Jiyah (2024), therefore, conceived a model called a 'sustainability polygon' to accurately represent the four pillars of sustainability as shown in Figure 3. Another model of subdivisions of four pillars of sustainability was, similarly, generated from this sustainability polygon (Figure 4).

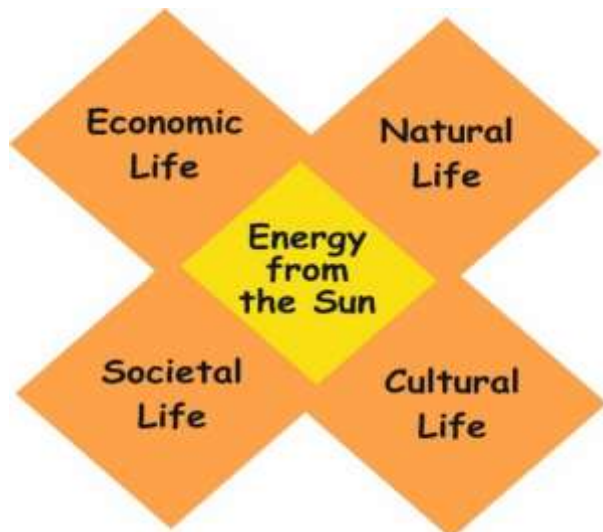


Figure 3: The Sustainability Polygon and the Four Fields of Life
Source: Jiyah (2024)

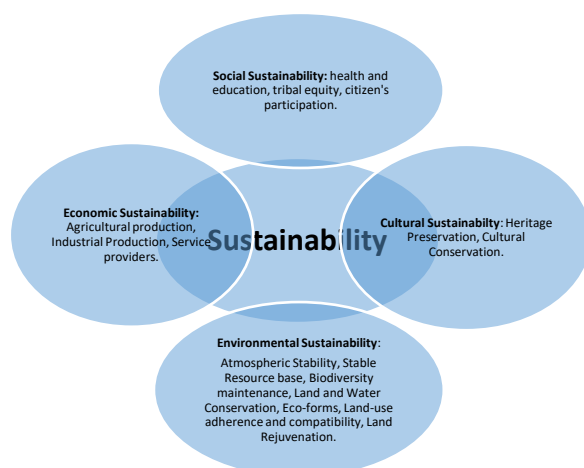


Figure 4: Model of Subdivisions of the Four Pillars of Sustainability
Source: Jiyah (2024)

The idea of sustainable development is often criticised for being unclear, having a difficult time in its measurement and being seen in inconsistent ways. According to Barkemeyer et al. (2014), the Brundtland's emphasis, did not give much attention to the world's poor, and attempts to implement this concept in resolving the current global civilisation challenges have not been wholly successful. This is partly because different countries, politicians, aristocrats and scholars have a controversial interpretation of "justice" and "balance". However, one point of agreement between the followers and the critics of the concept is the belief that the transition to the concept requires a remarkable transformation of the current civilisation.

Environmental Sustainability Indicators

The general sustainability of a community is measured using two major indicators: the environmental (ecological) input and the welfare (well-being) input. The environmental input is emphatic about the state of the air, water, and land, while the welfare input talks about the state of the economy, schooling, well-being, and civil environment of cities (Yannis *et al.*, 2017). Presented in Table 1 are the environmental sustainability indicators and their measurements. However, the study only employed the existing land use and land cover as environmental indicator.

Table 1: Environmental Sustainability Indicators

No	Indicators	Measurement
i	Existing Land use and land cover	Value of land (NL) Built-up area (CH) Built-up area per capita (CH). Increase in land use for housing and transport (DE), agriculture and commercial purposes.
ii	Water quality	In terms of surface water as a result of wastewater from car washes, agricultural farms, block-making industries, cassava processing industries, mechanic workshops, and food vendors
iii	Air quality	Emissions of air pollutants (NH ₃ , NO _x , PM ₁₀ , SO ₂) Air pollutants by type and by economic activity - Air pollutants per capita to examine some aggregated categories of impacts (e.g. acidification, particulate matter, eutrophication, etc.) in association with consumption patterns.
iv	Waste	Household waste (CH) and commercial waste.

Source: Jiyah (2024) adapted from Eurostat (2011)

In the same vein, physical planning is required to coordinate communal and private investment resolutions. Since it is challenging to modify land use after the land is constructed, development needs to be coordinated in advance to avoid incompetent arrangements of development (OECD, 2017). It is an obvious fact that land use influences the environment, public health, economic growth, wealth distribution, social outcomes and the attractiveness of metropolises and cities. Land-use practices have the main penalties for climate change alleviation; it has been connected to roughly one-third of all anthropogenic CO₂ releases. Land use, therefore, affects air pollution and defines whether the cities are walkable or not. In turn, both issues touch public health (OECD, 2017).

Physical Planning Standards Challenges and Commercial Land Use

Urban planners utilise certain methods to ensure that the physical planning standards of urban land use are not compromised. These are through planning tools or instruments. Zoning rules, building bylaws or codes, density limits, land acquisition legislation, and effluent discharge laws are a few of the instruments. Despite the availability of these planning tools, however, the urban poor are regularly forced to contravene the building regulations. The contravention results from extremely high land and building lease/rent costs for commercial use (Oduwaye and Olajide, 2010), the lengthy construction permit application process (UN-Habitat, 2013), and the absence of comprehensive regulatory urban planning. According to Wahab (2023), high administrative fees to obtain a planning permit in Ibadan are encouraging illegal developments. It was revealed that in March 2017, between N70,000 and N100,000 were required to obtain a planning permit for a 3-bedroom bungalow, but by 2023, about N200,000 was required for the same service.

METHODOLOGY

The data for this study were collected from both primary and secondary sources. Secondary data sources include archives, books and journals, and official records from the Niger State Ministry of Housing and Urban Development, and the Ministry of Commerce, Industry, and Cooperatives.

The primary data were obtained through the use of self-developed questionnaires, ground- truth, and the researcher's observation. The quantitative data were analysed using descriptive statistics, while the qualitative data were content-analysed. This research was carried out by examining the level of awareness and conformity of cereal processing mills' owners with the regulations guiding their compliance with urban planning standards on land-use location and zoning. A blend of sustainability concept, and physical planning standards like Vagale (1971), were used as yardsticks to evaluate the activities of cereal processing mills.

The cereal processing mills were purposively selected among other informal SMEs from the 14 neighbourhoods in Bida. This was based on their ubiquity and activities. Moreover, the study covered between 0-500 metres sphere of influence of the cereal processing mills' activities in the neighbourhood.

A cross-sectional survey design using a multi-stage sampling technique was adopted to select samples for the questionnaires. The selection passed through four stages. The first stage involved the selection of Bida and locations of the cereal mills, there were 249 recorded cereal processing mills, spread across the neighbourhoods. In the second stage, the 14 neighbourhoods were alienated into the streets. In the third stage, one main street was randomly selected as a representative for the analysis. Preference was, however, given to streets with the highest density of the cereal processing mills, as observed through satellite imagery and ground-truthing.

A systematic random sampling technique was then used to select the cereal processing mills owners from the sampled streets at the fourth stage. The sampling frame for the cereal processing mills was 249, to accurately justify the sample size, a 24.1% sampling ratio of the sampling frame was used to distribute the questionnaires, since the sampling frame is small. Thus, 60 cereal processing mills were randomly selected for the study.

THE STUDY AREA

Bida is a traditional town and the headquarters of the Bida local government in Niger state, Nigeria (Yahaya, 2002; Ononogbo, 2014; Jiyah, 2015). It is found in the southwest of the Minna, and, located at the junction of the routes from Agaie, Zungeru and Jebba. It connects Ilorin to Minna and Abuja (Mahmud & Umaru, 2018). It was founded on the Bako River, a tributary of the Niger River. Since the Nupe Kingdom's capital is Bida, the Nupe people constitute the majority of the ethnic group. There are numerous districts around Bida, these include Kutigi, Lapai, Agaie, and Mokwa. The emir is in charge of the historic town of Bida.

Bida town's total land area is 1,698 km² with a population size of 266,008 (National Population Commission, 2006). It is situated on latitude 9°05' - 9°07' north and longitude 6°00' - 6°01' east of the equator and experiences discrete dry and wet seasons (Jiyah, 2024). The wet season typically lasts for about 200 days from May to October, while the dry season is between November and April. The town has an average annual rainfall of 1000mm to 1,500mm (Odekunle, 2006). The wet conditions are brought about by the predominance of tropical maritime air masses, while the dry season in Bida is caused by inter-tropical continental air masses. Bida experiences average yearly temperatures, ranging from 26.5°C to 27.8°C, peaking in March and June and falling to its lowest point in December and January (Odekunle, 2006; Odekunle, *et al.*, 2007; Yakubu, 2014; Jiyah and Agbola, 2018).

Bida is the principal point of collection for wetland rice. It also trades in food crops like sugarcane, fruits, onions, yams, rye, millet, shea nuts, peanuts (groundnuts), palm oil, and kernels (Encyclopædia Britannica, 2014). Residential neighbourhoods are often found close to light industries such as blacksmiths and bakeries, as well as quarry sites. From the west, the town has a variety of land uses, including residential, commercial, educational, and industrial land uses. Industrial land use dominates the northern portion of the town, where commercial and residential land uses are also prevalent. Commercial land use is heavily found in the east, while the town's southern region has a mix of commercial, agricultural, educational, and residential land uses (Jiyah, 2015). The Federal Medical Centre, the State General Hospital, the Army Barracks, the Federal Aviation Authority of Nigeria (FAAN), and two polytechnics (the Federal Polytechnic, Bida, and the Niger State Polytechnic, Zungeru extension) are located in Bida. The Nigerian Cereal Research Institute's (NCRI) headquarters are situated in Badeggi, a suburb of Bida, due to Niger state's extensive grain cultivation (Jiyah, 2024). In Figure 1 is displayed the location of Bida in Niger State.

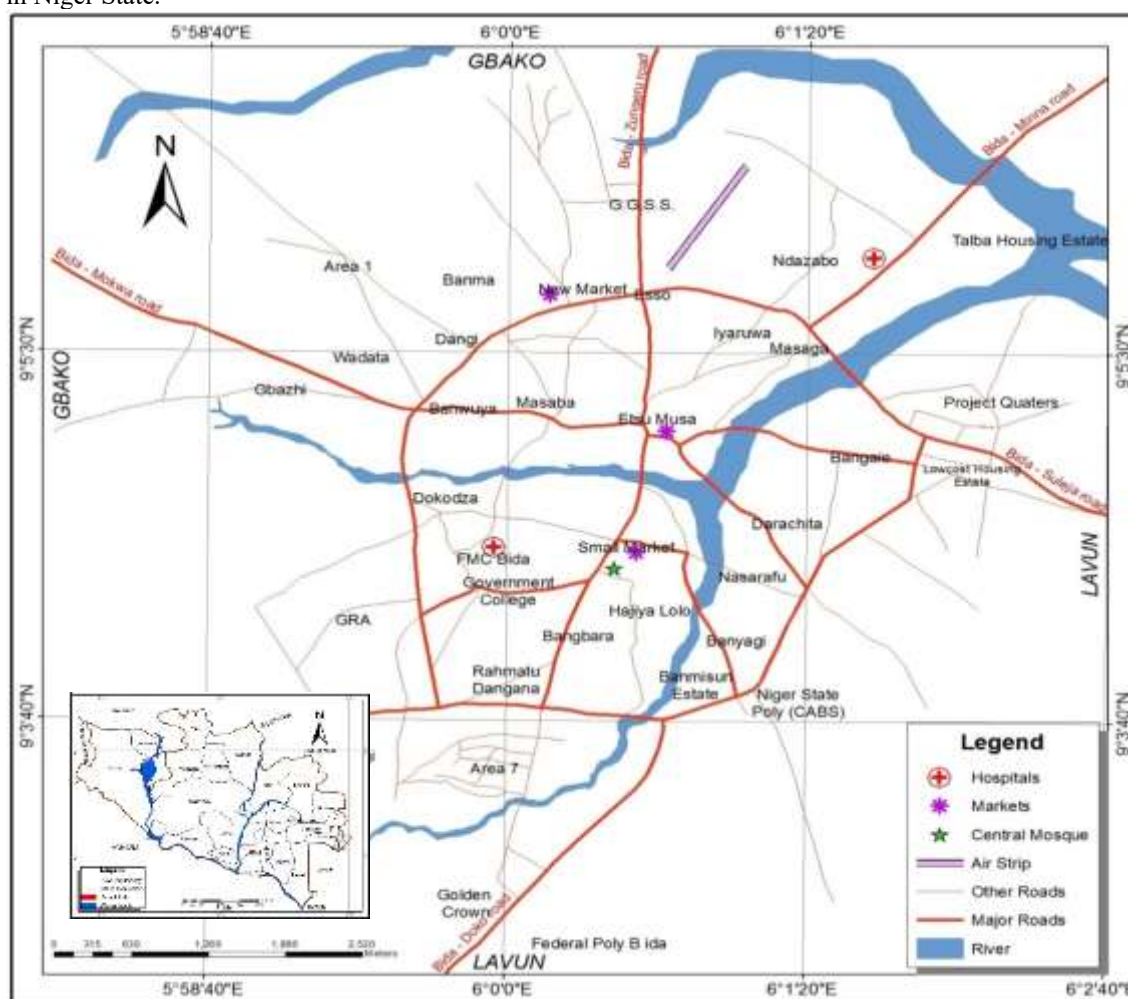


Figure 5: The Location of Bida in Niger State

Source: Niger State Ministry of Lands and Housing, (2015)

RESULTS AND DISCUSSIONS

Socio-Economic Characteristics of Cereal Processing Mills' Owners

The socio-economic characteristics of the cereal processing mills were discussed in this section.

The relevant socio-economic characteristics of the sampled cereal processing mill owners, as presented in Table 2, revealed the gender, age, educational level, and income of cereal processing mill owners. These characteristics were discussed because they are part of the criteria used in defining informal SMEs, as stated by Fisher and Reuber, (2000); Rahman, (2001); Kotane, (2017) and OECD, (2017). The male respondents accounted for 60%, while the female respondents accounted for 40%. This indicated that more males engaged in cereal processing mill activities and so dominated the cereal processing mills in Bida.

This finding confirmed the diagram of segmentation in the informal economy by Chen (2007), which showed that around the world, men tend to be over-represented in the top segment of the informal economy. Consequently, Orr's 1992 opinion of enabling conditions like more investment in human capital and empowerment of women for environmental quality needs to be encouraged in Bida.

The age composition of the respondents indicated that the highest number of respondents (33.3%) were in the 48–57 years age bracket, with a mean value of 43.0 ± 3.5 years. Next to it was the 38–47 age cadre, with 23.3% and 18.3% of the respondents falling within the 28–37 years age gap. This connotes that the majority of cereal processing mill owners were of active age. They therefore maximised their potentials in the business activities they engaged in, confirming the findings of the OECD, (2019).

The education status of the cereal processing mills' owners presented also in Table 2 revealed that a greater percentage of the owners were literate. University degree and higher national diploma degree holders accounted for 26.7%; the ordinary diplomas and national certificates of education holders was 21.7%; a 20.0% of the respondents had secondary school certificates; and 8.3% had higher degree certificates. Only a small percentage of the respondents (5.0%) had primary school education, while another 10.0% were attributed to being professionals who learned their skills without formal primary education. Other percentages include cereal processing mill owners with multiple certificates. This implies that many cereal processing mills' owners likely know the environmental impact of their cereal processing mills. They might also be operating legally in terms of their registration and financial obligations to the state. Since many of these mills' owners were educated, their entrance into the business could be to carry on the family business. It might also be a way of reducing poverty (Tibaijuka, 2009), and improving their quality of life, as affirmed by Angel-Urdinola and Tanabe, (2012); De Soto, (2000); and Magidi, (2018). These affirmations were contrary to the researchers' initial assumption that the entry point for informal SMEs is illiteracy.

The question on monthly income revealed that 28.3% of the cereal processing mills owners, which constituted the greater percentage made between ₦101,000 and ₦150,000 per month, and 21.7% of the respondents made between ₦151,000 and ₦200,000 per month. The result agreed with Meagher's (1995) assertion of informal SMEs' low-income feature. Similarly, the category of respondents who were making over ₦250,000 per month was 30.0%. The cereal processing mills owners who made between ₦201,000 and ₦250,000 per month constituted the lowest percentage of 20.0%. This finding indicated that many of the respondents met Nwokoye's (1988) requirement on the definition of informal SMEs as having an annual turnover of ₦400,000 only.

This study, like the studies of Ekot (2010) and Gulani *et al.* (2012), observed a scarcity of funds, young and educated people's interest in small businesses, and poor government support for cereal processing mills.

Table 2: Socio-Economic Characteristics of the Cereal Processing Mills' Owners

Variables	No of Respondents	Percentage
Cereal Mill Type		
Millet & Sorghum	14	23.3
Rice Mill	12	20
Corn/Maize Mill	15	25
Wheat	9	15
Others	10	16.7
Total	60	100
Gender		
Female	24	40
Male	36	60
Total	60	100
Age (years)		
18 – 27	7	11.7
28 – 37	11	18.3
38 – 47	20	33.3
48 – 57	14	23.3
58 – 67	8	13.3
Total	60	100
Education		
Primary	3	5.0
Secondary	12	20.0
ND/COE	13	21.7
HND/Degree	16	26.7
Higher Degree	5	8.3
Professional	6	10
Others	5	8.3
Total	60	100
Monthly Income		
₦101,000- ₦150,000	17	28.3
₦151,000- ₦200,000	13	21.7
₦201,000- ₦250,000	12	20.0
₦251,000 and above	18	30.0
Total	60	100

Source: Author's Fieldwork (2023) * Note: N= 60

Physical Planning Legislation on Commercial Land Use and Informal SMEs Activities in Niger State

The siting of informal SMEs in a location is expected to take land use compatibility into consideration. This is to ensure harmonious coexistence and an aesthetic outlook for the environment. It is, therefore, essential to document the laid-down planning parameters and space standards for various land uses in Niger State. This is considered important, especially for those land uses where informal SMEs are primarily located, to seek amends in areas where applicable.

The legal and legislative instruments that relate to urban development and management are the Land Use Act/Decree of 1978; the Nigerian Urban and Regional Planning (NURP) Act of 1992, and the Niger State Urban Development Board (NSUDB) Edict of 1999. Others include the Niger State Geographic Information Systems Agency Law of 2013; and the National Environmental Standards and Regulations Enforcement Agency (Establishment) Act of 2007. Some of the policy instruments put in place in Niger State to execute these laws and direct the affairs of the state are the National Urban Development Policy (2012), the National Housing Policy (2012), Niger State Vision 3:2020, and Niger State Blue Print 2015-2019. One of the objectives of the urban policy is to promote local economic development (LED) in all major towns and urban centres in the state.

The Land Use Act/Decree of 1978 was promulgated to facilitate easy access to land for development projects. The Act regulates the ownership, alienation, acquisition, administration, and management of land across Nigeria. Section 5(1) of the Act authorises the Governor of a State to give a constitutional right of occupancy to any individual in an urban area of the state. Challenges associated with access to land have been attributed to operational details contained in the law.

The Nigerian Urban and Regional Planning Act of 1992, likewise, spelled out the responsibilities of each of the three tiers of government. It also stipulates the types of plans to be prepared at each level. It is, nevertheless, not completely implemented, as many states in Nigeria do not have physical planning institutions, especially at the local government levels.

Niger State Urban Development Board Edict No. 3 of 1999 was also established to undertake urban and regional planning in all urban centres of the state. The edict has not been revised, and some of its provisions are considered outdated. This limits the effectiveness of the body saddled with its implementation. The functions of the Board include development control, issuance of building and development plan permits, open-air advertising, and telecom masts and tower licenses. Other duties of the Board include creating and developing serviced layouts, planning and implementing urban redevelopment schemes, and preserving monuments and other historical and architecturally significant buildings.

The Niger State Geographic Information Systems Agency Law 2013 was equally established to coordinate and enhance land use administration and documentation processes. The agency is in charge of issuing land titles and registration of land instruments, among others.

However, Niger State Urban Development Board (NSUDB) (Edict No. 3 of 1999) laws are the major instrument for its development permit and approval. It also adopts all the planning standards from Vagale (1971) and Obateru (2003). Thus, there is, an urgent need for regularisation to have uniform national planning standards that blend with our traditions.

Conformity of the Cereal Processing Mills to Physical Planning Legislation and Planning Approval in Bida

The field analysis on the distance of cereal processing mills to access roads showed that there was no conformity with the Vagale (1971) space standard for commercial land use, as shown in Figure 6. The distance of the cereal processing mills to access roads was comparatively less than the recommended setbacks in all types of road networks. 43.2% of the mills were located on a plot of land that was less than one metre as a setback to the access road, and 18.2% were between 1-3 metres and 4-6 metres, respectively. Another 9.1% was located between 7-9 metres. Only 11.4% of the total respondents had their mills located at a distance of 10 metres and above from the access road. This was the percentage that met the required minimum setback of 12 metres for the access road, 15 metres for the collector road, 18 metres for the major road, and a 24-metre standard for the highway setback.

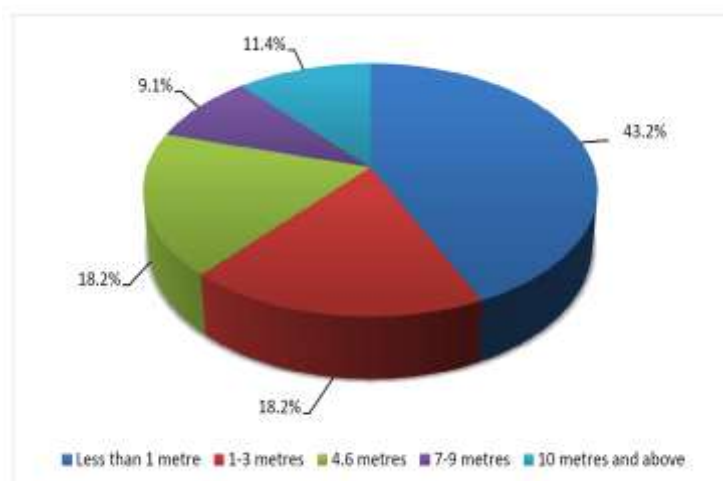


Figure 6: Distance of Cereal Processing Mills to Access Road

Source: Author's Fieldwork (2023)

The distance decay effect of the cereal processing mills' activities on the residents is revealed in Figure 7. The cereal processing mills that located at a distance of between 0-10 metres from residence were 40.90%, a 36.80% of the mills were at a distance of 11-20 metres while a small percentage of 1.20% of the mills were sited around 100 metres away from residence. Significantly, the effect of the effluent generated by the mills will be mostly felt among the residents living between 0-10 metres and 11-20 metres range of the cereal processing mills. The cereal processing mills' locations in Bida contradicted Vagale's (78) percentage area of 4.5% to 6.5% devoted to commercial development in a large town of over 250,000 population as obtained in the study area.

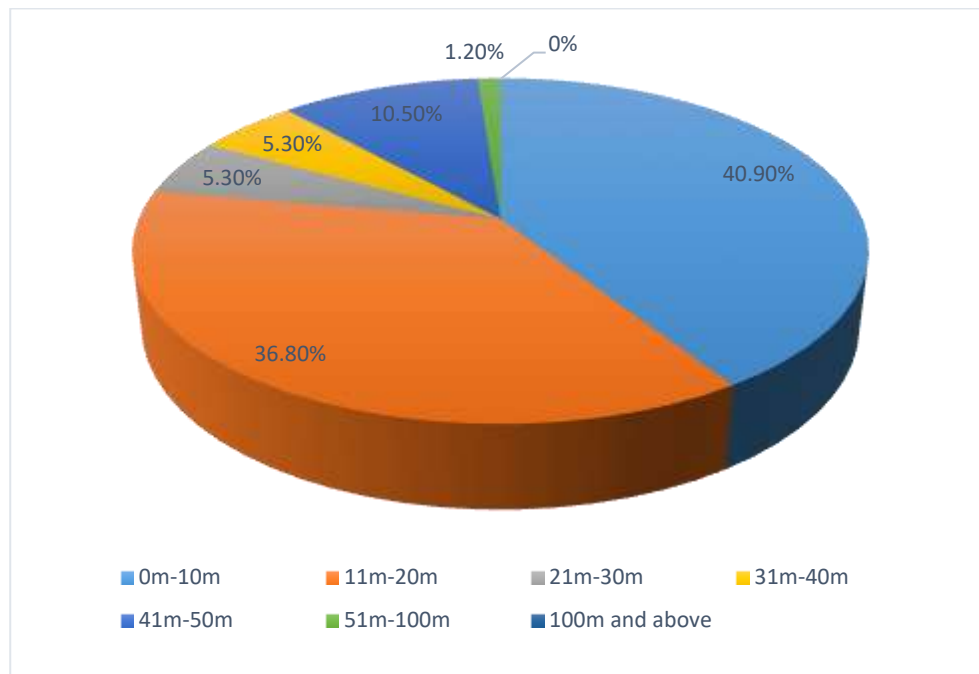


Figure 7: Distance of Cereal Processing Mills to the Closest Residence
Source: Author's Fieldwork (2023)

The observed planning parameters in the cereal processing mills' locations in the study area are indicated in Table 3. Only 36.67% of the cereal processing mills had planning approval for their locations. This could be because of very high rent/lease charges on buildings and land spaces for commercial purposes, as indicated by Oduwaye and Olajide, (2010) and Wahab, (2023), or the cumbersome procedures to obtain building permits (UN-Habitat, 2013). In Figure 8 is shown one of the cereal processing mills, located along a collector road.

Table 3: Planning Parameters in Cereal Processing Mills' Location

Percentage of Plot Built up area	No. of Respondents	Per cent
Less than 20%	7	11.7
21-40%	6	10
41-60%	11	18.3
61-80	11	18.3
81-100	25	41.7
Total	60	100
Water Provider to the Cereal Processing Mills		
Government	10	16.7
Community	13	21.7
Individual	37	61.6
Total	60	100
Planning Approval for the Cereal Processing Mills		
Yes	22	36.67
No	38	63.33
Total	60	100

Source: Author's Fieldwork (2023)



Figure 8: One of the Cereal Processing Mills in Government Reservation Area (GRA)

Source: Author's Fieldwork (2023)

However, the recommended setbacks for commercial land use can be seen in Table 4. Many of the cereal mills maximised the use of their space by building up almost all the space on their plot. The cereal mill owners were aware of the environmental issues created by their activities, however, there was little or no environmental pressure from stakeholders validating Aguilar (2016). The recommended setbacks on commercial land use by Vagale (1971) and the actual setbacks obtained from the researcher's fieldwork are revealed in Table 4.

Many of the cereal processing mills had less than a 1-metre setback on the collector street. This is against the recommended 12–14 metres for the collector street setback for markets, departmental stores, and commercial establishments (Vagale, 1971; Obateru, 2003; Oyo State Ministry of Physical Planning and Urban Development, 2014). However, convenience shops are not expected to be located on the distributor and collector's streets (Vagale, 1971).

Table 4: Recommended and Actual Setbacks of Commercial Property Line from Centre-lines of Abutting Streets in Niger State

No.	Types of Commercial Development	Recommended Setback in metres			Actual Setbacks from fieldwork (Metres)
		Distributor Street	Collector Street	Local/Access Street	Obtained/Actual
1.	Convenience shops	-	-	10.6 – 12	1-3
2.	Markets	-	12 – 14	10.6 – 12	4-6
3.	Department stores	15 – 18	12 – 14	10.6 – 12	8-10
4.	Commercial Establishments	15 – 18	12 – 14	-	< 1
5.	Banks	15 – 18	12 – 14	-	12-14

Source: (Vagale, 1971, Obateru, 2003, Oyo State Ministry of Physical Planning and Urban Development, 2014, and, Author's Fieldwork (2023))

Conclusion

The research work revealed that the generality of cereal processing mills in Bida were not well planned according to the existing physical planning legislation and policies guiding commercial land-use in Niger state. This is because of the over-utilisation of the air space and the standard setbacks.

Policy Implication and Practical Recommendations

Proliferation of incongruous activities by the erection of informal structures that house the cereal processing mills along major roads was due to high administrative charges for planning approval. This has led to noise pollution, traffic congestion, on-street parking, and, air pollution.

1. The high administrative fees charged to obtain planning permits should, thus, be reviewed to accommodate the poor in urban areas. It will afford them the privilege of obtaining development permits and automatically rightly locate their businesses. This will minimise encroachment on access roads, change in land use without planning approvals, and non-compliance with the relevant planning laws on zoning. The government will also be saved the cost of the demolition of buildings that are not properly place in space.
2. The owners of cereal processing mills should, also, be educated on the need to give setbacks in their work environment to allow for safety in unforeseen circumstances.
3. There should be a uniform national physical planning standard for all land use activities.

4. The setback of industrial and commercial land use in the state can be adjusted by the government for overriding public interest in urban planning, as stressed by the Land Use Act of 1978.

This is by adopting a feasible standard for inclusive land use planning that is in tune with contemporary realities. The author, consequently, reviews the setbacks of industrial and commercial land uses from the road centre lines to the property line to avail more spaces from the fallow spaces for economic activities. This is represented in Table 5.

Table 5: Recommended Feasible Setback of Industrial and Commercial Property Lines from Centre-Lines on Roads.

Type of Road	Minimum	Setback in Metres	
		Desirable	Feasible
Highway	24	30	20.5
Major Road	18	21	13.5
Collector Road	15	18	10.7
Access Street	12	15	9.5

Source: Author's Fieldwork (2023) modified from Vagale (1971)

Presented in Figure 9 is the proposed collector road setback. It is 10.7 metres. The setback was arrived at by summing up 5.7 metres, the length of a pick-up van in the navigation of the road with 3.5 metres, the road width from the centre line of the collector road (half of the 7 metres collector road width) and an additional distance of 1.5 metres to the property line.

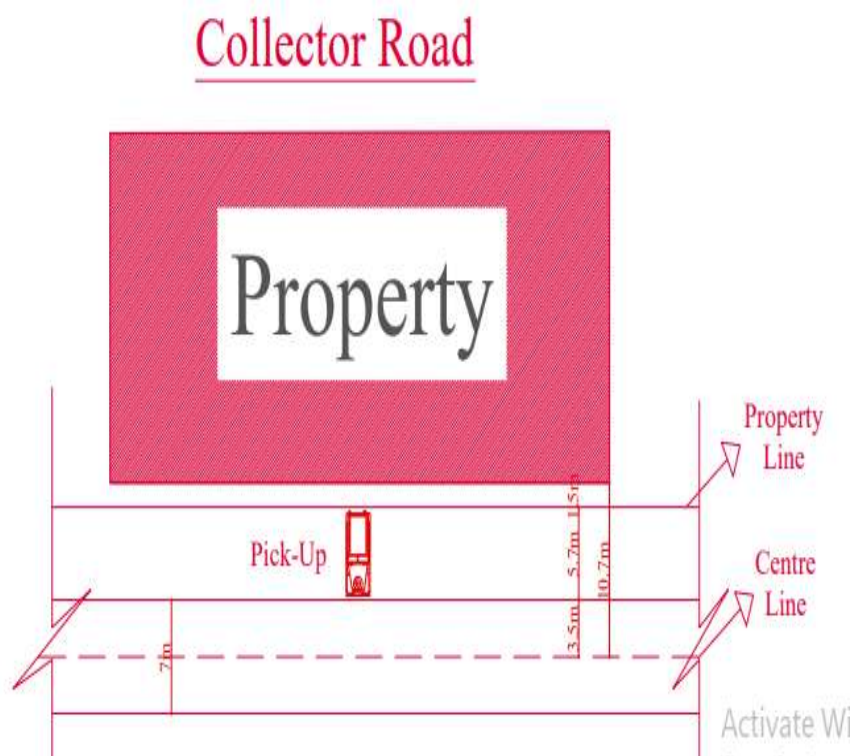


Figure 9: The Proposed Collector Road Setback for Industrial/Commercial Property Line from Road Centre Line.

Source: Author's Fieldwork (2024)

With this proposal, an extra space of 4.3 metres and 7.3 metres can, therefore, be annexed from the standard minimum setback of 15 metres and the desirable setback of 18 metres for additional economic purposes.

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Enhancing Passenger Navigation through Effective Wayfinding Strategies in Railway Stations

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ABSTRACT

Efficient passenger navigation plays a vital role in shaping the usability and sustainability of public transport infrastructure. However, many railway stations in Nigeria present significant challenges due to poor spatial organization, unclear signage, and limited accessibility. This research explores the integration of wayfinding strategies in the proposed design of a light railway station connecting Minna to Abuja. The study employs a qualitative, user-centered approach using case-study analysis, space syntax, and mobile ethnography to examine how intuitive design influences user experience. Notable international stations such as Utrecht Central (Netherlands), Grand Central Terminal (USA), and Kenitra Station (Morocco) are referenced to identify best practices. Findings reveal key factors influencing efficient navigation, including spatial clarity, use of visual landmarks, and multi lingual signage. In response, the proposed Minna–Abuja station design incorporates a central concourse, tactile pathways, and bilingual signs (English and Hausa) to support inclusive access for all user groups. By aligning architectural planning with behavioural patterns and user needs, the project contributes to the development of responsive, inclusive infrastructure that supports Nigeria's urban transformation goals. This paper advocates for human-centered solutions that can guide the evolution of rail systems into more accessible and sustainable environments.

Keywords: Wayfinding, Light Rail, Urban Infrastructure, Sustainable Design, Passenger Navigation

INTRODUCTION

Transportation hubs, such as railway stations, are critical infrastructures that facilitate mobility, enhance economic growth, and serve as gateways to cities. Effective wayfinding strategies play an essential role in improving passenger experience by ensuring efficient navigation and reducing stress, especially in complex and high-traffic environments. Railway transportation is widely regarded as one of the most reliable, convenient, and efficient modes of urban and regional transportation. It is also a sustainable means of mass transit, making it a priority for many countries aiming to reduce road congestion and enhance connectivity between urban and peri-urban centres. In Nigeria, the railway sector is witnessing renewed attention as part of the government's efforts to modernize infrastructure and promote regional integration.

Minna, the capital of Niger State, has historically served as a strategic transportation hub due to its location linking northern and southern regions of the country. However, its existing railway station has remained largely inactive for years, limiting its potential in addressing rising transportation needs (Oyesiku & Oduwaye, 2015). With the recent proposal by the Niger State Government to establish a light rail system connecting Minna to Abuja, there is a timely opportunity to rethink and redesign the Minna railway station as a modern, functional, and passenger-friendly facility. Globally, the quality of railway stations is judged not only by operational efficiency but also by the overall passenger experience. Studies have shown that passenger expectations are often rooted in three fundamental dimensions: safety and reliability, speed, and ease of navigation. Meeting these core expectations is essential in avoiding dissatisfaction, while also enabling a more pleasant and comfortable travel experience through good station design, intuitive circulation, and visual clarity (Hagen and Oort, 2019).

The current lack of adequate wayfinding systems at many Nigerian train stations including Minna has led to issues such as confusion, delays, and inefficient passenger flow. In light of the proposed Minna to Abuja light rail corridor, incorporating effective wayfinding strategies such as clear directional signage, user centered spatial organization, and digital navigation tools becomes not only necessary but central to the success of the project. A well-designed wayfinding system will ensure that all passengers including first-time users, the elderly, and people with disabilities can navigate the station with ease, thereby enhancing the overall travel experience.

This study therefore focuses on the integration of wayfinding strategies into the design of a modern light railway station in Minna, to support the proposed connection to Abuja. The goal is to create a seamless, inclusive, and intuitive transit environment that aligns with global best practices while responding to local needs.

METHODOLOGY

Study Area

The area of study is Minna, the capital city of Niger State, located in the north-central region of Nigeria. Minna serves as a strategic link between the northern and southern parts of the country and plays a vital role in regional transportation. The city is situated approximately 150 kilometers from Abuja, the Federal Capital Territory (FCT), making it a potential satellite city for workers commuting to Abuja. Minna has a mix of administrative, residential, and commercial zones, and is home to several public institutions and infrastructure assets. However, its current railway station facilities are underdeveloped and lack modern passenger-oriented features, including effective wayfinding systems. The proposed Minna–Abuja light railway corridor offers a unique opportunity to redesign the Minna station as a modern, efficient, and user-friendly terminal that meets international standards.

Research Design

This study adopts an empirical research design, as it is grounded in observable and measurable phenomena rather than abstract theories. Empirical research relies on data derived from actual experience, observation, and documented evidence (Carpman & Grant, 2001). In this context, the design of a railway station with effective wayfinding strategies is informed by the lived experiences of passengers, observations from existing stations, and case study comparisons. The researcher seeks to precisely explain the interaction between users and their built environment, acknowledging that passengers are life experts whose daily experiences provide valuable insight into spatial navigation challenges. The target population for this study comprises residents of Minna and Abuja who regularly interact with railway transport infrastructure, as well as users of contemporary quasi-public facilities such as airports and bus terminals. However, to streamline this broad population, sampling predictors drawn from literature and previous studies on passenger navigation (Hagen & Oort, 2019) are applied. These predictors emphasize user groups most affected by wayfinding challenges, including first-time travelers, persons with disabilities, and elderly passengers. The geographical scope focuses on Minna, the capital of Niger State, which lies approximately between latitudes 9°31'N to 9°40'N and longitudes 6°26'E to 6°33'E (NPC, 2022). Minna was selected due to its exposure to modern trends in architectural form and rapid urbanization, both of which influence passenger expectations of transport hubs. Additionally, its proximity to Abuja makes it a strategic location for the proposed light rail system. The research design therefore combines literature-based inquiry, observational analysis, and case study comparison, which together provide both theoretical grounding and practical validation. This triangulation ensures that the proposed design for the Minna–Abuja Light Railway Station is responsive, user-centered, and contextually relevant. The design relies on a mix of case studies, document reviews, and observational analysis. By studying both Nigerian and international railway stations, and by reviewing reports and standards, the research identifies common challenges and best practices. These insights are then translated into design principles that directly inform the proposal for the Minna–Abuja Light Railway Station.

Source of Data

Primary Data

The primary data for this study were collected through field surveys and structured observations at selected railway stations in Nigeria, including Idu, Rigasa, Ilorin, Minna, and the Mobolaji Johnson Railway Station in Lagos. These stations were chosen because they represent different scales, design eras, and operational contexts, making them useful for comparative analysis. Observations focused on passenger movement patterns, signage placement, accessibility features, circulation efficiency, and wayfinding challenges. In addition, questionnaires and informal interviews were conducted with passengers and station staff to capture user perspectives on navigation difficulties, service efficiency, and spatial comfort. This allowed the study to balance physical evidence with the lived experiences of actual users. The collection of this data provided firsthand insights that directly shaped the wayfinding strategies proposed for the Minna–Abuja Light Railway Station.

Secondary Data

Secondary data were sourced from academic literature, policy documents, and case study archives. Relevant books and journal articles on wayfinding (Arthur & Passini, 2002) provided the theoretical foundation, while international case studies such as Utrecht Centraal, Taiyuan South, Grand Central Terminal, and Kenitra Train Station offered practical benchmarks for modern station design. Reports from the Nigerian Railway Corporation (NRC), the Federal Ministry of Transport (FMoT), and project documents from the China Civil Engineering Construction Corporation (CCECC) were reviewed to understand the current state of Nigerian rail infrastructure. In addition, national guidelines such as the National Building Code (2006) and the Urban and Regional Planning Law (1992) were consulted to ensure regulatory compliance. Maps, photographs, and visual references were also obtained from government offices, professional publications, and online architectural databases such as ArchDaily and Jidipi.

Population of the Study and Sample Frame

The population for this study comprises railway stations and transport facilities that reflect different scales of operation, architectural design, and passenger use in Nigeria. From this population, a purposive sample of five railway stations within Nigeria; namely Idu (Abuja), Rigasa (Kaduna), Ilorin, Minna, and Mobolaji Johnson (Lagos) were selected for field observation and analysis. These stations were chosen because they represent both older and modern designs, allowing for comparative evaluation of wayfinding challenges and strategies. In addition, four international case studies Utrecht Centraal (Netherlands), Taiyuan South (China), Grand Central Terminal (USA), and Kenitra Train Station (Morocco) were examined through secondary data sources. These were included to provide global benchmarks and best practices in railway station design. A structured observation schedule was employed at the Nigerian stations to evaluate architectural design elements, passenger flow, signage systems, and accessibility features. To complement this, 250 questionnaires were administered to passengers and staff at the selected stations, with 200 valid responses retrieved, representing an 80% response rate. The sample size was determined using Morgan's Table of Sample Size Determination, ensuring that the data collected was representative of the study population. The sample frame therefore balances both local field data and international

reference cases, enabling the study to generate contextually relevant yet globally informed wayfinding strategies for the proposed Minna–Abuja Light Railway Station.

Data Collection Instrument

Visual Survey

A visual survey was conducted to capture existing conditions and design features in selected railway stations. According to Creswell (2014), visual surveys allow researchers to generalize from samples to populations by drawing conclusions about physical environments based on observed attributes. In this study, photographs were taken at Nigerian railway stations such as Idu, Rigasa, Minna, Ilorin, and Mobolaji Johnson to document spatial layouts, signage systems, circulation paths, and accessibility provisions. These visual records helped the researcher assess how wayfinding principles are currently applied in Nigerian railway stations.

Questionnaire

A descriptive survey was carried out using structured questionnaires. The goal was to understand how passengers and station staff perceive wayfinding elements such as signage clarity, circulation efficiency, and spatial orientation. Questionnaires were distributed at the Nigerian stations under study, and the responses provided insight into user experiences, challenges, and expectations. The data obtained were categorized, tabulated, and later analyzed to highlight recurring patterns in passenger navigation.

Interviews

Interviews were also conducted to gather deeper insights. Interviewing, simply put, is a guided conversation with a purpose. In this study, semi-structured interviews were used, allowing for flexibility while keeping discussions focused on wayfinding challenges. Passengers, railway staff, and station managers were interviewed about their navigation experiences, difficulties faced by first-time users, and recommendations for improving passenger flow. This approach ensured that the information collected reflected both professional and user perspectives.

Case Study Selection Criteria

Case studies were chosen based on purposive sampling guided by the following criteria:

1. Level of Patronage: Stations with significant passenger traffic were prioritized, since wayfinding challenges are most evident where volumes are high.
2. Geographical Scope: Nigerian stations within the study area (Abuja, Minna, Kaduna, Ilorin, Lagos) were selected to reflect local realities.
3. Purpose-Built: Only purpose-built railway stations were included, ensuring that findings were drawn from facilities designed specifically for rail transport rather than retrofitted structures.

Method of Data Collection

Data were obtained from both primary and secondary sources. Primary data came from field surveys, questionnaires, observations, and interviews at selected Nigerian railway stations. A total of 250 questionnaires were administered, with 200 valid responses retrieved, representing an 80% return rate. Structured observation schedules were also used, with each focusing on architectural elements, signage, circulation paths, and accessibility features. Secondary data were gathered through books, journals, conference papers, professional websites, and government documents.

Method of Data Analysis and Presentation

The data collected were analyzed using both descriptive and inferential techniques. Descriptive statistics such as frequency counts and percentages were used to show trends in passenger responses to questionnaires. Visual and observational data were organized into tables and charts to highlight recurring patterns in signage use, circulation challenges, and accessibility features. Inferential statistics, such as the chi-square test, were considered where necessary to establish relationships between passenger demographics (such as age or travel frequency) and wayfinding challenges.

RESULTS

Case Study One: Idu Railway Station, Abuja

The Idu Railway Station in Abuja stands as one of Nigeria's most significant transportation hubs, serving as the main interchange between the Abuja–Kaduna standard gauge railway and the Abuja Light Rail system. Commissioned in 2016 for the intercity line and expanded in 2018 to integrate with the light rail network, Idu has become a vital link for millions of passengers traveling within and outside the Federal Capital Territory. According to operational records, the Abuja–Kaduna line alone has transported over 6.5 million passengers since inception, a figure that underlines the station's critical role in regional mobility. Its importance was further recognized in 2021 when the Federal Government officially named the facility after Amina Mohammed, the United Nations Deputy Secretary-General, as a symbol of national pride and international relevance.

Site Planning and Landscaping

Strategically located in Idu's industrial district, the station benefits from proximity to industrial facilities, new residential developments, and key road networks. The site planning ensures seamless intermodal integration, allowing passengers to connect efficiently between the standard gauge railway, the city's light rail, and the Nnamdi Azikiwe International Airport. This connectivity is enhanced by its three-dimensional transport network, which caters not only

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to commuters but also to industrial logistics and visitors arriving from other parts of the country. The landscaping around the station is simple but functional, with clear access roads, defined pedestrian zones, and space provision for taxi ranks and drop-off points.



Aerial view of Idu Railway Station showing integration with Abuja Light Rail and airport link

Spatial Organization and Design

Architecturally, Idu Railway Station has often been described as an “architectural showpiece” for Nigeria’s rail modernization programme. The building presents a clean, orderly layout with wide circulation spaces, well-marked passenger halls, and clear separation of operational zones from public areas. Facilities such as the Rolling Stock Depot, Operations Control Centre, and dedicated signal rooms are integrated into the complex, ensuring that operational management is efficient and well-coordinated. The spatial organization prioritizes ease of movement, with direct sightlines from the entrance to the ticketing counters and onward to the platforms, making navigation relatively straightforward for passengers.



Interior concourse of Idu Railway Station with direct sightlines from entrance to platforms

Materials and Finishes

In terms of materials and finishes, the station reflects contemporary construction standards, with durable floor finishes, wide glass facades for natural lighting, and metallic cladding for weather resistance. Upon opening, the interiors were noted for their cleanliness and modern appeal, although subsequent reports have highlighted the importance of consistent maintenance. For example, both lifts and escalators fell into disrepair within a few years but were later restored following ministerial intervention, a sign that while the infrastructure is modern, ongoing upkeep is essential for sustaining operational quality.



Exterior façade of Idu Railway Station featuring glass curtain walls and metallic cladding

Source: NRC (2021)

Relevance to Wayfinding Strategy

For the purpose of wayfinding strategy development, Idu Railway Station offers several lessons. Its strong architectural identity can act as a visual landmark, aiding spatial orientation for first time users. The station's efficient circulation patterns and direct connections to multiple transport modes demonstrate how clear spatial organization can minimize navigation errors. At the same time, the shortcomings, particularly poor nighttime lighting illustrate that even the best wayfinding systems must operate within a safe, well-lit environment to be effective. By combining its architectural strengths with consistent maintenance and enhanced lighting, Idu Railway Station could stand as a model for the kind of passenger-friendly, intuitive rail terminal that the proposed Minna–Abuja Light Rail Station aspires to achieve.

Case Study Two: Rigasa Railway Station, Kaduna

Rigasa Railway Station, located on the outskirts of Kaduna in the Rigasa district, is the northern terminus of the Abuja–Kaduna standard gauge railway. Commissioned in 2016 alongside the Idu–Kaduna line, the station was developed as part of the Nigerian government's push to modernize rail infrastructure and improve intercity connectivity. It plays a vital role in linking northern Nigeria to the Federal Capital Territory, serving thousands of passengers daily. As the final stop on the line, Rigasa functions not only as a passenger terminal but also as a symbolic gateway between northern and central Nigeria.

Site Planning and Landscaping

The station is situated in an open, peri-urban setting surrounded by low density residential areas and pockets of commercial activity. Its location was chosen for accessibility from Kaduna city while avoiding the congestion of the central business district. The site layout accommodates road access from the Kaduna–Abuja expressway, a drop off and pick-up zone for private vehicles and taxis, and parking facilities. Landscaping is minimal, with limited green spaces, reflecting a functional rather than ornamental approach. Paved walkways connect the entrance to the platforms, while security fencing defines the station's perimeter.



Aerial perspective of Rigasa Railway Station and surrounding peri-urban environment

Source: Google Earth (2025)

Spatial Organization and Design

Rigasa Station's design follows a straightforward, utilitarian approach aimed at functionality and ease of maintenance. The building houses a main entrance hall that leads to ticketing counters, security screening points, and passenger waiting areas. From the concourse, passengers proceed directly to the platforms, which are covered by steel canopies to protect from sun and rain. While the interior is functional, the circulation space can become congested during peak

hours due to the high passenger demand, especially on Mondays, Fridays, and festive periods. The station's layout, although relatively simple, could benefit from more distinct zoning for arrivals and departures to reduce crowding at critical points.



Covered platform area at Rigasa Railway Station

Source: Author's fieldwork (2025)

Materials and Finishes

The station is constructed with reinforced concrete and steel, with tiled flooring in passenger areas and metal roofing for the platform canopies. Walls are painted in light, neutral colors to reflect natural light, while glazing along the façade allows daylight into the main hall. Seating in the waiting areas is made of metal benches designed for durability, though their comfort level is limited. Signage within the station is basic, with English text and occasional pictograms, but lacks the bilingual provision that would cater to Hausa-speaking passengers more effectively.

Relevance to Wayfinding Strategy

Rigasa Railway Station offers important lessons for the proposed Minna–Abuja Light Rail Station. Its simple layout demonstrates how clear sightlines and straightforward circulation paths can help passengers move efficiently, even in the absence of advanced navigation technology. However, its shortcomings particularly in signage clarity, bilingual communication, and congestion management highlight the need for more sophisticated wayfinding systems in future station designs. For Minna, this means integrating multilingual signage, digital information displays, and spatial zoning to separate arriving and departing flows. Ensuring seamless links with other transport modes, such as buses and taxis, will also be critical in avoiding the connectivity gaps observed at Rigasa.

Case Study Three: Mobolaji Johnson Railway Station, Lagos

Mobolaji Johnson Railway Station, also known as Ebute Metta Station, is the principal rail terminus in Lagos and the largest in West Africa, with a capacity to hold approximately 6,000 passengers. Commissioned on June 10, 2021, it replaced the older Lagos Terminus (Ido) and serves as the new flagship station for the Lagos–Ibadan standard gauge corridor (NRC, 2021).

Site Planning and Landscaping

Strategically located in Ebute Metta, the station anchors the Lagos–Ibadan rail corridor and connects Lagos mainland with major southwestern routes. Its proximity to key urban landmarks including the National Stadium and Tejuosho Market positions it as a vital node in the city's transit fabric (FMoT, 2021). The forecourt includes paved access roads, designated parking, and drop off zones, with security fencing to control entry. Landscaping is modest but functional, prioritizing clear vehicular and pedestrian circulation.



Aerial view of Mobolaji Johnson Railway Station showing Ebute Metta location and urban context

Source: Google Earth (2025)

Spatial Organization and Design

The modern design comprises two main buildings straddling the railway tracks and linked via over-track pedestrian bridges. The front building houses ticketing counters and security control points, while the rear contains spacious, air-conditioned waiting halls (NRC, 2021). Accessibility features include lifts, level boarding platforms, and Braille signage, ensuring inclusivity for all passenger categories (ADA, 2010). Digital display boards provide real-time travel information, while circulation spaces are arranged to minimize congestion and support intuitive navigation.



Aerial view of Mobolaji Johnson Railway Station showing Ebute Metta location and urban context Of the Platform

Materials and Finishes

The station features modern finishes that convey an “airport-style” standard expansive glass facades admit natural light, durable tiled floors support heavy foot traffic, and suspended ceilings conceal lighting and mechanical systems. Interiors are finished in neutral tones, providing a clean backdrop for wayfinding signage (FMoT, 2021).



Exterior façade of Mobolaji Johnson Railway Station with glass curtain wall design

Source: NRC (2021)

Relevance to Wayfinding Strategy

Mobolaji Johnson Railway Station demonstrates how modern station design can integrate wayfinding principles through spatial clarity, functional zoning, and inclusive features. The separation of ticketing, security, and waiting areas reduces disorientation, while accessibility provisions such as lifts, tactile paving, and bilingual signage cater to a diverse passenger base. For the proposed Minna–Abuja Light Rail Station, adopting a similarly structured layout, coupled with consistent maintenance and integrated ticketing systems, could greatly enhance navigation efficiency and passenger satisfaction.

Case Study Four: Minna Railway Station

Minna Railway Station emerged during the early days of British colonial rule as part of Nigeria’s expanding rail network. The railway reached Minna in 1911, forming a vital junction where the Lagos–Minna line merged with the Baro–Kano corridor (Wikipedia, 2023). The station is steeped in history Minna initially rose to prominence as a railway labor settlement and retains its heritage status with the preserved Hunslet 0-6-0ST steam locomotive built in Leeds, on display at the premises (Tourist Places Guide, 2024).

Site Planning and Landscaping

Nestled on Railway Station Road off Minna–Zungeru Road, the station holds a strategic yet charming position in the city, accessible by train, vehicles, and motorbike (Hotels.ng, 2024). Its foresight as a junction for multiple lines lends it functional significance. The surroundings reflect Minna’s dual identity, a mix of colonial relics and moments of

modern transformation mirroring the broader narrative of a city evolving from its railway roots (Tourist Places Guide, 2024).

Spatial Organization and Design

Minna's station retains its original modest layout: a waiting hall, ticket counter, and adjacent platform space. Simplicity defines circulation, yet the lack of structural enhancements such as signage or lighting improvements introduces navigational challenges, especially for unfamiliar visitors. Behind it, the locale is layered with pedestrian activities often clustered around the station zone, adding to spatial complexity.

Materials and Finishes

Materials are characteristic of early 20th-century architecture: brick walls, plaster finishes, and overhead corrugated metal roofing. There is minimal modernization, which preserves the site's heritage feel yet falls short in providing comfort or improved legibility for users. Amenities are basic and mostly functional, aligning with its historical rather than contemporary design ethos (Tourist Places Guide, 2024).

Relevance to Wayfinding Strategy

Minna Railway Station offers valuable insights. Its heritage brings strong landmark advantages key to enhancing orientation. Its simplicity allows efficient movement, yet exposes the design's reliance on user familiarity, which is not ideal for a growing commuter base. For the planned Minna–Abuja Light Rail Station, it will be crucial to preserve historical identity while introducing bilingual signage, clear circulation zoning, comfort-oriented finishes, and accessibility features to support diverse users and ensure intuitive navigation.

Case Study Five: Utrecht Centraal Station

Utrecht Central Station is the largest and busiest railway station in the Netherlands, serving over 200,000 boarding and alighting passengers per day as of 2019, excluding transfers (Wikipedia, 2024). In response to increasing demand in excess of 35 million travelers annually the station underwent a comprehensive redevelopment between 2008 and 2016, emerging as a modern, integrated mobility hub combining train, bus, tram, and bicycle transit modes under a sweeping undulating roof.

Site Planning and Landscaping

The station's redesign introduced a generous elevated concourse a light-filled, retail-lined promenade that spans above the tracks and connects two urban squares: one leading to the Jaarbeurs convention centre and the other to the historic city Centre (Wikipedia, 2024). The surrounding urban infrastructure was refined with widened pedestrian pathways and new forecourts, facilitating movement and accessibility from multiple directions (ArchDaily, 2019).



Plate 32: Aerial view of Utrecht Central Station with wave-like roof structure

Source: ArchDaily (2016)

Spatial Organization and Design

At the heart of the station is a vast, cathedral-like concourse that provides unimpeded visibility of trains, platforms, and the city beyond. The design, with its expansive glazing and triple-wave roof, creates an intuitive spatial structure; entrances and circulation paths are clearly legible in the overall form (ArchDaily, 2016). The elevated concourse separates arrival and departure flows, enhancing movement efficiency and visual clarity (1Library.net, 2024).



Interior concourse of Utrecht Central Station showing clear visibility of platforms and retail areas
Source: ArchDaily (2016)

Relevance to Wayfinding Strategy

This station provides profound lessons for the Minna–Abuja Light Rail project. Its clarity in circulation, seamless modal convergence, and architectural signaling through form are all aspirational benchmarks. To replicate this in Minna, the design should incorporate large-scale wayfinding signage, transparent spatial organization, and multimodal integration alongside the built structure ensuring visual legibility matches functional orientation.

Case Study Six: Taiyuan South (Taiyuannan) Railway Station

Taiyuan South Railway Station, commonly referred to as Taiyuannan, opened on July 1, 2014, as part of China's rapidly expanding high-speed rail network. It serves major lines including the Datong–Xi'an Passenger Railway and the Taiyuan–Jiaozuo High-Speed Railway, marking it as a primary transportation hub in Shanxi Province (Wikipedia, 2025).

Site Planning and Landscaping

The station is prominently located in the Xiaodian District of Taiyuan, designed to serve as a landmark within the city's evolving urban fabric. The east square covering approximately 15.8 hectares features a multi-layered transport interface, including bus terminals, a metro station, overpass drop off zones, and underground parking, all seamlessly integrated into the station's forecourt design (ChinaDaily, 2019).

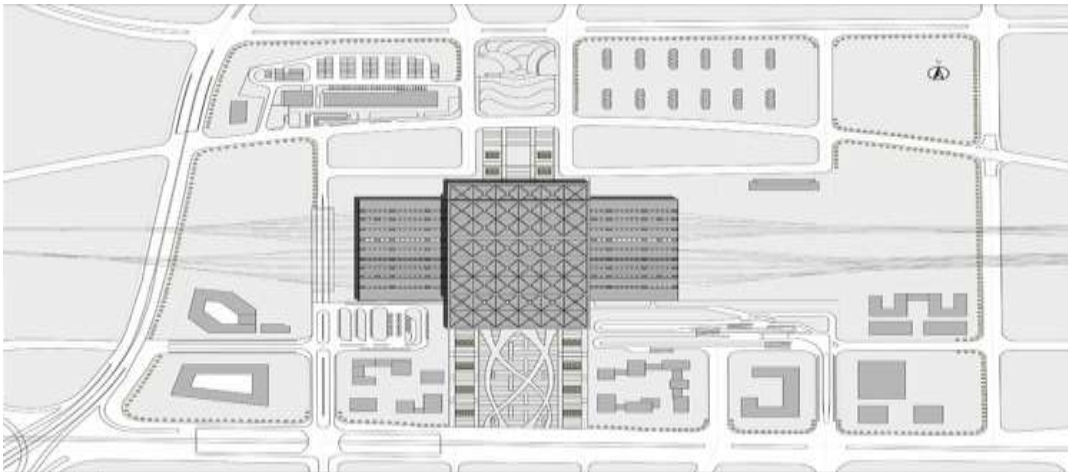


Plate 36: Site plan of Taiyuan South Railway Station showing spatial organization and integrated transport facilities
Source: ArchDaily (2016)

Spatial Organization and Design

Taiyuannan's architecture reflects a fusion of regional cultural identity and modern engineering. The design adopts a "Tang-style Shanxi character," incorporating traditional wooden bracket forms and layered façades, reinterpreted using contemporary steel and glass systems to enhance both visual and structural clarity (ArchDaily Colombia, 2016). Internally, the station follows a structured, intuitive layout where entry, waiting, and circulation areas are naturally organized to guide passengers through the space effectively (Jidipi Architectures, 2016).



Interior view of Taiyuan South Railway Station showcasing Tang-style Shanxi architecture
Source: Jidipi Architectures (2016)

Relevance to Wayfinding Strategy

Taiyuan South Railway Station offers powerful insights for your Minna–Abuja Light Rail project. Its architectural boldness and internal clarity encourage seamless navigation. Key lessons include:

Modular design: Large, organized spaces help passengers orient through form alone.

Cultural integration: Stylistic cues reinforce landmark recognition and civic identity.

Environmental systems: Natural lighting and cooling aid visibility and passenger comfort.

In applying these principles to Minna, consider adopting:

1. A strong landmark-form that readily signals arrival.
2. Modular interior layouts promoting intuitive circulation.
3. Fabrication strategies balancing aesthetics, efficiency, and climate responsiveness.

Case Study Seven: Grand Central Terminal

Grand Central Terminal, unveiled in 1913, is the world's largest railway station by track and platform count, with 44 platforms and 67 tracks, an unmatched figure globally (City Beautiful Blog, 2019). More than a transit hub, it is a prime example of Beaux-Arts architecture, merging aesthetic grandeur with functional design (Discovery to Wonders, 2023). Through the 20th century, it evolved from near obsolescence to an architectural icon, saved from demolition in part by preservation efforts led by Jacqueline Kennedy Onassis, a legacy reinforced by landmark legal rulings (Akinwale, 2020).

Site Planning and Landscaping

Conceived as an integrated urban gateway, Grand Central was among the first stations to relocate train traffic below street level, allowing Park Avenue to be constructed above. This move efficiently separated rail functions from city streets while creating air rights for urban development. The result is a multi-level infrastructure hierarchy that facilitates seamless connections between multiple transport modes and numerous station entrances.



Historic diagram showing multi-level layout of Grand Central Terminal
Source: New York Transit Museum Archives

Spatial Organization and Design

The central concourse is an awe-inspiring space measuring approximately 275 ft by 120 ft by 125 ft. The use of ramps rather than stairs improves circulation, especially for travelers carrying luggage, while accommodating heavy pedestrian flow (Bookey, 2024; See Sight Tours, 2023). Passageways like the Graybar and Lexington corridors link key transit areas, improving connectivity and making the station's large scale more navigable (See Sight Tours, 2023).



Main concourse of Grand Central Terminal with celestial ceiling

Source: *GrandCentralTerminal.com* (2024)

Relevance to Wayfinding Strategy

The terminal demonstrates the value of **architecture as a wayfinding tool** communicating direction through spatial form, maintaining strong visual axes, and incorporating iconic landmarks to anchor navigation. For the Minna–Abuja Light Rail Station, these strategies could translate into large, open concourses with visual landmarks, heritage-inspired details, and clear sightlines to guide movement naturally.

DESIGN REPORT

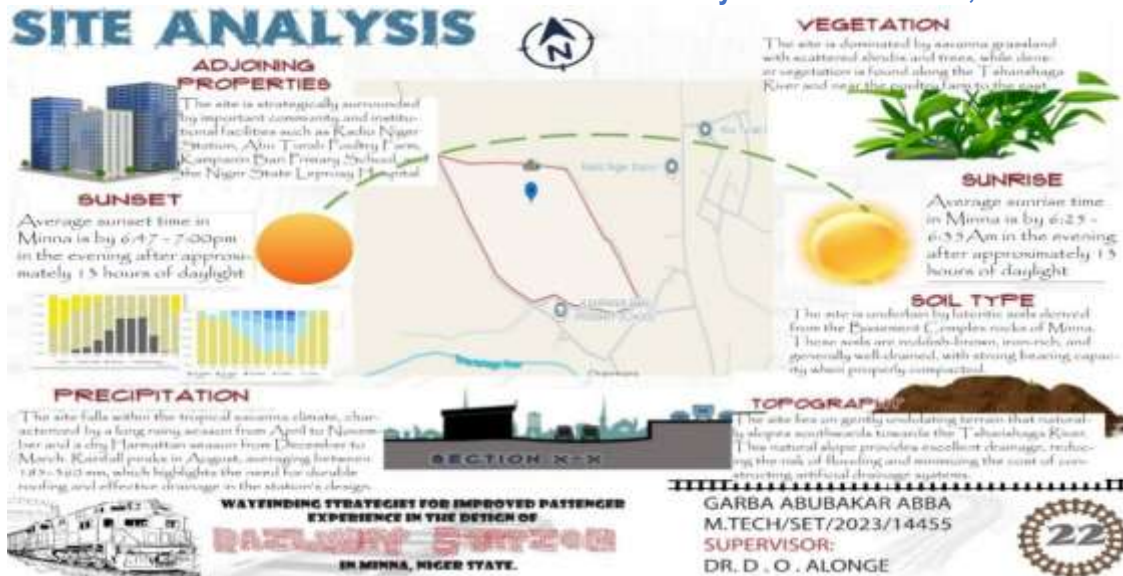
Design Brief

The proposed Minna–Abuja Light Railway Station, located in Chanchaga LGA of Minna, is conceived as a modern transport hub that enhances passenger navigation through effective wayfinding strategies. The design adopts a U-shaped building with a central tower as a landmark, accommodating three platforms and rail tracks, a central concourse with ticketing and waiting areas, VIP lounge, baggage claim, restaurants, shops, toilets, and administrative offices. Accessibility and inclusivity are prioritized through clear sightlines, tactile paving, Braille signage, digital displays, and universal design features. Safety provisions include CCTV coverage, fire safety systems, and controlled access zones, while sustainability is addressed through natural lighting, cross-ventilation, energy efficient systems, and use of durable local materials. The station also aims to support urban renewal, improve connectivity, and provide a vibrant passenger experience with integrated commercial spaces, thereby positioning Minna as a key gateway to Abuja.

Site Analysis

The proposed site for the Minna–Abuja Light Railway Station is located in Chanchaga Local Government Area of Minna, Niger State, positioned close to Radio Niger to the north. This prominent landmark provides an immediate visual reference for residents and visitors, making the station location easy to identify. The area is well connected to Minna's main road network, giving it strong potential to serve as a transport hub that is both accessible and highly visible (Auta & Musa, 2018).

The site lies on gently rolling terrain typical of Minna's landscape, with open stretches of land offering flexibility for construction and future expansion. Surrounding land uses include low-density residential areas, small commercial outlets, and public service facilities. This creates an environment where the station can integrate with existing urban activity without major disruption.



Analysis of the Proposed Site

Source: Author's fieldwork (2025)

Site Selection Criteria

The choice of Chanchaga as the preferred location for the Minna–Abuja Light Railway Station was guided by several key factors, consistent with established transportation infrastructure planning standards (Oluwaseun & Adeniran, 2018):

- I. **Accessibility and Connectivity** – The site enjoys direct access to the Minna–Paiko–Lapai Road, linking it to Minna's core road network and the wider region. This ensures smooth integration with feeder buses, private vehicles, and potential park-and-ride facilities (FMW&H, 2021).
- II. **Proximity to Landmarks and Urban Centres** – The broadcasting mast of Radio Niger serves as a strong wayfinding feature, aiding spatial orientation for travellers. The location is also close to commercial areas, schools, and residential districts, providing a broad potential passenger base (Auta & Musa, 2018).
- III. **Adequate Land Availability** – The open site offers ample space for station facilities, parking, pedestrian circulation, and possible future expansions, in line with Nigerian Railway Corporation (NRC) guidelines (NRC, 2021).
- IV. **Topography and Environmental Suitability** – The gentle slope and stable soil conditions make the site favourable for construction. Its elevation and natural drainage reduce the risk of flooding, an important factor for safety and long-term infrastructure resilience (Olanipekun et al., 2019).
- V. **Socio-Economic Potential** – Locating the station in Chanchaga is expected to stimulate local commerce, create employment opportunities, and encourage investments in nearby neighbourhoods, supporting Niger State's urban regeneration objectives (NSUDB, 2020).
- VI. **Future Integration** – The site layout allows for possible integration with retail spaces, transit-oriented developments, and community facilities, ensuring the station can adapt to future growth needs (Oluwaseun & Adeniran, 2018).



Analysis of the Proposed Site
Source: Author's fieldwork (2025)

Access and Connectivity

Strong road links make the site ideal for multimodal transport integration. Its proximity to major junctions like Kpakungu Roundabout boosts accessibility but also requires careful planning to prevent traffic congestion during peak periods (FMW&H, 2021).

Opportunities and Challenges

The site's visibility and open terrain are major advantages, reducing construction difficulty and giving the station a clear identity. However, traffic and potential noise from nearby broadcasting facilities will require mitigation measures, such as landscaped buffers and acoustic treatments (Lawal & Oke, 2016).

CONCLUSION

The study revealed that Nigerian railway stations often lack user-centered design features that support smooth navigation, particularly for first-time travellers, elderly passengers, and persons with disabilities. In contrast, international case studies demonstrated that clear spatial organization, hierarchical signage systems, architectural landmarks, and technological aids significantly improve the passenger experience.

Based on these findings, the research proposed a design for the Minna–Abuja Light Rail Station that integrates intuitive circulation paths, a central tower as a landmark, clear signage systems, digital display boards, tactile paving, and inclusive design principles. The conclusion reached is that effective wayfinding is not merely an add-on feature but a core aspect of railway station design that directly influences safety, inclusivity, and efficiency.

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Integration of Experiential Architecture Principles in Design of a Community Centre for the Gbagyi People of Kwali, FCT, Nigeria

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Abstract

While the Federal Capital Territory is envisioned as a centre for Nigeria's unity, its rapid urbanisation has marginalised the Gbagyi people, the original inhabitants of the region. This study aims to foreground Gbagyi cultural identity within the broader context of inclusive and sustainable urban design for all Nigerians. The goal is to create meaningful spatial experiences that enhance social cohesion and cultural identity. Through experiential design methodologies, the investigation shows Gbagyi cultural values, traditional building methods, and spatial organization patterns can be incorporated into modern community architecture. The study employs ethnographic research, participatory design, and community engagement, to uncover the traditional spatial organisation, social structures, and building techniques of the Gbagyi people. The findings inform a prototype community centre that harmonises indigenous materials with contemporary, climate-responsive construction technologies. This approach results in flexible, resilient, and immersive spaces that promote environmental comfort, social cohesion, and cultural continuity. Key design features include circular courtyards, transitional zones, storytelling areas, vocational training rooms, and spaces for intergenerational interaction. Passive design strategies, such as natural lighting, cross ventilation, and acoustic treatment, are deliberately employed to enhance sustainability and user experience. By fusing traditional knowledge with modern construction innovation, the project demonstrates how urban infrastructure can be transformed to be more inclusive, equitable, and environmentally responsible. The resulting design not only supports essential community needs—education, healthcare, and economic empowerment—but also reinforces Gbagyi cultural identity through spatial narratives and symbolism. This research provides a replicable model for integrating indigenous perspectives into urban infrastructure, advancing the goals of equitable access, cultural preservation, and sustainable development in line with Nigeria's vision for a sustainable urban future.

Keywords: *Experiential Architecture, Indigenous Infrastructure, Sustainable Development, Inclusive Urban Design, Gbagyi Community, Cultural Identity, Climate-Responsive Design, Equitable Access, Construction Innovation*

INTRODUCTION

Architecture is not neutral. It is a carrier of memory, identity and social practice — especially in indigenous contexts where built form is an extension of cultural life (Moses, 2020). In Abuja's Federal Capital Territory (FCT), the Gbagyi people are the land's original custodians but their spatial traditions and cultural narratives have been marginalised during rapid urbanisation and standardised public works (Bashir et al., 2021). Contemporary community centres in Abuja commonly adopt generic modernist templates that rarely reflect local ritual, material or spatial logics; the result is under-used, culturally alienating civic infrastructure (Adebara, 2024).

This paper sets out to translate experiential architecture — a design paradigm that prioritises multi-sensory engagement, atmosphere, and cultural meaning — into a practical community centre design framework for Kwali Area Council, a culturally significant Gbagyi locality (Saxena & Sehgal, 2024; Moussaoui, 2024). It dives into how do Gbagyi spatial traditions and contemporary needs intersect, and how can architects can operationalise that intersection in a resilient, inclusive building (Mba et al., 2024).

This study pursues four key aims: first, to document Gbagyi heritage and spatial traditions; second, to examine the functional and experiential shortcomings of existing community centres; third, to distil experiential design principles that reinforce cultural preservation and inclusivity; and fourth, to propose a climate-responsive, accessible, and adaptable design framework for Kwali. Positioned within the broader agenda of sustainable development (SDGs 4, 10, 11, and 13), the research provides practical guidance for architects, planners, and policymakers committed to delivering inclusive and culturally grounded urban infrastructure (Alnsour et al., 2024).

LITERATURE REVIEW

Experiential Architecture: Theory And Thrust

Experiential architecture argues that buildings must engage more than sight; they must be felt and remembered (Gregory, 2024). Foundational voices in this paradigm emphasise atmosphere, tactility, sound and the embodied experience of place (Brand, 2022). The critique is straightforward: modernist functionalism over-prioritised efficiency and visual form at the expense of sensory depth and cultural meaning (Erlmann, 2020). Experiential theory reframes architecture as a medium for memory, ritual and social cohesion — traits essential to community infrastructure serving indigenous users (Karim, 2020).

Core experiential principles relevant to community centres include: user-centred participation in design; multisensory programming (light, texture, sound, smell); narrative embedding (symbolic motifs and storytelling places); and resilience through vernacular, low-energy strategies (Özer, 2024). These principles provide a counterbalance to one-size-fits-all public buildings and translate directly into architectural moves such as sequenced thresholds, shady courtyards, tactile materials and acoustic design that supports oral tradition (Wijaya & Warnata, 2022).

Cultural Architecture and Indigenous Identity

Architecture encodes social values. In contexts like Kwali, traditional Gbagyi layouts — circular compounds clustered around courts — are not accidental: they structure daily life, ceremonial practice and intergenerational exchange. Colonial and modernist impositions disrupted these patterns, replacing responsive, place-based forms with imported typologies (Moussaoui, 2024). Recovering culturally embedded design is therefore a political as well as technical act: it repairs representational injustice while improving usability (Acharya, 2022). The literature shows successful precedents where contemporary projects adopt vernacular logics and materials to create civic spaces that feel familiar and empowering to local communities (the thesis surveys global and African examples and draws lessons relevant to Kwali). The key learning is not mimicry but synthesis: hybridise local knowledge and modern requirements so buildings perform thermally, economically and culturally (Bocco Guarneri & Habert, 2024).

Typologies and Case Studies Relevant to Community Centres

Comparative case studies — from Zeitz MOCAA (Cape Town) to Makoko's floating experiments and globally recognised civic projects — illustrate how sensory engagement, flexible programming and cultural narratives coalesce into high-performing public architecture (Jain, 2024). This study distils lessons on courtyard use, adaptive reuse, multisensory landscapes and participatory programming that are directly applicable to a Kwali community centre brief. In short: the typology that best supports experiential objectives is rarely a single enclosed hall; it is a network of indoor-outdoor thresholds, multipurpose shells and framed courtyards that mediate ritual, learning and economic activity.

Participatory and Inclusive Design

The insights from literature reviews emphasises participation as a non-negotiable. The insights from literature reviews emphasises participation as a non-negotiable. Co-design of community spaces with elders, artisans, women and youth reveals tacit knowledge that informs spatial layout, material choice and program sequencing (Calvo & Sclater, 2021). Inclusion extends beyond consultation: design must incorporate universal access, gendered safety, and age-sensitive circulation. These considerations align with the Gbagyi tradition of communal decision-making and ensure the centre does not reproduce the exclusion it seeks to remedy (Dropkin & Smith, 2021).

Sustainability and the SDG Agenda

Culturally embedded architecture intersects well with sustainable imperatives: local materials (rammed earth, timber), passive design (thermal mass, cross-ventilation), and on-site systems (rainwater harvesting, solar) reduce energy and operational costs while strengthening identity. The thesis positions this integration as central to meeting SDGs — a useful policy lever to secure funding and institutional support for culturally informed community infrastructure (Dash & Shetty, 2020).

Synthesis: Experiential architecture supplies the conceptual toolkit (sensory richness, narrative embedding, participatory process); the Gbagyi context provides the content (courtyards, craft traditions, material palette); the policy environment supplies the incentives (SDGs, cultural preservation mandates). The design task is to translate toolkit + content into a feasible, maintainable building brief.

METHODOLOGY

This study uses a mixed qualitative approach rooted in ethnography, supported by structured survey data and comparative case study analysis. The methodological choices are deliberate: ethnography captures emic perspectives (insider meanings), surveys supply population-level patterns, and case studies provide transferable precedents (Lowis, 2025).

Data Collection Methods

- I. Participant observation in Gbagyi settlements (to record movement, rituals, sensory atmospheres).
- II. Semi-structured interviews with elders, artisans, youth, women and local leaders (to capture narratives and normative rules).
- III. Questionnaire survey (223 respondents) to quantify spatial preferences, material familiarity and program needs.
- IV. Photographic documentation to record materiality and spatial sequence.
- V. Comparative case studies of local and global community spaces to extract design lessons.

Sampling and Reliability

Purposive and snowball sampling were used to ensure representation across age, gender and cultural role. The survey sample included 223 respondents (70% aged 0–29, 52% female, 67% self-identified as Gbagyi), a cohort that provided both traditional knowledge holders and aspirational youth voices (Nyimbili & Nyimbili, 2024). Reliability testing of questionnaire items produced a Cronbach's alpha of 0.86, indicating good internal consistency for the constructs measured (cultural needs, material preference, experiential qualities) (Schrepp, 2020).

ANALYSIS

Thematic analysis (coding of interview transcripts and observation notes) was used to identify recurring experiential themes (courtyard importance, sensory markers, ritual zones), while survey responses were analysed descriptively to

support generalisability of major preferences. Case study synthesis identified typological and material strategies transferable to Kwali (Banda et al., 2024).

Ethics and Limitations

Informed consent, anonymity and cultural protocol were observed. Limitations include language barriers, constrained immersion time and logistical constraints accessing some demographic groups; mitigations included local interpreters and extended field visits to build trust. The study is intentionally confined to schematic/conceptual design outcomes; detailed structural engineering and construction documentation were outside its scope.

RESULTS AND DISCUSSION

Quantitative Analysis: Interpretation of Key Metrics

The 223 survey respondents reflect a predominantly young, fairly educated population (approx. 80% tertiary/postgraduate) with balanced gender representation and a strong Gbagyi presence (67%). Respondents ranked family gathering areas highest (85%), followed by marketplace functions (60%), worship spaces (55%) and storytelling/ceremonial sites (30%). Layout preferences showed a split — 50% preferring rectangular plans and 35% expressing continued affinity for circular layouts — indicating openness to hybrid typologies that reconcile tradition with contemporary program uses. Cement block familiarity was high (70%), yet mud, timber and thatch retained symbolic and emotional value and were preferred when combined with modern technologies.

Interpretation: The quantitative profile suggests a community that values traditional spatial functions but is pragmatically open to modern materials and hybrid solutions. This creates fertile ground for a design that blends vernacular atmospheres with durable, low-maintenance construction technologies.

Qualitative Findings: Lived Experiences and Priorities

From interviews and observations, several experiential needs emerged repeatedly:

- i. *Courtyard centrality* — the courtyard is described as the social “heart,” supporting ceremonies, storytelling, informal markets and evening gatherings.
- ii. *Tactile atmospheres* — earthen walls, textured timber and water features register as markers of “home” and “security.”
- iii. *Climate comfort* — shading, cross-ventilation and thermal mass are not optional; they define usability in daytime and evening.
- iv. *Intergenerational spaces* — places that support both elders’ storytelling and youth training are vital for cultural transmission.
- v. *Economic adjacency* — spaces for pottery sales, vocational training and markets need to be physically integrated within the centre to support livelihoods.

These qualitative priorities point to a centre that must do more than host events: it must be a living set of social machines that support ritual, economy and pedagogy concurrently.

Case Study Deductions and Typological Implications

Comparative projects highlight recurring design moves applicable to Kwali: courtyards as organizing elements (allowing indoor-outdoor programming), material honesty married to modern systems (e.g., rammed earth with structural reinforcement), and layered thresholds (sequence of approach, public plaza, semi-private courtyard, intimate rooms) that scaffold ritual behaviour. The thesis’ case syntheses show that hybrid typologies — combining multipurpose halls, vocational clusters, and curated outdoor spaces — deliver the experiential richness and functional flexibility communities require.

Proposed Design Framework — Operationalising the Findings

From the integrated evidence the study proposes a concise, operational framework composed of five interlocking design strategies:

- i. *Organising Move* — Courtyard Network: Use a series of linked courts — a primary ceremonial courtyard, secondary vocational courtyards and intimate storytelling niches — to replicate Gbagyi compound logic at civic scale. Courtyards function as passive cooling reservoirs and flexible event spaces.
- ii. *Material Strategy* — Hybrid Vernacular: Combine earthen walls or stabilized rammed earth (for thermal mass and tactile atmosphere) with reinforced block or lightweight timber frames where durability is needed. Use thatch or green roofing strategies in peripheral pavilions to signal tradition without compromising code.
- iii. *Sensory Programming* — Multimodal Atmospheres: Design lighting, acoustic and olfactory cues intentionally: shaded light wells, water features for sound masking, textured surfaces for tactile engagement and planting schemes to anchor smell and biodiversity. These cues from memory triggers and welcome users into culturally legible spaces.
- iv. *Functional Zoning* — Mix of Fixed and Flexible: Provide fixed facilities (library/archive, vocational classrooms, administrative hubs) combined with large flexible halls that can host festivals, markets and training. Adjacency rules: vocational workshops adjacent to market nodes; story spaces near elders’ rooms; quiet rooms with controlled acoustics for study and reflection.

- v. *Participation & Management* — Co-stewardship Model: Embed management structures that ensure community ownership: a cultural council, rotating stewards for programs, and artisan cooperatives for maintenance and revenue generation. This keeps the centre culturally animated and financially resilient.

These strategies are encapsulated in a conceptual scheme the thesis terms the “Circle of Memory and Continuity” — a physical and programmatic translation of Gbagyi compound logic into a civic building: circular spatial sequencing, layered thresholds, and an ecology of uses supporting ritual, education and enterprise.

Sustainability, Inclusion and Maintenance

Sustainability measures are not add-ons; they are integral to the centre's viability. Passive strategies (thermal mass, ventilation, orientation), on-site renewables (photovoltaic arrays for lighting and equipment), greywater systems and rainwater harvesting reduce operating costs and increase resilience. Universal design features (gradual ramps, tactile wayfinding, gender-segregated but safe ablution blocks and flexible seating) ensure accessibility for elderly and people with disabilities. Maintenance planning — a frequent omission in public work — must be embedded in the design (modular roofing systems, replaceable cladding panels, training local maintenance teams) to avoid decay and obsolescence. The thesis underscores maintenance as a design outcome requiring budgeting, training and institutional buy-in.

Risks and Realistic Trade-Offs

Practical trade-offs are inevitable: earthen finishes require craftsmanship and maintenance; modern funding mechanisms prefer uniform, cheaply replicable designs; and institutional procurement often excludes participatory processes. The design framework therefore recommends targeted interventions: use earth where it offers the most experiential value (courtyards, visitor interfaces) and durable, low-maintenance materials in high-wear functions (sanitary blocks, kitchens). Programmatic revenue streams (marketing of craft, venue hire) balance cultural aims with economic realism.

CONCLUSION

This study demonstrates a pragmatic path for integrating experiential architecture into community centre design in Kwali: one that respects and operationalises Gbagyi spatial traditions, responds to contemporary needs, and aligns with sustainability objectives. The evidence base — ethnographic observation, a 223-respondent survey, and comparative case studies — consistently indicates that a hybrid approach (vernacular atmospheres + modern performance) is both desirable and feasible.

Key takeaways:

- i. Courtyard logic matters. Reinstating courtyard networks at civic scale restores social choreography and provides natural climate control.
- ii. Materials communicate. Earthen surfaces, timber and craft elements are not decorative extras; they are essential sensory markers that affirm identity and belonging. Use them where they will be touched and experienced.
- iii. Design must be participatory and sustained. Co-design ensures cultural accuracy and local stewardship is the best insurance against neglect.
- iv. Sustainability is social as much as environmental. Low-energy measures reduce costs and strengthen resilience; vocational and market functions support livelihoods and civic buy-in.

Practical recommendations (short list for practitioners & policymakers):

- i. Make participatory design mandatory for community infrastructure in culturally sensitive districts.
- ii. Prioritise mixed material strategies — earthen or rammed earth for public interfaces, durable materials for high-wear zones.
- iii. Design maintenance and revenue pathways at the concept stage (artisan cooperatives, market rents, cultural programming).
- iv. Insist on post-occupancy evaluation: experiential quality is measurable over time (use surveys, observation, and management logs).
- v. Contribution and future work: This paper translates thesis-level ethnographic and design research into a concise, actionable model for community centre design that is culturally grounded, climate-responsive and administratively realistic. Future work should document a built prototype with post-occupancy evaluation to test the hypothesis that experiential architecture materially increases use, cultural transmission and civic resilience over time.

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Enhancing Psychological Wellbeing through Landscape Design: A Review Assessment of Public Parks in Abuja

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ABSTRACT

Public parks in Abuja, Nigeria, have been under more strain as vital mental health infrastructure due to the city's rapid urbanization (population increased from 300,000 in 1991 to 3.7 million by 2020). The design of therapeutic landscapes in African urban settings has received little attention. The psychological well-being of park visitors in sub-Saharan Africa is examined in this study in relation to native vegetation, water features, sensory pathways, and culturally grounded spaces. 412 adults over the age of 18 participated in a mixed-methods study conducted in four parks in Abuja in 2022–2023. Qualitative interviews and focus groups, WEMWBS, behavioural mapping, and the WHO-5 Well-Being Index were used to gather the data. There is a strong positive correlation ($r = 0.61$, $p < 0.01$) between psychological well-being and landscape design. The highest well-being scores were found in parks with native vegetation and water features ($\beta = 0.47$, $p < 0.01$). Stress reduction, emotional stability, and social connectedness were among the main advantages. In African urban settings, culturally sensitive landscape design greatly improves psychological well-being by facilitating the incorporation of local vegetation, water features, and public areas into urban planning.

Keywords: landscape design, community mental health, public parks, therapeutic landscape, psychological well-being, Abuja

INTRODUCTION

Background and Theoretical Framework

Abuja's rapid expansion highlights the problems associated with urbanization in sub-Saharan Africa, destroying traditional ties to nature and upsetting social support networks (Rotimi, 2024). In order to comprehend how indigenous knowledge systems improve landscape therapy in African contexts, this study makes use of the Attention Restoration Theory, Stress Reduction Theory, and Therapeutic Landscapes Theory (Chinedu & Onuorah, 2023). Because they offer easily accessible areas for rest, socializing, and connecting with nature, public parks are essential for urban mental health. But according to Askarizad et al. (2025), Western landscape architecture frequently influences their management and design in African contexts, possibly ignoring culturally unique pathways.

Research Gap and Objectives

Recent systematic reviews (Fon, 2022) identified only 12 peer-reviewed studies that examine therapeutic landscapes in sub-Saharan Africa, with none focusing on culturally responsive design. This study tests four hypotheses: (1) native vegetation will show higher user wellbeing than exotic species, (2) water features correlate strongest with stress reduction, (3) cultural elements predict increased usage, and (4) accessibility barriers moderate design-therapeutic relationships.

METHODOLOGY

Study Sites and Participants

Four strategically selected parks representing diverse approaches. These are: **Millennium Park (150ha)**: 60% native species, artificial lake; **City Park (45ha)**: Exotic landscaping, limited water features; **Jabi Lake Park (300ha)**: Natural lakefront, indigenous vegetation; and, **Garki Park (25ha)**: Community-designed, medicinal plant gardens. There was a total of 412 participants via stratified systematic sampling (78.3% response rate). Demographics: 58% female, mean age 34.2 years, diverse ethnic representation reflecting Abuja's federal capital status.

Data Collection and Analysis

Quantitative measures: WHO-5 Well-Being Index ($\alpha = 0.84$), WEMWBS ($\alpha = 0.89$), custom Likert scales, behavioral mapping, cortisol sampling ($n=120$ subset). *Qualitative measures:* 30 semi-structured interviews, 8 focus groups exploring cultural connections and barriers. Analysis used SPSS v29.0 for correlations/regression and NVivo 12.0 for thematic analysis with triangulation.

RESULTS AND FINDINGS

Findings

Wellbeing Measures

Mean WHO-5 scores of 67.3 (SD=18.4) with significant park variations: Millennium Park (74.2) > Jabi Lake (71.8) > Garki (69.1) > City Park (58.7).

Landscape Correlations

Water features: $r = .64$ with stress reduction; native vegetation: $r = .58$ with WHO-5. Cultural spaces: $r = .37$ with WHO-5; sensory pathways: $r = .41$ with WHO-5.

Native Vegetation Impact

Parks with >60% indigenous species showed significantly higher wellbeing (M=71.2) vs exotic-dominated landscapes (M=63.8, $p<0.01$). Strongest associations with *Parkia biglobosa*, *Vitellaria paradoxa*, and *Borassus aethiopum*.

Qualitative Insights

Participants described parks as "pressure release valves" according to (Stuart-Smith, 2021), with four therapeutic mechanisms: cognitive restoration, emotional regulation through familiar sensory experiences, spiritual connection via indigenous plant symbolism, and physiological relaxation. Cultural connections were profound: "*When I smell the mint and ugu leaves growing along the paths, it takes me back to my village. These plants remind me who I am.*" Focus groups revealed extensive traditional knowledge about medicinal properties.

Barriers identified

Entry fees (₦200-500), transportation costs, poor maintenance, and cultural disconnection from foreign design elements (Mteti, Mpambije, & Manyerere, 2025). *Behavioral Observations: Water areas:* Longest stay durations (89 vs 54 minutes), highest contemplative behaviors. *Native plant gardens:* Varied walking paces, frequent stopping, increased social interactions. *Well-maintained areas:* 2.3x higher usage rates, 67% longer visit durations.

DISCUSSION

Mechanisms

The $r=0.61$ correlation confirms therapeutic landscape effectiveness in African contexts with culturally specific amplification. Native vegetation's superior impact ($\beta=0.47$) suggests evolutionary familiarity and cultural meaning enhance restoration beyond basic nature exposure. Opined by (Ogar, 2023) Water features showed universal appeal, enhanced by African spiritual associations. Participants referenced traditional water ceremonies and ancestral connections, amplifying universal psychological mechanisms through cultural frameworks.

Social and Equity Dimensions

African cultural values emphasizing collective wellbeing distinguish this context from individualistic Western approaches. (Bonham-Corcoran, Armstrong, O'Briain, Cassidy, & Turner, 2022) Parks facilitating social interaction showed enhanced therapeutic outcomes beyond individual benefits. Accessibility barriers create environmental justice issues, excluding vulnerable populations who most need nature-based interventions (Bauer, 2023). Well-designed parks serving affluent neighbourhoods, while underserved areas lack green spaces, reflect broader urban inequality.

RECOMMENDATIONS

Evidence-Based Design Guidelines

Indigenous Plant Standards

In therapeutic zones, at least 60% of the species are native. Priority species include *Moringa oleifera*, *Vitellaria paradoxa*, and *Parkia biglobosa*. Gardens with medicinal plants with signs in the native tongue. aromatic paths with *Cymbopogon citratus* and *Ocimum gratissimum*.

Water and Sensory Features

Water features that are accessible in parks larger than 20 hectares. Natural water features are favoured over man-made ones. paths that use several senses and local resources. Water flowing is included in the sound design.

Cultural and Accessibility Standards

meeting places and traditional architectural features. Accessible to anyone with no obstacles in the way. several ports of entry with connections to public transit. Adaptable areas that support cultural customs.

Implementation Strategy

Community Participation

consultations with several stages that employ conventional consensus techniques. include those with traditional ecological expertise. co-management contracts with neighbourhood associations. courses for caretakers of public parks.

Sustainability Approaches

Every year, 500 volunteers are trained by community stewardship initiatives. native nurseries and networks for plant propagation. generating income through suitable business ventures. Professional supervision combined with community application.

Healthcare Integration

Parks should function as a mental health infrastructure through Instruction on nature-based interventions for healthcare providers. "Park prescription" procedures for those suffering from depression or anxiety. weekly support groups in environments that are helpful. measuring health outcomes over time.

LIMITATIONS AND FUTURE RESEARCH

Study Limitations

A cross-sectional design prevents causal inferences. Self-selection bias as participants chose to visit parks. Seasonal variations not captured (dry season only). Focusing on 30+ minute users may exclude negative experiences. Generalizability beyond Abuja's unique federal capital context is uncertain.

Research Priorities

Longitudinal Studies

A 24-month wellbeing tracking with quarterly assessments to identify optimal usage patterns and sustained benefits.

Physiological Validation

Expand cortisol sampling to include heart rate variability, blood pressure, and inflammatory markers with wearable technology integration. *Cross-Cultural Analysis*: Replication in Lagos, Kano, and Accra to identify universal vs culturally specific mechanisms. *Economic Evaluation*: Cost-effectiveness analyses comparing therapeutic parks with other mental health interventions, quantifying healthcare savings and property value increases.

CONCLUSION

This research provides robust evidence that culturally responsive landscape design significantly enhances psychological well-being in African urban contexts ($r=0.61$, $p<0.01$). Native vegetation emerges as the strongest predictor ($\beta=0.47$), while water features achieve a $r=0.64$ correlation with stress reduction.

Contributions

The findings establish critical principles for African therapeutic park design: prioritizing indigenous species, incorporating natural water bodies, emphasizing community gathering spaces, and ensuring equitable accessibility (Dawson et al., 2021). The integration of traditional ecological knowledge with contemporary design creates uniquely African approaches honouring cultural heritage while addressing urban mental health challenges. *Policy Implications*: Evidence supports "park prescriptions" as cost-effective mental health treatments. (Tantoh & McKay, 2021) opined that Community-based management addresses municipal resource constraints while enhancing outcomes through cultural relevance. Healthcare system integration could significantly expand treatment capacity in resource-constrained settings.

Global Impact

This study challenges assumptions about universal therapeutic mechanisms, demonstrating that cultural familiarity amplifies restoration effects (Niu et al., 2025). The emphasis on collective vs individual benefits offers insights for community-cantered mental health approaches globally. As African urban populations reach a projected 1.2 billion by 2050, thoughtfully designed parks can serve as critical psychological well-being infrastructure. The research establishes therapeutic landscape design as both a public health intervention and sustainable city-building strategy, supporting individual well-being and community resilience in rapidly changing urban environments.

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Utilization of Biophilic Design Principles in High-Rise Residential Buildings; A Case Study Approach for Abuja, Nigeria

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Abstract

Abuja's rapid growth is creating a higher demand for high-rise residential buildings, placing more pressure on the country's already insufficient energy infrastructure. Abuja's tropical climate, conventional high-rise developments typically rely on energy-intensive mechanical cooling and artificial lighting, intensifying existing energy challenges and highlighting the need for sustainable architectural solutions. Biophilic design offers a promising yet underexplored approach to solving this problem by integrating natural systems and elements that passively reduce energy consumption while enhancing occupant well-being. Despite its potential, the direct application of biophilic design principles for energy efficiency within the Nigerian context remains limited. This study aimed to propose a high-rise residential design for Abuja that incorporated biophilic principles to optimize energy performance. A mixed-methods approach was adopted, quantitatively analysing existing energy consumption trends in Abuja's residential sector through analysis of secondary data, while qualitatively identifying effective biophilic design strategies via a comprehensive literature review and structured observations of international and local precedents. These insights, along with the climatic data of the location, informed the development of a comprehensive design proposal. The proposed scheme was evaluated through energy simulation modelling in DesignBuilder™, with its results compared against a conventional baseline to assess improvements in cooling loads, daylighting efficiency, and overall energy demand. The research aimed to demonstrate significant potential for reducing operational energy use through passive strategies like maximized daylighting, natural cross ventilation, integrated green infrastructure, and strategic water features. The resulting framework provided a replicable, sustainable model for high-rise developments in Abuja, with broader implications for energy efficient, human-centric urban development across Sub-Saharan Africa.

Keywords: High-rise residential, biophilic design, energy efficiency, passive strategies, sustainable architecture, Abuja.

INTRODUCTION

The rapid urbanization in Sub-Saharan Africa, particularly Abuja, Nigeria, has led to the increased construction of high-rise residential buildings to meet housing requirements in dense urban environments. This rise in high-density structures has led to an increase in energy demands placing a greater strain on the already limited energy supply. 42% of the energy produced in Nigeria is used up by residences which is the highest energy consumption by sector in the country (International Energy Agency, 2021). Zhang *et al.* (2019) proposed sustainable building design to reduce the energy consumption of these buildings.

Biophilic design was proposed by Nitu *et al.* (2022) as an alternative approach to energy efficiency in buildings. Biophilic design leverages the human affinity for nature, aiming to integrate natural elements within the built environment in ways that reduce energy dependency while enhancing occupant well-being. As past studies Kellert (2018) have already explored the psychological benefits of biophilia improving mental health, productivity, and overall quality of life.

However, the application of biophilic design specifically for energy efficiency in Nigerian high-rise residential buildings remains limited highlighting the need for research that addresses Abuja's unique energy and urban challenges. Priority in this study will be placed on the "nature in the space" approach, one of the biophilic design categories proposed by Ryan *et al.* (2014), using direct natural elements such as sunlight, plants, and airflow to achieve energy efficiency.

LITERATURE REVIEW

Residential Architecture in Abuja

Rapidly growing cities like Abuja have seen a surge in the construction of high-rise residential buildings (Ogunbiyi *et al.*, 2023). Driven by limited land availability, rising property prices, and the need to fit in more families within a limited area, high-rise construction offers a practical solution in high density areas. This shift to vertical living brings significant challenges, not seen within the scope of lower density residential constructions, especially in managing energy consumption, optimizing access to natural ventilation, lighting and green spaces, and overall occupant comfort.

Definition of High-rise Residential Buildings

High-rise residential buildings are structures primarily designed to accommodate human habitation, distinguished by their significant vertical height. Globally, what quantifies a 'high-rise' structure varies based on regional standards and building codes. According to the International Code Council (2018), a high-rise building is any structure exceeding 23 metres in height, this typically corresponds to seven to ten stories. The National Building Code for Nigeria classifies high-rise structures as any building with floors used for human occupancy located more than 15 metres above the lowest level of fire department vehicle access (*Federal Republic of Nigeria National Building Code*, 2006).

These buildings serve the essential purpose of providing housing in densely populated urban centres where land availability is limited. By extending vertically, high-rise residential buildings offer a practical solution to the challenges of urbanisation and population growth.

Trends in Residential Architecture

One of the key factors shaping residential architecture is sustainability. There is an increasing interest in efficient resource management and the creation of healthy living environments. By prioritising sustainable principles, architects can enhance building performance while reducing the resource demands typical of traditional construction methods (Mba *et al.*, 2024). Energy efficiency and the reduction of carbon footprints are also dominant priorities. High-performance building envelopes with advanced insulation, passive design strategies such as optimal orientation and shading devices, and renewable energy systems like photovoltaic panels and solar thermal solutions are becoming standard (Capeluto & Ochoa, 2016).

Other than sustainability, human centred design is also an increasingly important consideration. By integrating natural light and ventilation, improving indoor air quality, and fostering social interaction through engaging public spaces, this trend prioritises occupant well-being. Biophilic design serves as an efficient way of enhancing the quality of life for residents while promoting sustainable construction (Tabassum & Park, 2024).

The Concept of Biophilic Design

Biophilic design as a concept is majorly drawn from the theory of biophilia, refers to the inherent tendency in humans to seek out connections with nature. The idea was first popularised by Wilson (1984) in his book *Biophilia* where he defined it as ‘the innate tendency to focus on life and lifelike processes’. Biophilic design is a transformative approach in architecture that seeks to reconnect people with nature through the built environment (Kellert, 2018). Kellert saw biophilic design as an approach that integrates natural elements, patterns, and systems into architecture and urban planning.

Key Patterns of Biophilic Design

Ryan *et al.* (2014) categorised the various patterns of biophilic design, which were extensively studied and refined by scholars like Stephen Kellert and Judith Heerwagen, into three overarching groups, nature in the Space, natural Analogues, and nature of the Space, each addressing distinct aspects of human interaction with natural elements. In this study, focus will be on specific patterns with the Nature in the Space and Nature of the Space categories.

Visual Connection with Nature

This is a core element of the Nature in the Space category of biophilic design. It emphasises providing occupants with views of natural elements such as greenery, landscapes, and water bodies (Totaforti, 2020). Studies have shown that exposure to natural light not only improves occupant well-being but also decreases reliance on artificial lighting systems, leading to lower energy consumption (Akinbami, 2024; Mahmoud, 2024). By aligning interior design with the outside environment, occupants can benefit from daylighting, reducing the need for electrical lighting during the day and thus contributing to energy savings.

Access to Thermal and Airflow Variability

This pattern, also in the Nature in the Space category, emphasizes designing spaces that embrace natural fluctuations in temperature and airflow. This strategy replicates the dynamic thermal conditions found outdoors, thereby reducing reliance on energy-intensive mechanical systems like HVAC and enhancing occupant comfort (Stasi *et al.*, 2024). Designing to allow natural thermal variation through elements like operable windows and strategically located vents directly enhances the comfort of residents by letting them experience fluctuations in temperatures without needing high-cost methods to adjust interior temperatures (Omer, 2014).

Presence of Water

As a key element in the Nature in the Space category, this pattern emphasizes integrating water features into building design to enhance both energy efficiency and occupant well-being. Although water features are often viewed primarily as aesthetic enhancements, their inclusion can improve a building's thermal performance. Water elements, such as fountains, ponds, or water walls, can create a natural cooling effect that reduces reliance on energy-intensive HVAC systems (Jin *et al.*, 2017).

Dynamic and Diffuse Light

The final pattern considered in this study under the Nature in the Space category is Dynamic and Diffuse Light. It focuses on the importance of strategically using natural light to enhance both energy efficiency and occupant well-being. Unlike harsh, direct sunlight, diffuse light, characterized by its soft, even distribution, mimics the gentle light found in natural environments, promoting a more calming and comfortable atmosphere (Nasrollahi & Shokri, 2016). Techniques such as the use of light shelves, strategically placed skylights, and atriums redirect and soften daylight, ensuring a balanced distribution of light throughout interior spaces. This approach not only minimizes energy consumption but also reduces thermal loads by mitigating excessive heat gain.

Prospect

Moving to the Nature of the Space category, the "Prospect" pattern addresses our innate desire for open, expansive views that offer a sense of surveillance and security. Evolutionarily, having unobstructed views of one's surroundings has been essential for identifying both potential threats and valuable resources (Kaplan & Kaplan, 1989).

Biophilic Design and Energy Efficiency

Biophilic design principles align with passive design strategies, and broader sustainable design goals, aiming to reduce energy consumption by leveraging natural resources. This is particularly seen in the Nature in the Space pattern which directly incorporates natural elements into buildings (Agboola *et al.*, 2024).

Daylighting through large windows, skylights and lightwells provides visual connection to the outdoors, reducing artificial lighting needs. This not only decreases energy consumption but also fosters a calming and restorative effect on occupants (Omran *et al.*, 2020). Natural ventilation via operable windows and cross-ventilation corridors brings natural airflow indoors, lowering reliance on mechanical systems. This engagement with natural airflow not only enhances thermal comfort but also reduces reliance on mechanical ventilation systems (T. Yang & Clements-Croome, 2020). Green infrastructure, such as green roofs, facades, and vegetated spaces serve as both functional and biophilic features. By introducing natural greenery into building designs, these elements connect occupants with nature while acting as thermal regulators. These green elements mitigate the urban heat island effect, resulting in a more moderate microclimate and consequently lower cooling demands (Nasr *et al.*, 2024). Carefully designed water features using recycled greywater can offer evaporative cooling while minimizing consumption and pest breeding (Yang *et al.*, 2021). Allowing airflow variability conditions, reducing HVAC dependence and strengthening environmental connection (Sorgato *et al.*, 2016).

METHODOLOGY

This study adopts a mixed-method approach, integrating qualitative and quantitative methods to comprehensively explore the relationship between biophilic design and energy efficiency in high-rise residential buildings.

Energy consumption trends in Abuja's high-rise residential buildings were analysed quantitatively using secondary data from government reports and academic publications, with comparable typologies examined to establish baselines for energy use. Globally recognised biophilic strategies with demonstrated energy-efficient benefits were identified through literature review and structured observations of selected high-rise residential buildings. These insights guided the development of a biophilic high-rise design proposal for Abuja's climate. The proposal was evaluated with energy simulation modelling in DesignBuilder™ to enable comparison to baseline energy use.

RESULTS AND DISCUSSION

General Energy Use

A 2016 modelling of a standard naturally ventilated 3-bedroom bungalow, with a floor area of 200 m², gave a baseline Energy Use Intensity (EUI) of about 55 kWh/m²/yr. An apartment block, with each unit having a floor area of 100m², had an Energy Use Intensity of 98 kWh/m²/yr (Arup & Genre, 2016).

Biophilic Design Strategies for Energy Efficiency

The analysis (

Table 1), showed that the international examples integrated large-scale living systems such as vertical greenery, green walls, and internal plating, which provided passive cooling and shading benefits. The Nigerian examples relied mainly on high-performance glazing, atria and mechanical HVAC systems rather than living vegetation. Differences were also noted in the strategies for ventilation, shading, and water integration with the international cases employing more openable windows, cross ventilation, and rainwater reuse tied to their greenery.

Table 1. Summary of Case Studies

Building	Openable Windows	Cross Ventilation	Courtyard / Atrium	External Shading	Overall Lighting	Overall Ventilation
Trudo Vertical Forest	✓	Partial	✗	✓ (vegetation)	Very Good	Good
Bosco Verticale	✓	Partial	✗	✓ (vegetation)	Very Good	Good
Tower One WTC	Partial	✗	✗	✗	Good	Poor
One Central Park	✓	✓	✓ (Podium)	✓ (green walls, heliostat)	Excellent	Excellent
Nestoil Tower	Partial	✗	✓ (Podium)	✗	Good	Poor

Design Proposal Incorporating Biophilic Elements to Optimize Energy Use

The proposed high-rise residential building is located in Jabi, Abuja, adjacent to the Jabi Lake. The site's gentle slope, existing vegetation and proximity to the lake's cooling microclimate supports passive drainage and biophilic integration. The design is comprised of 3 wings, shown in **Error! Reference source not found.**, radiating from a central multi-storey atrium containing vertical circulation and service shafts. The atrium admits daylight deep into the plan and encourages vertical air movement, creating a social space that supports passive cooling. Each wing opens

towards the surrounding landscape with shaded balconies, expansive glazing and integrated greenery to maximise daylight, cross-ventilation and views. Typical residential floors are arranged around the central atrium, providing 64 apartments with private planted balconies. This layout blurs indoor and outdoor boundaries and embodies the project's biophilic, energy-efficient identity.



Figure 1. Aerial View of Proposed Design

Energy Simulation

The simulation was conducted for a single typical residential floor which contains 6 apartment units. This approach is considered valid for high-rise residential buildings, where floor plans and occupancy patterns are generally uniform across levels (Ellis and Torcellini, 2005). As such, the results are reflective of whole-building performance when normalised per square metre, which is the basis for EUI.

Energy modelling was carried out in DesignBuilder using geometry imported from Autodesk Revit. A single typical residential floor was modelled, with thermal zones divided into bedrooms, living areas and corridors to reflect different uses. The envelope comprised reinforced concrete structural elements, with exterior walls made from hollow sandcrete blocks filled with polyurethane foam insulation for energy efficiency. Windows were specified with double glazed glass. The roof was designed as a green roof with insulation and water proofing layers. Sun shading was achieved through projecting balconies with integrated planters and façade greenery. A mixed-mode ventilation strategy combined natural and mechanical operation. The Abuja weather data was gotten from the publicly available data at climate.onebuilding.org.

The results of the simulation focused on the Energy Use Intensity (EUI) of the proposed high-rise residential building, expressed as the annual energy consumption per unit of gross floor area (kWh/m²/year). This metric provides a standardized and comparable measure of energy performance across varying building sizes and uses. Additionally, the use of the EUI ensures consistency with the baseline data from the earlier study. This enables a clear and meaningful comparison of the improvements achieved.

The design achieved an EUI of 79.94 kWh/m²/yr which was 24% lower than the benchmark 3 story apartment block at 98 kWh/m²/yr. Although still above the detached bungalow EUI, with its accommodation of 64 units across multiple floors, the scheme demonstrates more efficient use of urban land by combining high density with improved energy performance. Table 2 compares these outcomes to the baseline data.

Table 2. Simulation Results Compared to baseline Data

Building Type	Units	Area per Unit (m ²)	Energy use Intensity (kWh/m ² /yr)
Detached 3-bedroom bungalow (baseline)	1	200	55
3-storey apartment block (baseline)	12	100	98
Proposed Design (simulated)	6	193	79.94

Baseline data from Arup & Genre (2016); simulation by Author, 2025

The simulation outcomes indicate that integrating biophilic principles into high-rise residential design can support measurable improvements in energy performance, particularly through passive means such as natural ventilation, daylight access, and green infrastructure. These findings highlight the potential for biophilic strategies to contribute not only to environmental responsiveness but also to energy efficiency goals in residential developments within Abuja's climate context. While the results are specific to the proposed design, they provide a foundation for further exploration into the broader applicability of such approaches.

Practical Strategies for Implementing Biophilic Design in Abuja's High-Rise Residential Projects

Building on these findings, several strategies emerged for integrating biophilic design into Abuja's high-rise residential projects. Vertical greenery systems on facades, balcony planters and green ledges were identified as effective for cooling, reducing heat gain and enhancing resident interaction with nature. Internal atria and shared green spaces can improve daylight penetration and natural ventilation, while private balconies with integrated planters offer personal retreats that support passive cooling. Rooftop gardens provide additional benefits such as urban agriculture, relaxation and stormwater management. Finally, careful building orientation and cross ventilation design during the early planning stage were highlighted as critical for reducing dependence on mechanical systems. Together these strategies form a practical road map for architects and developers to enhance energy efficiency while improving residents' well-being in Abuja's high-rise buildings.

CONCLUSION

This study examined how biophilic design principles can be integrated into high-rise residential developments in Abuja to enhance energy efficiency within a hot, humid tropical climate. Drawing from international and local case studies, it demonstrated how strategies such as natural ventilation, enhanced daylighting, green balconies, and integrated greenery can meaningfully reduce energy demand while improving occupant comfort and connection to nature. Energy simulation of the proposed design revealed an approximate 24% reduction in Energy Use Intensity compared to an established benchmark, highlighting the potential of these strategies to address Abuja's energy challenges. By tailoring these approaches to local conditions, the research fills a critical knowledge gap and contributes to environmentally responsive and climate adaptive urban housing models in Sub-Saharan Africa.

Building on these findings, several recommendations can emerge for future practice and research. Integration of vertical greenery systems on facades, balcony planters, and rooftop gardens should be encouraged as they enhance passive cooling and biodiversity. Private green balconies and water-efficient irrigation systems using locally adapted plants should be prioritised to balance energy, health, and sustainability goals. Long-term monitoring of such interventions and analysis of occupant behaviour can provide evidence for refining design guidelines, while cost-benefit studies can support wider adoption of biophilic features in high-rise residential projects.

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Rethinking Construction: Advancing Sustainable Materials and Circular Practices in Urban Areas of Nigeria

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ABSTRACT

The construction sector is a major contributor to greenhouse gas emissions and resource depletion globally, and Nigeria's accelerating urbanization makes a transition to low-carbon, resource-efficient practices urgent. This paper synthesizes current evidence on three priority pathways for Nigeria: (1) substitution of high-impact conventional materials with locally available, renewable or recycled alternatives (bamboo, compressed earth blocks, and recycled aggregates/plastic-derived bricks); (2) adoption of circular design and delivery strategies (modular/offsite manufacture, design for disassembly, and life-cycle planning); and (3) governance and market instruments to scale pilots to mainstream practice. Using a mixed-methods narrative review and focused case analyses drawn from documented Nigerian pilots and practitioner reports, the paper shows that sustainable materials and circular practices can reduce embodied carbon and construction cost while improving local resilience — but regulatory, technical and market barriers remain. Practical recommendations include adoption of whole-life carbon assessment in procurement, targeted pilot procurement and capacity building, and development of national material standards and testing protocols for alternative materials.

Keywords: sustainable construction; circular economy; compressed earth blocks; bamboo; recycled aggregates; whole-life carbon; Nigeria

INTRODUCTION

Population growth and urbanization in Nigeria are driving an urgent need for scalable, affordable housing and infrastructure. Conventional construction materials and practices especially heavy reliance on cement, steel and sandcrete blocks — are energy-intensive, supply-vulnerable and environmentally damaging (high embodied emissions, resource depletion and significant waste streams). A circular built-environment approach that prioritizes material efficiency, reuse and lifecycle planning offers an opportunity to decouple housing delivery from the worst environmental impacts while supporting local supply chains and affordability (Allwood *et al.*, 2011).

This paper argues that three interconnected actions are required in Nigerian urban contexts:

- a. Prioritize low-impact, locally available materials where appropriate (for example; bamboo, compressed earth blocks, recycled aggregates/plastic bricks);
- b. Embed circular practices in project delivery (modular/offsite manufacture, design for disassembly, and whole-life planning); and
- c. Strengthen governance, standards and incentives to move pilots into widely accepted practice.

The analysis combines a targeted literature review with case synthesis and policy analysis to produce actionable recommendations for practitioners, policymakers and city managers.

LITERATURE REVIEW

Circular economy and material efficiency in construction

Material efficiency and circular economy frameworks emphasize extending product life, reusing components, designing with less and circulating materials at high value (Allwood *et al.*, 2011). For the built environment these frameworks have been linked to large potential emissions reductions: major international analyses indicate that circular strategies could reduce embodied CO₂ from building materials substantially by mid-century and deliver economic benefits from avoided raw material demand and new circular businesses. The Ellen MacArthur Foundation frames the sector transition around eliminate-circulate-regenerate principles and estimates large abatement potential when material reuse, recycled content and longevity are widely applied.

Whole-life carbon assessment and lifecycle practice

Measuring whole-life carbon (embodied + operational) is essential to compare alternative materials fairly. ISO 14040 (LCA framework) and professional standards such as the Royal Institution of Chartered Surveyors' Whole Life Carbon Assessment provide frameworks and reporting templates for consistent assessment, enabling procurement and regulatory decisions that reward low-carbon choices.

Evidence on alternative materials and circular practices

Peer-reviewed and practice literature shows promising technical and economic performance of certain low-impact materials where locally appropriate: bamboo (Adetunji *et al.*, 2015), compressed earth blocks (Iwuagwu & Onyegiri, 2023), and recycled aggregates/plastic-derived bricks (AZoBuild, 2025). At the delivery level, modular/offsite manufacturing and design for disassembly reduce on-site waste, improve quality control and make future component recovery feasible; however, these approaches require new skills, initial capital and supportive procurement to flourish (Kolo *et al.*, 2016).

Barriers identified in the literature

Common constraints include limited technical standards and testing protocols for alternative materials, weak supply chains and industrial capacity, perceived higher upfront costs, insufficient client confidence and gaps in national regulation and procurement that favour conventional materials. Overcoming these barriers requires coordinated action across standards bodies, government procurement, and industry training and demonstration-scale public projects.

METHODOLOGY

This study uses a mixed-methods, pragmatic approach to produce actionable evidence for conference audiences:

Narrative review

Systematic searches were conducted in Google Scholar, Scopus and sector reports (2000–2025) using keywords such as 'compressed earth blocks Nigeria', 'bamboo construction Nigeria', 'circular economy-built environment', 'recycled aggregates Africa', and 'offsite construction Nigeria'. Priority was given to peer-reviewed studies, conference proceedings, government reports and well-documented pilot projects.

Case synthesis

Documented Nigerian pilot projects and practitioner reports (including the Avu–Owerri CEB project; bamboo classroom pilots; and recycled material pilots reported in regional media and practitioner outlets) were synthesized to extract unit cost estimates, reported performance, enabling conditions and constraints. These Nigerian case materials and original project reporting were drawn from the author's submitted manuscript and underpin the examples cited here.

Standards and policy scan

International standards (ISO 14040 for LCA) and professional guidance (RICS WLCA) were reviewed to identify measurement and procurement levers that can be applied in Nigerian contexts.

Case syntheses and comparative analysis

Compressed earth blocks — Avu–Owerri example (Imo State)

Documented reporting on the Avu–Owerri demonstration indicates that well-designed and constructed CEB houses can achieve thermal comfort and durability with substantially lower embodied energy and cost compared with sandcrete block alternatives; reported unit costs are approximately half those of comparable conventional units in the project reporting (Iwuagwu & Onyegiri, 2023).

Bamboo prototypes (classroom pilots)

Classroom prototype work in southwestern Nigeria shows that locally sourced, treated bamboo elements can produce robust structural and non-structural assemblies at lower cost and embodied energy than imported mild steel solutions for small spans (Adetunji et al., 2015).

Recycled aggregates and plastic bricks (regional pilots)

Regional pilot projects and industry reporting highlight opportunities to convert post-consumer plastic and construction demolition waste into engineered blocks/bricks and aggregate substitutes for specified non-critical uses (Ajayi, 2024).

Modular/Offsite Construction

Although still in its infancy in Nigeria, offsite manufacturing (OSM) is recognized for its potential to reduce onsite waste, shorten construction timelines, and enable design for disassembly. Feasibility studies recommend awareness campaigns, workforce training, and policy support to address industry reluctance and supply constraints (Kolo et al., 2016).

Table 1: Comparative table

Material / Approach	Typical benefits	Key constraints	Best use case (Nigeria)	Example Source
CEB (compressed earth blocks)	Low embodied energy, thermal mass, low cost	Quality control, soil variability, limited codes	Low-rise housing, community facilities	Iwuagwu & Onyegiri (2023).
Bamboo	Renewable, low embodied carbon, high strength-to-weight	Treatment, detailing, supply chains	Classrooms, pavilions, lightweight roofs	Adetunji et al. (2015).
Recycled plastic bricks	Waste diversion, resource savings	Testing, long-term durability data	Infill walls, non-critical masonry	AZoBuild (2025).
Modular Offsite	Waste reduction, faster delivery	Capital, skills, logistics	Social housing, standardized repeatable units	Kolo et al. (2016).

DISCUSSION

why scale-up is achievable (and what's needed)

International analyses suggest substantial abatement and economic opportunity from circular strategies in the built environment if implemented at scale; circular interventions can reduce demand for cement, steel and virgin aggregates and generate new local value chains. Applying these lessons locally requires adapting global standards to Nigerian contexts, leveraging public procurement as an early market, and committing to measurement via WLCA/LCA to ensure decisions reduce whole-life impacts rather than shifting burdens.

Key enablers for Nigeria include measurement and procurement (adopt WLCA-aligned requirements for pilot public projects), standards & testing (develop national testing protocols for CEBs and bamboo), supply chain & skills (invest in localized production hubs and technical training), policy & incentives (targeted procurement, tax incentives), and social acceptance (visible demonstrations and transparent monitoring).

Policy recommendations (practical, short-term to medium-term)

Pilot procurement programme

Commission a 12–24-month pilot program for low-income housing and public facilities that require WLCA reporting and use at least one low-embodied-carbon material (CEB, bamboo or recycled aggregate solutions).

Adopt WLCA in public tenders

Require whole-life carbon reporting for larger public building tenders using WLCA templates consistent with RICS guidance.

Standards & testing initiative

Launch a national standards and testing programme for CEB strength/durability, bamboo treatment protocols, and recycled material leachate/durability tests.

Capacity building & certification

Fund short-course training and certification for local manufacturers, site supervisors and architects in circular construction techniques, modular manufacture and LCA basics.

Finance & incentives

Offer tax relief or concessional financing for firms that create domestic supply chains for low-carbon materials and that commit to procurement of recycled inputs.

Limitations and research agenda

This study synthesizes documented reports and peer-reviewed sources but does not present a new primary LCA or exhaustive cost database. Reported unit-cost and embodied-carbon advantages vary by site, design and local inputs, so full WLCA studies and standardized cost comparisons are necessary to validate claims at scale.

Future research priorities include conducting project-level WLCA and life-cycle cost analyses for representative Nigerian building typologies, longitudinal post-occupancy evaluations of pilot projects, and market studies on supply-chain development and willingness-to-pay for low-carbon housing in urban Nigeria.

CONCLUSION

Sustainable materials (bamboo, CEBs, recycled aggregates/plastic-derived bricks) combined with circular design and delivery strategies (modular construction, design for disassembly and WLCA-led procurement) present practical pathways to reduce embodied carbon, cut costs and expand access to resilient housing in Nigerian cities. Immediate action — beginning with WLCA-informed public pilot procurement, national testing and training programmes — will translate promising pilots into mainstream practice.

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Integration of Green Roofs for Sustainable Urban Office Buildings: A Strategy for Urban Heat Island (UHI) Mitigation and Energy Efficiency Enhancement

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ABSTRACT

The urban heat island (UHI) phenomenon has emerged as one of the most pressing environmental challenges confronting contemporary cities. Its direct influence on the thermal comfort of office building occupants, and on the energy demands of commercial buildings more broadly, has made it an urgent concern for architects, urban planners, and policymakers alike. This study examines the strategic deployment of green roof systems in sustainable urban office buildings as a viable and evidence-based response to both UHI mitigation and the imperative for enhanced energy efficiency. Drawing on a mixed-methods research framework that combines systematic literature review, comparative case study analysis, and quantitative performance evaluation, the investigation reveals that extensive green roof systems are capable of reducing rooftop surface temperatures by between 15°C and 40°C, while simultaneously cutting building energy consumption by 10 to 30 percent. Economic analysis further demonstrates that, under favourable conditions, green roof investments achieve payback periods of between 7 and 15 years, and generate a range of ancillary benefits including appreciable increases in property value, reduced municipal infrastructure expenditure, and measurable improvements in worker productivity. The study delineates the critical design parameters that govern green roof performance, maps the principal implementation challenges that practitioners encounter, and evaluates the policy frameworks that have proven most effective in facilitating large-scale adoption. The findings suggest that the deliberate and strategic placement of green roofs across urban office districts in cities such as Minna, Niger State, can materially reduce ambient UHI intensity, strengthen climate resilience, and advance the broader goals of sustainable urban development. The paper concludes with targeted recommendations for architects, urban planners, building developers, and legislators seeking actionable pathways to integrate green infrastructure solutions into the existing urban fabric.

Keywords: Green roofs; Urban heat island; Sustainable buildings; Energy efficiency; Office buildings; Climate resilience; Nature-based solutions; Urban sustainability

INTRODUCTION

Cities across the world are grappling with an environmental paradox of their own making. As urban populations grow and built environments expand, the very infrastructure that sustains modern life is simultaneously generating conditions that undermine it. Nowhere is this tension more evident than in the urban heat island (UHI) effect a well-documented phenomenon in which densely developed urban areas register significantly higher ambient temperatures than the surrounding rural and peri-urban landscapes (Golestani et al., 2024). The differential, which typically ranges from 1°C to 7°C and is most pronounced during summer nights, arises from a convergence of factors: the proliferation of heat-absorbing impervious surfaces, the suppression of natural vegetation, altered wind circulation patterns, and the continuous discharge of anthropogenic heat from buildings, vehicles, and industrial processes (Saher et al., 2021). As global temperatures continue to rise, the compounding interaction between baseline warming and localised UHI intensity is amplifying the frequency and severity of urban heat events, with cascading consequences for public health, infrastructure resilience, and ecological function (Brimicombe, 2023).

Office buildings occupy a central and largely underexamined role in both the creation and potential amelioration of the UHI effect. As major consumers of energy and generators of waste heat, commercial buildings collectively account for approximately 40 percent of total energy consumption and 36 percent of global CO₂ emissions, with heating, ventilation, and air conditioning (HVAC) systems alone responsible for between 40 and 60 percent of energy use in typical office environments (Min et al., 2022). The large, exposed roof surfaces of commercial buildings represent a significant but underutilised opportunity: conventional roofing materials absorb solar radiation intensely, driving rooftop surface temperatures well above ambient air temperature and contributing to the thermal loading of the urban canopy layer. Addressing this specific vulnerability through targeted design interventions has the potential to yield benefits that extend far beyond the building boundary (Hashemi & Mills, 2025).

Green roof systems have attracted growing scientific and policy interest precisely because they address this challenge through a suite of mutually reinforcing mechanisms. By introducing a vegetated layer above the building envelope, green roofs provide shade, facilitate evapotranspiration-based cooling, and create a thermal buffer that reduces heat transfer through the roof structure. Beyond these thermal functions, green roofs contribute to stormwater attenuation, biodiversity enhancement, urban air quality improvement, and the psychological wellbeing of building users (Mihalakakou et al., 2023). Technological developments in lightweight growing media, advanced waterproofing membranes, and drought-tolerant plant selection have substantially broadened the range of building types and climatic contexts in which green roofs can be viably implemented (Zaina, 2023). This convergence of environmental performance, economic rationale, and technological feasibility positions the green roof not merely as an architectural amenity, but as a strategic instrument of sustainable urban development (Tycho, 2025).

This paper investigates the integration of green roof systems into urban office buildings in the context of Minna, Niger State, Nigeria, with the dual aim of reducing UHI intensity and improving building energy efficiency. It evaluates thermal performance outcomes, economic returns, environmental co-benefits, and implementation considerations, and

situates its findings within a broader framework of climate-responsive urban design. The research is intended to inform the decisions of architects and building designers, as well as the policy positions of urban planners and legislators seeking to embed nature-based solutions within the regulatory and incentive structures that shape urban development.

LITERATURE REVIEW

The Urban Heat Island Effect and Office Buildings

The literature on urban heat islands has established with considerable consistency that the built environment is both a primary driver of the UHI phenomenon and the domain in which its consequences are most acutely felt. The relationship between office buildings and UHI operates through several interlocking pathways. Surface material characteristics particularly the low albedo and high thermal mass typical of conventional commercial roofing determine how much solar energy is absorbed and subsequently re-emitted as longwave radiation. Urban morphology, including the orientation, density, and height of building masses, governs air circulation patterns and the extent to which longwave radiation is trapped within street canyons (Ziaemehr *et al.*, 2023). Under summer conditions, conventional flat rooftops used in commercial construction can reach surface temperatures exceeding 70°C, directly elevating ambient air temperatures in the surrounding urban environment and driving up the cooling energy demands of buildings already operating under thermal stress (Tian *et al.*, 2023).

This dynamic creates a particularly problematic feedback loop in dense urban office districts. As ambient temperatures rise, buildings consume more energy for cooling; as more energy is consumed, more waste heat is discharged into the urban environment; and as the urban environment warms further, cooling demands increase still further (Ren *et al.*, 2021). Breaking this cycle requires interventions at the building scale that reduce the thermal interaction between individual buildings and their immediate environment a challenge for which green roof systems are increasingly regarded as one of the most promising responses.

Roof Systems and Thermal Performance

Green roofs function as engineered ecosystems that modify the thermal behaviour of building envelopes through several complementary mechanisms. The growing medium absorbs solar radiation, reducing the quantity of heat transmitted to the underlying roof structure. The vegetation layer intercepts direct sunlight and, crucially, dissipates absorbed energy through evapotranspiration rather than re-emitting it as sensible heat a process that provides continuous passive cooling without energy input. The substrate and plant layers together act as a thermal insulator, attenuating temperature fluctuations at the roof membrane and reducing heat flux into and out of the building interior (Nasr *et al.*, 2024). Modelling studies projecting forward to 2100 suggest that, under scenarios of continued urban growth and climate warming, green roofs could reduce HVAC energy consumption in commercial buildings by as much as 65.51 percent compared with conventional roofing (Song & Chen, 2025). While such long-range projections carry uncertainty, they underscore the magnitude of the potential contribution that green roof technology can make to building energy performance over its operational lifetime.

Typologies and Design Considerations

Green roof systems are conventionally classified into extensive, semi-intensive, and intensive typologies, each defined by substrate depth, plant diversity, structural load requirements, and maintenance intensity. Extensive systems employ shallow substrates typically between 60mm and 150mm planted with drought-tolerant, low-growing species such as sedums and mosses. They impose relatively modest additional structural loads and require minimal maintenance once established, making them the most common choice for retrofit applications and for buildings where structural capacity is a primary constraint (Edelman, 2025). Intensive systems, by contrast, feature deeper substrates capable of supporting a diverse range of plant species, including shrubs and, in some cases, trees. They offer richer ecosystem services, greater aesthetic flexibility, and the possibility of creating accessible rooftop amenity spaces, but require substantially greater structural capacity, maintenance input, and capital investment. Semi-intensive systems occupy a middle position, balancing moderate maintenance requirements with enhanced ecosystem service delivery relative to extensive systems (Hirlav, 2024).

Beyond these established typologies, innovation in green roof design has produced hybrid configurations that expand the performance envelope of conventional systems. Blue-green roofs integrate water retention capacity with the vegetated surface, using controlled drainage mechanisms to maintain moisture availability during dry periods and thereby sustaining the evapotranspiration cooling function. Modular systems in which pre-vegetated trays or cassettes are used rather than in-situ substrate installation offer advantages in installation flexibility, ease of maintenance access, and adaptability to irregular roof geometries (Ismael *et al.*, 2024). The selection of an appropriate typology for a given office building project requires careful evaluation of structural capacity, climatic context, budget, maintenance provision, and the relative priority of different performance objectives.

Energy Performance and Economic Benefits

The energy performance benefits of green roofs in office buildings are well supported by empirical evidence and simulation-based modelling. During summer months, the principal benefit accrues from the reduction of cooling loads through rooftop shading and evapotranspiration. During winter months, the substrate and vegetation layer provides supplementary insulation that reduces heat loss through the roof, contributing to heating energy savings of between 5 and 15 percent (Juras, 2022). The magnitude of energy savings varies with climate severity, building envelope

characteristics, HVAC system type, and green roof design parameters; however, the literature consistently identifies the reduction of peak cooling demand which can reach 15 to 40 percent under severe weather conditions as a particularly significant benefit, since peak demand reduction has direct implications for grid stability and the sizing of utility infrastructure.

The economic case for green roof investment in office buildings is multidimensional. Direct financial returns arise from energy cost savings and the extension of roof membrane lifespan that results from reduced thermal cycling and UV exposure. Indirect benefits include reduced stormwater management costs particularly in urban areas where combined sewer overflow is a concern as well as higher rental values and property prices attributable to the sustainability credentials and amenity value that green roofs confer on the buildings they serve. Evidence also suggests that the presence of greenery and biophilic design elements in the workplace environment is associated with improvements in worker productivity and wellbeing, generating further economic value for building occupants (Khamis, 2024). When these multiple benefit streams are aggregated over the service life of a green roof system typically estimated at between 40 and 60 years the investment case becomes considerably more compelling than a simple calculation of energy savings alone would suggest.

Implementation Challenges and Barriers

Despite the demonstrated performance and economic benefits of green roofs, their adoption in urban office buildings remains constrained by a range of technical, economic, regulatory, and institutional barriers. At the technical level, the most significant challenges relate to structural capacity particularly for retrofit applications on existing buildings not originally designed to accommodate the additional dead load of a vegetated roof system waterproofing integrity, root barrier performance, and the complexity of integrating green roof systems with existing building drainage and HVAC infrastructure (Senarathne et al., 2023). Long-term maintenance requirements, particularly in relation to plant establishment, irrigation management during drought periods, and periodic substrate replacement, represent a further operational consideration that must be incorporated into project planning and budgeting from the outset.

At the economic and regulatory level, the primary barriers are the relatively high upfront capital costs of green roof installation, the uncertainty that often surrounds the quantification and realisation of indirect benefits, and the absence in many jurisdictions of building codes, planning requirements, or financial incentive structures that recognise and reward green roof integration. The effective removal of these barriers requires coordinated action across multiple domains: research institutions must develop and disseminate the performance data needed to underpin the business case; industry stakeholders must standardise installation practices and maintenance protocols; and policymakers must design regulatory frameworks and financial instruments that reflect the public benefits that green roofs generate.

METHODOLOGY

Research Approach and Framework

This study adopts a mixed-methods research framework designed to generate both breadth and depth of insight into the integration of green roofs in urban office buildings. The research combines three complementary methodological strands: a systematic review of peer-reviewed and grey literature on UHI mitigation, green roof technology, and sustainable office building design; a comparative case study analysis drawing on documented examples of green roof implementation in a range of urban and climatic contexts; and a quantitative performance evaluation that synthesises published empirical data on thermal performance, energy consumption, and economic outcomes. The methodological approach was selected to accommodate the multi-dimensional nature of the research problem, which spans physical, economic, environmental, and policy domains that no single method would adequately capture.

The literature review was structured to capture the most current state of knowledge, with particular emphasis on advancements in green roof technology and UHI mitigation strategy published within the preceding five years. The case study analysis was designed to illuminate the relationship between design parameters, implementation context, and performance outcomes, and was structured to encompass both new-build and retrofit scenarios to ensure the relevance of findings across the full spectrum of practical application.

Data Collection and Analysis

Quantitative data collection focused on four primary categories of performance indicator: thermal performance metrics (including rooftop surface temperature differentials and ambient air temperature reductions attributable to green roof coverage); energy consumption data (including annual HVAC energy savings and peak cooling demand reductions); economic indicators (comprising capital costs, maintenance costs, energy cost savings, and payback periods); and environmental impact measurements (including stormwater retention rates, carbon footprint reduction, and air quality improvement indices).

Economic analysis was conducted using life cycle cost assessment methods that account for both direct and indirect benefit streams over the projected 40- to 60-year service life of green roof systems. Life cycle assessment methodologies were also employed to evaluate the net environmental benefits of green roof integration relative to conventional roofing alternatives, taking into account the embodied energy and carbon associated with green roof installation as well as the operational benefits that accrue over the system's life.

RESULTS AND ANALYSIS

Thermal Performance and UHI Mitigation

The evidence base assembled through this study provides a consistent and compelling picture of the thermal performance benefits that green roofs deliver in the context of urban office buildings. During peak summer conditions, green roofs achieve rooftop surface temperature reductions of between 15°C and 40°C relative to conventional roofing materials, a differential that reflects both the direct shading effect of the vegetated surface and the latent heat dissipation associated with evapotranspiration. The magnitude of this reduction is influenced by substrate moisture content and therefore by precipitation patterns and supplementary irrigation as well as by the density and growth habit of the plant community.

The implications of these building-scale thermal effects extend to the wider urban environment. Urban-scale modelling studies indicate that in office districts where green roof coverage reaches between 20 and 30 percent of available roof area, mean ambient air temperatures can be reduced by between 0.5°C and 1.5°C, with localised cooling effects exceeding 2°C in the immediate vicinity of densely vegetated rooftops. These reductions are most pronounced during afternoon and evening periods, precisely the timeframe when urban heat stress is most acute and the demand for mechanical cooling is at its peak. Importantly, the evapotranspiration-based cooling mechanism of green roofs persists into the evening hours in contrast to the rapid re-emission of stored heat that characterises conventional rooftops providing a more sustained thermal benefit to the surrounding urban environment.

Energy Performance and Efficiency Gains

The thermal performance benefits described above translate directly into quantifiable improvements in building energy efficiency. The analysis found that office buildings equipped with green roofs achieve annual HVAC energy savings of between 10 and 30 percent, a range that reflects the substantial variability in climate severity, building envelope characteristics, HVAC system type, and green roof design parameters across the cases examined. In climates characterised by hot summers and high solar radiation intensity conditions broadly representative of the Nigerian context savings tend toward the upper end of this range, particularly when green roof installation is combined with other passive design strategies that reduce the building's baseline cooling load.

Peak cooling demand reductions of between 15 and 40 percent under severe weather conditions represent a finding of particular significance for utility infrastructure planning and grid management, as peak demand is the primary driver of generation and transmission capacity requirements. The additional insulation provided by the substrate and plant layer also delivers meaningful heating energy savings of between 5 and 15 percent per heating season a benefit of greater relevance in temperate and sub-tropical climates than in the hot-arid or hot-humid contexts typical of much of Nigeria, but one that should nonetheless be incorporated into whole-life energy assessments. Across the range of cases examined, annual energy cost savings per unit of green roof area ranged from USD 0.50 to USD 2.00 per square foot, with the highest returns associated with the most energy-intensive buildings in the most severe climatic conditions.

Economic Analysis and Return on Investment

Initial capital costs for green roof installation in the office building sector range from approximately USD 8 to USD 25 per square foot, reflecting the considerable variation in system typology, substrate depth, plant selection, structural modification requirements, and local labour and material costs. Under conditions that combine high energy costs, a supportive policy environment, and a climate that maximises cooling energy savings, payback periods of between 8 and 15 years are achievable. In contexts where supportive policy mechanisms including capital grants, tax credits, or stormwater fee reductions are available, payback periods can be shortened materially.

Beyond energy savings, the economic case for green roofs in the office building context is reinforced by evidence of property value enhancement. Buildings incorporating high-performance green roof systems have been found to command property value premiums of between 5 and 15 percent relative to otherwise comparable properties, reflecting both the reduced operating costs they offer tenants and the reputational and branding value that sustainability credentials provide to occupiers. The extension of roof membrane lifespan that results from the protective function of the green roof substrate reducing the degrading effects of UV radiation and thermal cycling further strengthens the economic case by deferring what is, in conventional buildings, a significant capital expenditure. Taken together, these multiple benefit streams make a compelling financial case for green roof integration that extends well beyond the energy savings calculation alone.

Environmental Co-benefits

The environmental benefits associated with green roof systems extend considerably beyond the direct energy and UHI mitigation effects that constitute the primary focus of this study. Stormwater management represents one of the most consistently documented co-benefits: by retaining between 40 and 80 percent of annual precipitation within the substrate layer, green roofs reduce the volume and peak flow rate of stormwater runoff entering urban drainage networks, thereby lowering the risk of localised flooding and combined sewer overflow during intense rainfall events. In rapidly urbanising contexts such as Minna, where drainage infrastructure may not have kept pace with the rate of built environment expansion, this benefit has immediate and practical significance.

The contribution of green roofs to urban air quality improvement, while less easily quantified than stormwater or energy benefits, is nonetheless material. The vegetation layer generates oxygen, filters airborne particulate matter, and sequesters atmospheric CO₂, contributing modestly but measurably to the improvement of ambient air quality in the surrounding urban environment. In densely developed office districts where traffic-related air pollution and the re-

suspension of particulate matter from impervious surfaces are ongoing concerns, the aggregated effect of widespread green roof coverage can provide a meaningful supplement to other air quality management measures. Additionally, the creation of vegetated habitat on otherwise impervious rooftop surfaces contributes to urban biodiversity by providing refuge and foraging opportunities for invertebrates and birds.

Implementation Success Factors

The analysis of case study evidence identified a set of factors that consistently distinguish successful green roof implementations from those that underperform or fail to deliver their projected benefits. Early integration of green roof design within the overall building design process emerged as the most critical success factor: projects that incorporate the green roof from the conceptual design stage are able to optimise structural design, drainage integration, HVAC configuration, and maintenance access in a coordinated and cost-effective manner, whereas retrofit projects must navigate the constraints imposed by existing building fabric at considerably greater cost and complexity. Plant selection proved to be another determinant of long-term performance. In climatic contexts characterised by seasonal drought which is highly relevant to the semi-arid conditions of Minna the preference for native species with demonstrable drought tolerance not only reduces maintenance requirements and supplementary irrigation demand, but also maximises the ecological integrity and resilience of the green roof plant community. Engagement of qualified horticulturalists and landscape architects in both the design and establishment phases has been found to substantially improve plant survival rates and ecological functionality. Finally, robust maintenance planning including the scheduling and resourcing of regular inspection, irrigation, substrate replenishment, and plant replacement is essential to ensure that the performance characteristics demonstrated at commissioning are sustained over the full operational life of the system.

DISCUSSION

The findings of this study confirm that the integration of green roof systems into urban office buildings represents a viable and multi-beneficial strategy for addressing the compounding challenges of UHI intensity, building energy consumption, and climate resilience. What distinguishes green roofs from many other proposed urban sustainability interventions is the breadth and simultaneity of the benefits they deliver: a single design decision creates positive effects across the thermal, energy, economic, environmental, and social dimensions of building performance. This multi-functionality is particularly significant in resource-constrained contexts where the opportunity cost of investment is high and where decision-makers require robust justification for departing from established construction practice.

The emergence of smart monitoring and control technologies represents a significant opportunity to enhance green roof performance beyond what is achievable through passive design alone. Soil moisture sensors, weather-responsive irrigation controllers, and building management system integration can optimise substrate moisture content the primary determinant of evapotranspiration rate and therefore of cooling performance in real time, ensuring that the green roof operates at or near its thermal performance potential even during extended dry periods. Internet of Things integration further enables remote condition monitoring and predictive maintenance scheduling, reducing the operational cost and management burden associated with large-scale green roof portfolios while generating the performance data needed to support continuous improvement and evidence-based policy development.

The role of policy frameworks in enabling and accelerating green roof adoption deserves particular emphasis. Even where the technical case for green roof integration is well established and the economic returns are demonstrably favourable over reasonable time horizons, adoption will remain limited without supportive regulatory and financial structures. Building codes that formally recognise and accommodate green roof systems, planning requirements that incentivise or mandate green roof integration in new commercial developments above a certain scale, and financial instruments that reduce the upfront cost burden whether through capital grants, accelerated depreciation allowances, or stormwater fee reductions all have documented roles in driving market transformation. The experience of cities that have successfully implemented green roof programmes at scale demonstrates that the combination of regulatory clarity and financial incentive is consistently more effective than either mechanism in isolation.

Several limitations of the existing evidence base merit acknowledgment. The volume of long-term performance monitoring data for green roof systems particularly in tropical and sub-Saharan African climatic contexts directly comparable to Minna remains limited, and the majority of the empirical literature has been generated in European and North American settings where climate, building typology, and construction industry practice differ substantially from those prevailing in north-central Nigeria. Design guidelines developed in these contexts cannot be applied uncritically to the local setting; site-specific adaptation, informed by local climate data and building performance monitoring, is essential. Standardised performance measurement and reporting frameworks would materially strengthen the evidence base and facilitate more reliable cross-context comparison.

CONCLUSION

This study has demonstrated that the integration of green roof systems into urban office buildings constitutes a technically sound, economically viable, and environmentally significant strategy for mitigating the urban heat island effect and improving building energy performance. When designed and executed with attention to local climatic conditions, structural constraints, and long-term maintenance requirements, green roofs can reduce rooftop surface temperatures by between 15°C and 40°C, cut building cooling energy consumption by between 10 and 30 percent,

and contribute to meaningful reductions in ambient air temperature at the urban district scale. Economic analysis confirms that, under favourable conditions, these systems generate positive financial returns with payback periods of between 8 and 20 years, and deliver additional value through property appreciation, stormwater cost reduction, and productivity enhancement.

The broader significance of green roof integration lies in its contribution to the climate adaptation and mitigation objectives that define the agenda of sustainable urban development. As cities like Minna continue to grow and as the intensity of climate-related heat stress increases, the imperative to embed nature-based solutions within the built environment and specifically within the commercial building sector that dominates urban energy consumption will only become more urgent. Green roofs are not a panacea, and their effectiveness depends critically on appropriate design, quality installation, sustained maintenance, and enabling policy. But the growing body of evidence reviewed in this study, combined with the expanding market viability of green roof technology, provides a compelling basis for their recommendation as a core element of sustainable urban office building strategy.

RECOMMENDATIONS

On the basis of the evidence reviewed and the analysis conducted, this study advances the following recommendations for practitioners, policymakers, and researchers engaged with green roof integration in urban office buildings: Green roof design for urban office buildings should be **climate-responsive from the outset**, using local data (temperature, rainfall, solar exposure, wind) to guide system type, soil depth, and plant selection. Emphasis should be placed on **native, drought-resistant species** to reduce irrigation and enhance resilience, while integrating structural, drainage, HVAC, and maintenance considerations within a coordinated design process handled by experienced contractors. For developers, **economic viability depends on a life-cycle approach**, capturing not just energy savings but also extended roof lifespan, reduced stormwater costs, increased property value, and improved occupant productivity. Incentives such as rebates, credits, and green certifications can further strengthen returns. Policymakers should establish **supportive regulatory frameworks and financial incentives** to offset high upfront costs, using region-specific climate data to tailor policies effectively. Researchers are needed to fill key gaps, particularly through **long-term performance studies in tropical regions**, standardized evaluation methods, and deeper investigation into retrofit integration challenges, to strengthen evidence for wider adoption.

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Enhancement of Indoor Air Quality Through Passive Design Strategy in Visualization Research Centre Abuja, Nigeria

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ABSTRACT

Visualization centres a type of research facility, depend on high-performance computing and advanced display systems, but face good indoor air quality challenges from equipment heat and volatile organic compounds emissions. Maintaining good indoor air quality is therefore crucial to preserve visual acuity and cognitive performance, which are vital for effective use of visualization technologies and collaborative research. This study examined Abuja's climate the location of the study area and its impact on indoor air quality, evaluates passive design strategies, and proposes a visualization research centre that enhances comfort and sustainability. The study concludes that inadequate passive design reduces indoor air quality in Abuja, while strategies like orientation, ventilation, and biophilic elements can enhance comfort and reduce mechanical cooling. The proposed visualization research centre serves as a sustainable model for research facilities in the hot-dry climate. This study shows that climate-responsive use of ventilation, solar control, and vegetation can greatly enhance indoor environmental quality. It reduces dependence on energy- intensive systems while promoting occupant health and comfort. The findings offer a practical framework for the proposed centre's design. They also serve as a transferable model for similar buildings in Abuja and other hot-dry tropical regions.

Keywords: Visualization, Passive design strategies, Indoor air quality, Volatile organic compounds, Biophilic elements.

INTRODUCTION

Indoor Air Quality (IAQ) is a crucial factor for safeguarding human health, productivity, and overall well-being within built environments, particularly in spaces intended for intellectual engagement and research activities (Nimlyat et al., 2023). Poor IAQ, often resulting from elevated levels of pollutants such as particulate matter, volatile organic compounds (VOCs), and biological contaminants, has been linked to numerous health problems, including respiratory conditions, allergic reactions, headaches, and reduced cognitive efficiency (Zhang et al., 2021). These concerns are especially significant in research facilities, where maintaining optimal environmental quality is essential for both occupant wellness and sustained performance.

Research centres, as hubs of innovation and knowledge generation, face distinctive IAQ challenges. High occupancy levels, specialized equipment, and laboratory operations frequently contribute to increased pollutant loads (Tham, 2016). Given that research often involves the use of chemicals, electronics, and other emission-generating materials, proactive IAQ management becomes vital to protect researchers and staff while supporting productivity. Visualization centres, a specific type of research facility, depend on advanced computing systems, immersive displays, and collaborative environments. The technological infrastructure of these centres generates substantial heat and may emit VOCs from equipment and building materials (Nandan et al., 2021). Since visualization requires high visual acuity and cognitive sharpness, IAQ plays a defining role in ensuring the effective operation of these technologies.

The connection between IAQ and visualization performance is therefore fundamental. Empirical studies show that exposure to degraded air quality negatively impacts cognition, visual processing speed, and decision-making ability, all of which are critical for successful interpretation and application of visualization outputs (Du et al., 2020). In this sense, poor IAQ not only undermines occupant health but also diminishes the full potential of visualization technologies in research settings.

Several strategies exist to improve IAQ in such environments, ranging from mechanical ventilation and purification systems to the use of low-emission construction materials (Jarrahi et al., 2024). While effective, these mechanical solutions often demand significant energy inputs. Passive design strategies such as maximizing natural ventilation, implementing effective shading, and incorporating vegetation offer more sustainable and cost-efficient means of improving air quality (Altan et al., 2016). By leveraging natural elements, passive approaches support healthier indoor environments while reducing reliance on energy- intensive systems.

STATEMENT OF RESEARCH PROBLEM

Indoor Air Quality (IAQ) significantly influences occupant health, comfort, and cognitive performance in built environments, particularly in settings that demand extended concentration and precision (Nimlyat et al., 2023; Abdulkareem & Al-Maiyah, 2025). Elevated pollutant levels such as fine particulate matter (PM_{2.5}), volatile organic compounds, and excess CO₂ are associated with respiratory ailments, allergic reactions, headaches, and declines in mental acuity. These issues are magnified in research and visualization centres, where specialized equipment, dense occupancy, and technological infrastructures often contribute additional pollutant emissions and heat build-up, posing both health risks and performance constraints. While mechanical ventilation and air purification systems are frequently deployed to mitigate IAQ problems, their energy demands and maintenance complexity limit their long-term viability in hot-dry climates (Abdulkareem & Al-Maiyah, 2025). Accordingly, recent studies have explored passive design strategies as viable alternatives. Strategies such as building

orientation, natural ventilation, effective shading, window-to-wall ratio optimization, and the integration of vegetation have been shown to reduce indoor temperatures, lower cooling loads, and improve occupant comfort (Abdulkareem & Al-Maiyah, 2025).

In contexts similar to Abuja, these findings are especially relevant. Research in Abuja offices has revealed substantial discomfort levels around 70% in some cases when passive cooling is insufficient, with key contributing factors including lack of operable windows, poor shading, and suboptimal building envelope design (Oluwatayo & Nduka, 2025). Furthermore, systematic reviews of Nigerian architecture indicate that while passive and biophilic strategies demonstrably enhance thermal comfort, IAQ, and energy efficiency, their adoption remains sporadic, hindered by weak regulatory enforcement, high upfront costs, and lack of awareness among stakeholders. Hence, this paper appraised the enhancement of indoor air quality through passive design strategy in visualization research centre Abuja, Nigeria with a view to promote sustainability.

LITERATURE REVIEW

Passive Building Design

Passive design refers to the strategic use of architectural and structural features to reduce reliance on mechanical systems and minimize overall building energy demand. By tailoring the building envelope to local environmental and climatic conditions, passive design ensures that structures are more responsive to their natural context (Ragheb et al., 2015). Central to this approach is passive solar design, which capitalizes on solar energy to regulate indoor temperatures. This is achieved through the thermal properties of construction materials and the careful configuration of openings, shading devices, and spatial layouts to optimize heating, cooling, and daylighting.

When integrated holistically, these strategies function as complementary systems that promote energy efficiency while maintaining indoor comfort and ecological balance. As illustrated in Figure 1, passive design measures are adapted and refined to achieve peak performance within specific climatic settings. Beyond reducing energy consumption, the application of passive strategies contributes significantly to occupant well-being and the broader goals of environmental sustainability.

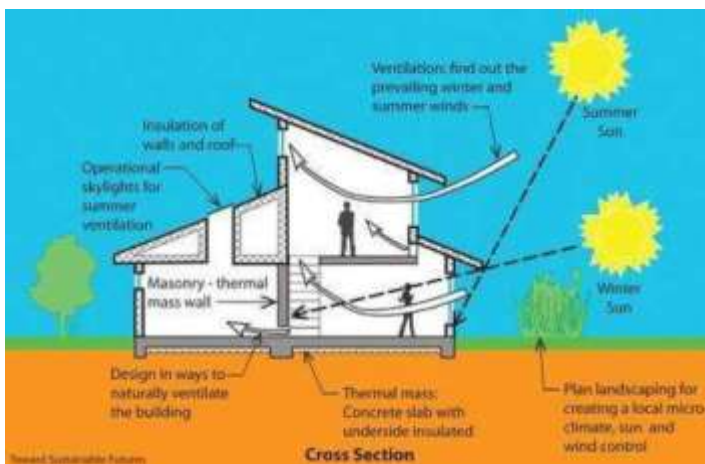


Figure 1: Passive design strategies

Source: Ragheb et al., (2015)

Natural Ventilation in Building

Natural ventilation remains one of the most effective passive strategies for enhancing indoor air quality (IAQ), minimizing energy consumption, and improving thermal comfort in buildings. Recent studies emphasize that ventilation modes including single-sided, cross-ventilation, and stack systems are largely dependent on building orientation, window configuration, and local climatic variables. Advances in computational fluid dynamics (CFD) modelling and wind tunnel testing have enabled a more nuanced understanding of airflow dynamics, allowing designers to optimize ventilation performance during early design stages (Zhang et al., 2024).

The efficiency of natural ventilation is strongly influenced by external conditions such as wind speed, direction, and seasonal variations. Empirical investigations in Nigeria have revealed that spatial configuration and orientation significantly affect both pollutant concentrations and thermal performance in educational and institutional buildings. Seasonal IAQ studies further demonstrate that CO₂, VOCs, and particulate matter fluctuate between dry and wet seasons, with architectural factors such as facade design, window type, and material finishes shaping overall air quality (Ifeanyi et al., 2024). In Abuja, recent scholarship has increasingly emphasized the role of passive design in improving thermal comfort and indoor air quality within the built environment. Abdulkareem and Al-Maiyah (2025) demonstrate that optimizing orientation, shading devices, window-to-wall ratios, and insulation in affordable housing can significantly reduce indoor heat build-up and lower reliance on mechanical cooling. Similarly, Oluwatayo and Nduka (2025) assess passive cooling strategies

in selected office buildings in Abuja, showing that features such as cross-ventilation, shaded openings, and material choices directly enhance occupants' comfort levels. Yusuf and Akande (2023) further highlight a gap in practice, noting that many residential buildings in Abuja are inadequately designed to integrate passive features, resulting in poor environmental performance and reduced indoor air quality. Complementing these findings, Akubue and Adesina (2024) investigate courtyard geometries in Abuja and reveal how form and spatial configuration significantly influence airflow regimes and ventilation effectiveness. Together, these studies reinforce that context-specific passive strategies remain essential in Abuja's hot-dry climate for achieving healthier and more sustainable indoor environments.

Types of Natural Ventilation

Natural ventilation can be classified into three principal types depending on airflow dynamics and the physical mechanisms that drive them: single-sided, cross, and stack ventilation.

Single-Sided Ventilation

Single-sided ventilation occurs when both air entry and exit are facilitated through a single opening or multiple openings located on one side of a space. This approach is often adopted in situations where cross-ventilation is impractical due to spatial or architectural limitations. The system operates primarily on small pressure differences generated by wind or temperature gradients, though its efficiency is relatively limited, as airflow tends to remain localized. Consequently, its application is most effective in narrow rooms, particularly where the depth does not exceed approximately 2.5 times the window height (Etheridge & Sandberg, 1996).

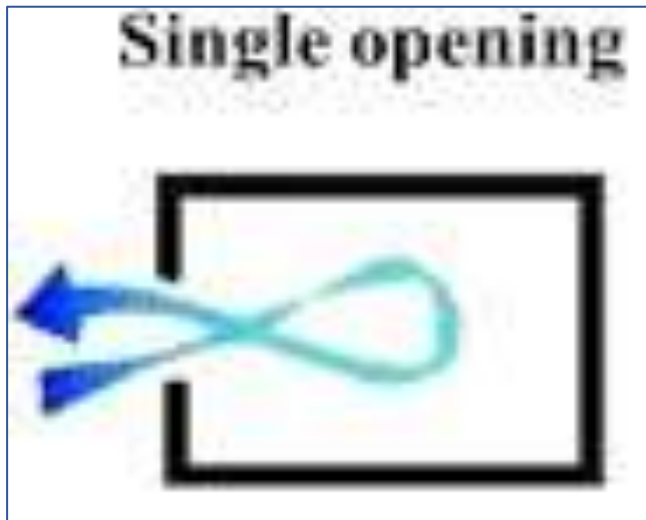


Figure 2: Single Sided ventilation air flow

Source: Ghiaus and Allard (2012)

Cross-Ventilation

Cross ventilation operates by harnessing wind pressure differentials across a building, driving air movement from openings on one façade to corresponding outlets on the opposite side. This method supports more effective air exchange, facilitating the displacement of heat and indoor contaminants. The efficiency of cross ventilation is largely influenced by the orientation, size, and positioning of openings relative to prevailing wind directions. It is particularly advantageous in single-story structures and open-plan layouts, where unobstructed airflow pathways can be maintained (Givoni, 1994).

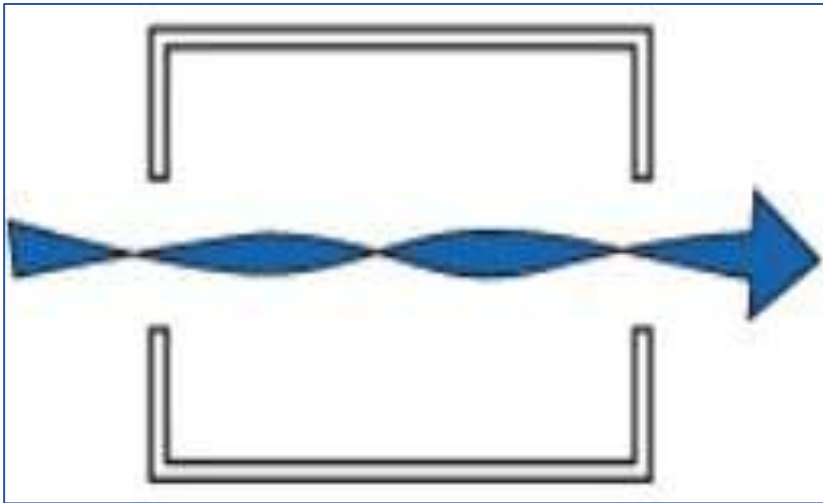


Figure 3: Cross Ventilation Air Flow
 Source: Ghiaus and Allard (2012)

Stack Ventilation

Stack ventilation complements single-sided and cross-ventilation systems by utilizing the principle of thermal buoyancy to drive airflow. In this process, warm indoor air, being less dense, rises and exits through high-level openings, while cooler and denser outdoor air is simultaneously drawn in through lower-level inlets. This mechanism establishes a continuous vertical airflow that functions independently of external wind conditions, making it particularly advantageous in calm climates or dense urban contexts where wind flow is restricted. The strategy is especially effective in tall architectural spaces such as atriums, stairwells, and multi-story buildings where increased vertical height amplifies the buoyancy effect and ensures consistent air circulation (Chudnovsky et al., 2004).

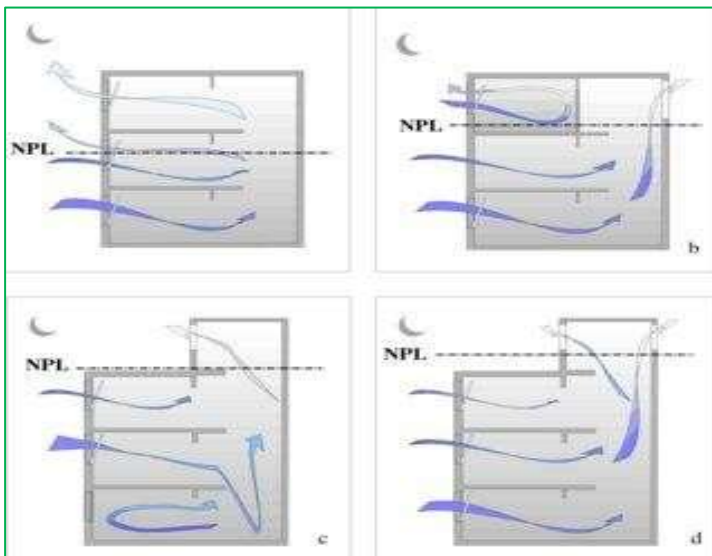


Figure 4: Stack Effect- Different ways to cool upper level
 Source: Ghiaus and Allard (2012)

Table 1: Comparison of Ventilation Types

Type	Driving Force	Airflow Pattern	Efficiency	Applications
Single-Sided	Wind or buoyancy	Bidirectional or pulsating	Lower	Rooms with limited openings
Cross-Ventilation	Wind or buoyancy	Unidirectional (inlet to outlet)	Higher	Buildings with opposing openings
Stack Ventilation	Buoyancy (temperature)	Vertical (bottom to top)	High in tall spaces	Atriums, tall Buildings

Source: Ghiaus and Allard (2012)

Natural Daylighting in Building

Natural daylighting refers to the strategic use of sunlight to illuminate interior spaces through architectural elements such as windows, skylights, or light wells. It has been widely acknowledged for its positive influence

on occupant well-being, satisfaction, and productivity in workplace environments. Exposure to natural light supports the regulation of circadian rhythms, reduces fatigue and stress, and enhances cognitive performance, thereby improving overall health and efficiency (Boubekri et al., 2014). Furthermore, daylighting has been linked to reduced risks of Seasonal Affective Disorder (SAD) and other mood-related conditions, contributing to a more positive indoor atmosphere. Beyond health and psychological benefits, daylighting reduces dependence on artificial lighting, leading to lower energy consumption, reduced heat emissions, and more thermally comfortable environments. Importantly, its contribution extends to indoor air quality (IAQ), making it a vital element of sustainable building design.

Daylighting improves IAQ both directly and indirectly. Windows and skylights designed for daylight penetration often serve as operable openings, facilitating natural ventilation that introduces fresh air and dilutes indoor pollutants such as volatile organic compounds (VOCs) and carbon dioxide (CO₂). Improved ventilation rates have been correlated with higher cognitive performance and reduced prevalence of sick building syndrome symptoms (Allen et al., 2016). Additionally, sunlight carries disinfectant properties through ultraviolet (UV) radiation, which helps suppress mold and bacterial growth on interior surfaces (Reed, 2010). By reducing moisture accumulation and microbial proliferation, daylighting further supports healthier indoor conditions. Nevertheless, its effectiveness depends heavily on design considerations. Poorly insulated or oversized glazed surfaces may lead to overheating, glare, condensation, or excessive energy demands for cooling, ultimately undermining both comfort and air quality (Heschong, 2002). Thus, an integrated approach combining daylighting with shading systems, thermal insulation, and mechanical ventilation is essential to optimize benefits while mitigating drawbacks.

When carefully planned, daylighting serves as a dual-function design strategy, simultaneously enhancing visual comfort and indoor air quality while advancing energy efficiency and workplace health. Incorporating adjustable blinds, shading devices, or supplementary artificial lighting ensures balanced illumination and thermal regulation. Ultimately, well-designed daylighting systems not only create healthier and more sustainable environments but also foster productivity and overall satisfaction, demonstrating their value as a cornerstone of high-performance workplace design.

Shading Devices

Shading devices constitute a fundamental component of architectural design in tropical regions, where persistent high solar radiation and elevated temperatures significantly influence building performance. As noted by Baker and Steemers (2014), shading elements are vital in moderating daylight penetration and mitigating solar heat gain, thereby improving thermal comfort and reducing dependence on energy-intensive cooling systems. Common strategies include the use of overhangs, louvers, pergolas, and brise-soleil, which limit direct solar exposure while facilitating natural ventilation and admitting diffused daylight. Through this dual function, shading devices not only regulate indoor thermal conditions but also contribute to energy efficiency by lowering cooling demands.

Shading devices can broadly be categorized as internal or external, depending on their placement relative to the building envelope. Internal devices such as curtains, blinds, roller shades, window films, and shutters are typically easier to operate and provide greater control over light levels and privacy, but they are less effective in reducing heat gain since solar radiation is already admitted indoors. In contrast, external devices, including overhangs, fins, louvers, brise-soleil, vegetative shading, awnings, and solar screens, offer superior thermal performance by blocking sunlight before it enters the building. While both types contribute to visual and thermal comfort, external shading is generally more effective in tropical climates, where mitigating excessive heat gain is a critical design priority.

Material Selection for Improved Indoor Air Quality (IAQ)

Building materials exert a profound influence on indoor air quality (IAQ), particularly in hot-dry tropical climates such as Abuja, where thermal performance and moisture regulation are crucial design considerations. A primary concern is the emission of volatile organic compounds (VOCs), which readily vaporize at ambient temperatures. These emissions often arise from construction finishes and furnishings, including paints, adhesives, varnishes, composite wood, and carpeting. Prolonged exposure to VOCs has been linked to acute discomfort, such as eye and throat irritation, headaches, and dizziness, as well as long-term health complications including respiratory diseases and certain cancers (Levin, 1989). Formaldehyde, a highly toxic VOC frequently released from pressed wood products, insulation, and textiles, is of particular concern. The International Agency for Research on Cancer (IARC) has classified formaldehyde as a carcinogen strongly associated with nasopharyngeal cancer and leukemia. For Abuja, where enclosed spaces are often mechanically cooled with limited natural ventilation, the risks posed by VOC accumulation are heightened (U.S. EPA, 2017).

In addition to gaseous pollutants, particulate matter (PM) from building components such as gypsum board, flooring, and fibrous insulation also threatens IAQ by aggravating respiratory conditions, particularly in a climate already prone to high dust levels from the Harmattan season. Furthermore, although Abuja's climate is predominantly hot and dry, episodic rainfall and localized humidity can lead to moisture retention in porous or hygroscopic materials such as ceiling tiles, drywall, and certain insulation systems. These conditions foster mold growth in inadequately ventilated spaces, introducing airborne spores that can trigger asthma, hypersensitivity,

and allergic reactions (Fisk et al., 2006). Therefore, material selection in Abuja's research and educational buildings must emphasize low-emission, non-toxic, and moisture-resistant alternatives, alongside strategies such as passive ventilation and sustainable finishes, to ensure healthier and more resilient indoor environments.

Types of Low-Emission and Natural Materials

Enhancing indoor air quality (IAQ) in Abuja's hot-dry tropical climate increasingly depends on selecting low-emission and locally available natural materials that limit the introduction of harmful pollutants into research and educational facilities. Natural wood, when sourced sustainably and used untreated, presents a healthier option than composite products that often rely on formaldehyde-based adhesives, which are associated with elevated volatile organic compound (VOC) emissions (Levin, 1989). Similarly, clay plaster widely available in Northern Nigeria offers substantial IAQ benefits due to its breathable properties and ability to regulate humidity. By absorbing and releasing moisture gradually, clay reduces the likelihood of mold growth while supporting thermal comfort in naturally ventilated spaces. In addition, lime-based plasters and paints, also common in traditional West African construction, contribute to improved IAQ by buffering humidity, preventing mold formation, and eliminating reliance on chemical additives (Fisk et al., 2006).

Natural fibre-based insulation, such as hemp, jute, and cotton, which are locally produced in parts of Nigeria, provides an eco-friendly alternative to synthetic insulation materials. These fibres are free from toxic additives, while offering thermal and acoustic performance suitable for Abuja's climate (Levin, 1989). Low- and zero-VOC paints further complement IAQ-conscious design by replacing conventional coatings, which remain a significant source of indoor pollutants. By reducing chemical content, these finishes mitigate health risks such as respiratory irritation and long-term toxic exposure (Wolkoff & Nielsen, 2010). Collectively, integrating natural, regionally available, and innovative materials into Abuja's research and educational facilities not only promotes sustainability but also safeguards occupant health, aligning with climate-responsive and culturally grounded architectural practices. Building materials substantially influence indoor air quality (IAQ), especially in hot-dry climates like Abuja's, through their roles in pollutant emissions, moisture regulation, and thermal performance. Locally sourced natural finishes such as clay plaster and lime-based renders noted in some regional studies for their breathable and hygroscopic properties can help moderate humidity fluctuations, reduce mould incidence, and limit VOC emissions. Natural fibre insulation materials, including jute, hemp, and other plant-based fibres, have shown promise as eco-friendly alternatives to synthetic insulators in Nigerian contexts; they offer lower chemical emissions and good thermal comfort. Similarly, simulations of different roof insulation materials in nearby climatic regions (e.g. Lagos) demonstrate that improved insulation significantly reduces cooling loads and enhances indoor comfort under conditions comparable to Abuja. Thus, material choices in the Abuja context should prioritize low-VOC, moisture-resistant, and thermally efficient materials such as clay plasters, natural wood finishes, lime renders, and natural fibre insulations both to improve IAQ and reduce energy dependency. These materials, when matched with appropriate passive design features and regular maintenance, can greatly enhance occupant comfort, health, and sustainability in research and educational facilities.

The application of low-emission and natural materials has been widely demonstrated across diverse building typologies, highlighting their effectiveness in enhancing indoor air quality (IAQ). A prominent case is the Bullitt Centre in Seattle, USA often described as the world's greenest commercial building which incorporates low-VOC finishes, untreated natural wood, and clay plaster to promote a healthier indoor environment. The project's achievement of the Living Building Challenge certification underscores the critical role of sustainable material selection in advancing both occupant well-being and environmental performance.



Plate I: Interior of Bullitt Centre, showing the wooden ceiling
Source: John Stamets (2013)

Indoor Plants and Biophilic Design

Indoor vegetation has gained significant attention for its capacity to enhance indoor air quality (IAQ) through pollutant removal and overall environmental improvement. Recent studies emphasize the air-purifying potential of several commonly used species, including the Spider Plant (*Chlorophytum comosum*), Peace Lily (*Spathiphyllum spp.*), Snake Plant (*Sansevieria trifasciata*), and Boston Fern (*Nephrolepis exaltata*). These plants are not only valued for their aesthetic contribution but also for their demonstrated ability to absorb volatile organic compounds (VOCs), regulate humidity, and contribute to healthier indoor environments.

Spider Plant (*Chlorophytum Comosum*)

Spider plants are widely recognized for their air-purifying properties, with recent research confirming their effectiveness in removing indoor pollutants such as formaldehyde and xylene chemicals frequently emitted by adhesives, paints, and synthetic household materials (Kim et al., 2018). The purification process occurs as the plant absorbs contaminants through its leaves and roots, where soil-based microbial activity facilitates their breakdown, thereby contributing to healthier indoor air conditions (Soreanu et al., 2013).



Plate II: Spider Plant (*Chlorophytum Comosum*)

Source: Mokkie (2014)

Peace Lily (*Spathiphyllum spp.*)

Peace lilies have been recognized for their effectiveness in removing volatile organic compounds (VOCs), including benzene, formaldehyde, and trichloroethylene, which are commonly released from furniture, cleaning agents, and electronic devices (Morgan et al., 2022). In addition to their air-purifying capacity, peace lilies enhance indoor environmental quality by regulating humidity through natural transpiration processes (Pérez-Urrestarazu et al., 2015).



Plate III: Peace Lily (*Spathiphyllum spp.*)

Source: Wikimedia Commons. (2010)

Snake Plant (*Sansevieria Trifasciata*)

Snake plants possess the distinctive capacity to carry out photosynthesis during nighttime hours, enabling them to absorb carbon dioxide and release oxygen when most other plants are inactive. This attribute makes them particularly effective for enhancing air quality in interior spaces such as offices and bedrooms, with added benefits for sleep quality and overall productivity (Yang et al., 2020). Their resilience, low maintenance

requirements, and adaptability to diverse indoor conditions further position them as an ideal choice for environments with high activity or limited upkeep capacity.



Plate IV: Snake Plant (*Sansevieria Trifasciata*)

Source: Wikimedia Commons. (2010)

Boston Fern (*Nephrolepis Exaltata*)

Boston ferns have been identified as highly effective in mitigating formaldehyde, one of the most prevalent indoor pollutants emitted from building materials and household products (Pérez-Urrestarazu et al., 2015). In addition to their pollutant-removal capacity, these plants function as natural humidifiers by releasing moisture through transpiration, thereby contributing to balanced indoor humidity levels and alleviating issues associated with dry air (Pérez-Urrestarazu et al., 2015).



Plate V: Boston Fern (*Nephrolepis Exaltata*)

Source: Wikimedia Commons. (2010)

In addition to their air-purifying capacity, indoor plants contribute substantially to both psychological and physiological well-being. Empirical studies have demonstrated that integrating greenery into interior spaces can alleviate stress, elevate mood, and enhance cognitive functioning (Bringslimark et al., 2009). These benefits align with the principles of biophilic design, which highlight the intrinsic human affinity for nature. The presence of vegetation indoors has been shown to foster restorative effects, mitigate mental fatigue, and improve overall productivity in professional and educational settings. Furthermore, plants aid in regulating indoor humidity through transpiration, releasing moisture into the atmosphere and maintaining relative humidity within the optimal range of 40%–60%. This balance not only enhances thermal comfort but also lowers the incidence of respiratory ailments, skin dryness, and eye irritation (Pérez-Urrestarazu et al., 2015). Consequently, indoor plants should be regarded as integral components of sustainable interior environments, providing multifunctional benefits that simultaneously promote environmental quality and human health.

RESEARCH METHODOLOGY

Research Method

The study adopted a descriptive survey design, which is widely used in the built environment to capture patterns, behaviours, and conditions without manipulating variables (Creswell & Creswell, 2023; Saunders et al., 2023). Both primary and secondary data were utilized to strengthen validity and provide a comprehensive understanding. Primary data was collected through fieldwork using structured observations, questionnaires, and interviews, ensuring context-specific and up-to-date findings. Secondary data, sourced from academic literature, government reports, and digital databases, was employed to supplement primary findings and provide comparative perspectives (Bryman, 2016).

Case study selection followed purposive sampling to ensure alignment with research objectives (Palinkas et al., 2015). Buildings were chosen based on three criteria: (i) their function as visualization research or studio-based facilities, (ii) the integration of passive design strategies such as natural ventilation, optimized spatial layouts, and vegetation, and (iii) the use of sustainable materials aimed at reducing indoor pollutants. The study population comprised architects, facility managers, building managers, and users of visualization research centres in Nigeria, as well as selected buildings representative of contemporary facilities designed to enhance indoor air quality through passive strategies.

Sampling Size and Sampling Method

The sample size was determined based on the availability of suitable buildings and the feasibility of gathering sufficient data from a manageable number of participants who are knowledgeable about the space and its operations.

For the purposes of this study, a purposive sampling technique was employed to select buildings that meet specific criteria related to green architecture, passive design strategies, and sustainable building materials aimed at improving IAQ. The sample is comprised of three architectural visualization studios in Nigeria that are known for their innovative architectural designs and emphasis on sustainability. Each selected building is associated with 20-50 participants, including key stakeholders such as building users, facility managers, and architects. This ensures a diverse and comprehensive representation of perspectives regarding the performance of the buildings in relation to IAQ. The sample size was determined based on the feasibility of data collection and the availability of appropriate case studies that align with the research objectives.

ANALYSIS AND DISCUSSION OF RESULTS

Survey Report

The quantitative data for this study was collected through the distribution of questionnaires and is presented using descriptive and statistical tables. Out of 80 questionnaires distributed, 73 were duly completed and returned, yielding a response rate of 87%. These 73 responses formed the basis for the valid data analysis.

Table 3: Participants' Response Rate

Location	Distributed (X)	Returned (Y)	Not Returned	Rate (%) (Y/X*100)
Grey Boulders Abuja Nigeria	24	22	2	92
Hall 7 Real Estate Abuja, Nigeria	54	51	3	94
Direct Construction Lagos, Nigeria	21	19	2	90
Total	80	73	7	92

Source: Author's Fieldwork (2025)

Reliability and Validity Test

A Cronbach's alpha of 0.834 and 0.841 based on standardized items indicates a strong level of internal consistency, exceeding the commonly accepted threshold of 0.7. This suggests that the 14 questionnaire items across Sections II and III are closely related and reliably measure the underlying constructs of passive design strategies and their effects on indoor air quality. In essence, the items consistently capture the intended concepts, which enhances the reliability and trustworthiness of the data for evaluating indoor air quality and the effectiveness of passive design strategies in the Visualization Research Centre, Abuja.

Table 4: Reliability Test

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No of Items
0.834	0.841	14

Source: Author's Fieldwork (2025)

Respondents' Demographics

The demographic profile of the 73 respondents indicates a much higher participation of males (66%) compared to females (34%). The majority of respondents were young adults aged 25–34 years (38%), followed by 18–24 years (29%), showing that the facility primarily serves a younger population. In terms of occupation, students formed the largest group (45%), with academic staff (25%), non-academic staff (20%), and visitors (10%) comprising the remainder. Regarding usage duration, most respondents reported using the facility for 1–3 years

(40%), followed by less than 1 year (28%), 4–6 years (22%), and more than 6 years (10%). This indicates a mix of both new and long-term users, providing a balanced perspective on user experience and perceptions.

Table 5: Demographic Information of Participants

Variable	Category	Frequency (f)	Percentage (%)
Gender	Male	48	66
	Female	25	34
Age Bracket	18–24	21	29
	25–34	28	38
	35–44	15	20
	45–54	6	8
	55 and above	3	5
Occupation/Status	Student	33	45
	Academic Staff	18	25
	Non-Academic Staff	15	20
	Visitor	7	10
Duration of Use	Less than 1 year	20	28
	1–3 years	29	40
	4–6 years	16	22
	More than 6 years	8	10

Source: Author's Fieldwork (2025)

Passive Design Strategies in Existing Visualization Research Centres.

The assessment of passive design strategies revealed that operable windows were rated Very High (36%) and High (16%) by most respondents, indicating good provision for natural ventilation. Shading devices such as louvers and overhangs were also rated favourably, with High (29%) and Very High (27%), suggesting effectiveness in controlling solar heat gain. In contrast, courtyards or atriums were rated Moderate (27%) and High (26%), reflecting partial integration of open spaces for airflow and daylight. The building orientation for natural wind received mostly Moderate (27%) and High (23%) ratings, indicating limited optimization of airflow pathways. Indoor plants or green walls were rated lower, with Low (30%) and Moderate (25%), highlighting a need for improved biophilic features. Overall, while some passive design elements like windows and shading devices are well implemented, greenery and building orientation require further attention to enhance indoor air quality.

Table 6: Passive Design Strategies in Existing Visualization Research Centres

Variables		Very High (5)	High (4)	Moderate (3)	Low (2)	Very Low (1)
Operable windows		26 (36%)	12 (16%)	14 (19%)	11 (15%)	10 (14%)
Courtyards/Atriums		15 (21%)	19 (26%)	20 (27%)	10 (14%)	9 (12%)
Shading	devices	20 (27%)	21 (29%)	15 (21%)	10 (14%)	7 (10%)
(louvers/overhangs)						
Orientation	for natural wind/airflow	14 (19%)	17 (23%)	20 (27%)	12 (16%)	10 (15%)
Indoor plants/green walls		8 (11%)	12 (16%)	18 (25%)	22 (30%)	13 (18%)

Source: Author's Fieldwork (2025)

Determine The Effect of Indoor Air Quality on Users of a Visualization Research Centre

The results for indoor air quality indicate a strong perceived impact on comfort, health, and productivity. A majority agreed or strongly agreed that air quality positively affects comfort (54%) and that naturally ventilated spaces feel more refreshing (59%). Respondents also reported that poor ventilation in some areas hinders concentration (48%) and contributes to fatigue (46%). Health symptoms such as headaches and eye irritation were reported by 39% of participants. Inadequate air quality was noted to negatively affect productivity (42%), with 37% sometimes avoiding certain areas due to stuffy conditions. Additionally, 44% indicated that indoor air quality influences how much time they spend in the building. These results emphasize that indoor air quality significantly affects user experience, underlining the importance of passive design strategies to enhance ventilation and comfort.

Table 7: Determine the Effect of Indoor Air Quality on Users of a Visualization Research Centre

Question	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)
Air quality positively affects overall comfort	20 (27%)	19 (27%)	14 (19%)	11 (15%)	9 (12%)
Poor ventilation makes concentration difficult	18 (25%)	17 (23%)	16 (22%)	12 (16%)	10 (14%)
Fatigue increases when air feels stuffy	16 (22%)	17 (23%)	15 (21%)	13 (18%)	12 (16%)
Health symptoms linked to poor air quality	14 (19%)	15 (21%)	20 (27%)	12 (16%)	12 (16%)
Naturally ventilate spaces feel more refreshing	21 (29%)	22 (30%)	12 (16%)	10 (14%)	8 (11%)
Adequate airflow improves focus and task performance	18 (25%)	19 (26%)	14 (19%)	11 (15%)	11 (15%)
Poor air quality negatively affects productivity	15 (21%)	16 (22%)	17 (23%)	13 (18%)	12 (16%)
Avoidance of areas due to poor air quality	12 (16%)	15 (21%)	18 (25%)	15 (21%)	13 (18%)
IAQ influences the amount of time spent in the building	16 (22%)	16 (22%)	18 (25%)	13 (18%)	10 (14%)

Source: Author's Fieldwork (2025)

Observation Report

A thorough field observation was conducted at selected Visualization Research Centres in Abuja and Lagos. A structured observation checklist was employed to identify passive design strategies that enhance indoor air quality and respond effectively to Abuja's climatic conditions. The checklist focused on key variables such as natural ventilation, shading devices, building orientation, indoor greenery, and airflow movement, which were systematically assessed across the case study buildings.

Outdoor Climatic Conditions

Observations across the two case studies in Abuja and one in Lagos revealed variations in temperature, humidity, wind patterns, and solar radiation throughout the day. Morning temperatures were generally moderate, while midday readings often reached high levels, especially in Abuja. Humidity levels tended to be moderate in the mornings but increased in the afternoons during Lagos' more humid climate. Natural breezes were more consistent in Lagos, while Abuja sites experienced calmer conditions. Solar radiation was intense during midday hours across all sites, with limited natural shading in some areas. Rainfall was minimal during the observation period, having little immediate impact on ventilation.

Table 8: Outdoor Climatic Conditions

Observation Category	Criteria	Case 1 Abuja	Case 2 Abuja	Case 3 Lagos	Remarks
Temperature (°C)	Morning / Midday / Evening	Morning: Moderate / Midday: High / Evening: Moderate	Morning: Moderate / Midday: High / Evening: Moderate	Morning: Moderate / Midday: High / Evening: Moderate	Lagos slightly more humid, Abuja hotter at midday
Humidity (%)	Relative humidity	Low– Moderate	Low– Moderate	Moderate–High	Lagos more humid due to coastal influence
Wind Speed & Direction	Natural airflow	Breezy	Calm	Breezy	Abuja cases had less consistent airflow
Rainfall	Impact on ventilation	Not Present	Not Present	Present	Rain in Lagos improved air freshness temporarily

Source: Author's Fieldwork (2025)

Indoor Environmental Conditions

Indoor observations indicated that temperature comfort varied depending on building design and ventilation features. In Abuja, some indoor spaces maintained comfortable temperatures due to cross-ventilation, while others became warm during peak hours. Windows and vents were often partially open, with a few cases fully closed due to security or dust concerns. Indoor air quality ranged from fresh to slightly stale, depending on ventilation and airflow. Indoor plants were rare, with only a few spaces incorporating greenery as a natural air purifier.

Table 9: Indoor Climatic Conditions

Observation Category	Criteria	Case 1 Abuja	Case2 Abuja	Case 3 Lagos	Remarks
Indoor Temperature	Comfort	Warm	Hot	Comfortable	Lagos had better thermal comfort due to shading
CO2	Indoor air	Elevated	High	Low	Lagos case
Concentration	quality proxy				maintained lower CO ₂ levels due to better ventilation
Airflow Movement	Cross-ventilation	Moderate	Still	Active	Lagos had more open windows and functional ventilation
Ventilation Openings	Windows/vent s/louvers	Partially Open	Close	All Open	Lagos building optimized for natural airflow
Odour or Staleness	Indoor air freshness	Slightly Stale	Stuffy	Fresh	Abuja cases suffered some stagnancy; Lagos fresh
Presence of Indoor Plants	Biophilic contribution	Few	None	Many	Indoor greenery more prominent in Lagos case, improving perceived IAQ

Source: Author's Fieldwork (2025)

Building Design Influence

The orientation of the buildings generally aligned to take advantage of prevailing winds, though some faced less optimal directions, reducing airflow potential. Courtyards and atriums were present in a few buildings and proved effective in enhancing ventilation. Shading devices such as louvers and overhangs were partially implemented, with varying effectiveness. Building materials played a significant role in thermal performance; structures with heat-resistant materials maintained cooler interiors, while heat-retentive finishes contributed to warmer indoor conditions. The maintenance of openings varied, with some sites ensuring vents and windows were well-kept, while others showed partial neglect, affecting airflow efficiency.

Table 10: Building Design Influence

Observation Category	Criteria	Case 1 Abuja	Case 2 Abuja	Case 3 Lagos	Remarks
Orientation	Sun & wind	Average	Poor	Optimal	Lagos building better aligned to prevailing winds and sunlight
Shading Devices	Louvers, screens, trees	Partial	Absent	Effective	Shading in Lagos mitigated heat and gain significantly
Building Envelope Material	Thermal performance	Heat-Retentive	Heat-Retentive	Neutral	Lagos buildings used insulated materials; Abuja cases retained heat
Maintenance of Openings	Operability & Cleanliness	Partial	Poor	Well-Maintained	Lagos buildings had functional and clean openings improving airflow

The observation results revealed notable variations in outdoor and indoor environmental conditions across the case study sites in Abuja and Lagos. In Abuja, morning and evening temperatures were generally moderate, with midday heat intensifying the need for effective shading and ventilation strategies. Relative humidity levels fluctuated between moderate and high, while wind patterns indicated the potential for harnessing natural breezes through strategic building orientation and operable openings. Indoor observations showed that buildings with adequate cross-ventilation, openable windows, and indoor plants maintained fresher air quality compared to those with limited ventilation options. In terms of building design features, centres with optimal orientation, functional shading devices, and well-maintained openings demonstrated a stronger ability to regulate indoor temperatures and improve air circulation. Conversely, facilities lacking these features experienced warmer indoor conditions, reduced airflow, and higher instances of stale air. Overall, the findings highlight the critical role of passive design strategies such as orientation, shading, natural ventilation, and indoor greenery in enhancing indoor air quality under the climatic conditions of Abuja and Lagos.

CONCLUSION

The study revealed significant variations in indoor air quality (IAQ) between case studies in Abuja and Lagos, with Abuja buildings showing higher indoor temperatures, stagnant airflow, and elevated CO₂ levels due to limited passive design measures, while Lagos facilities benefited from effective cross-ventilation, vegetation shading, and biophilic integration. Findings highlight a gap between the acknowledged importance of passive strategies and their actual application in Abuja, constrained by weak policy enforcement, cost barriers, and limited awareness. Poor IAQ was shown to negatively impact health, comfort, and productivity, emphasizing the need for climate-responsive approaches such as operable windows, shading devices, biophilic features, and low-VOC materials. The proposed Visualization Research Centre incorporates these strategies through orientation, courtyards, and landscape buffers, providing a replicable framework for IAQ-sensitive design in tropical institutional buildings. This research contributes empirical data on IAQ patterns in Nigeria, identifies barriers to sustainable practices, and links IAQ directly to well-being and productivity, offering both practical recommendations and a context-specific model for future facilities.

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An Appraisal of Passive Fire Protection Defects in Public Office Buildings of Abuja, Nigeria

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ABSTRACT

Public office buildings in Nigeria remain alarmingly vulnerable to fire, as recurring incidents, including the 2019 Accountant General's Office fire in Abuja, continue to expose deep-seated failures in passive fire protection. This paper appraises the state of passive fire protection in six public office buildings within Abuja's Central Business District, systematically identifying defects, assessing compliance with the Nigerian Building Code, and situating the findings within a broader conversation about fire safety governance in rapidly urbanising African cities. Data were gathered through technical inspections, laboratory material testing to ASTM E119 standards, compliance scoring across four domains (structural fire resistance, compartmentalization, fire-resistant openings, and egress protection), and semi-structured interviews with facility managers, fire safety officers, building occupants, and regulatory officials. Quantitative data were analysed using SPSS; qualitative data were thematically coded using NVivo. The study found that only 33% of the assessed buildings achieved full compliance, with a mean compliance score of 68.2 ± 15.4 out of 100. The most critical defect categories were inadequate compartmentalization (74% of buildings), non-compliant fire-resistant door and glazing systems (67%), deficient structural fire resistance (52%), and compromised egress routes (43%). A strong inverse relationship was observed between building age and compliance: newer buildings (under 10 years) scored 84.5% against only 50.4% for those exceeding 15 years. Stakeholder interviews identified regulatory under-enforcement, limited technical expertise, and chronic underfunding as the primary systemic barriers. The findings point to an urgent need for revised building codes, improved compartmentalization standards, material upgrades, and stronger enforcement mechanisms tailored to the Nigerian urban context.

Keywords: passive fire protection, compliance, public office buildings, Abuja, fire safety, Nigerian Building Code, compartmentalization

INTRODUCTION

Fire incidents in Nigerian public buildings have repeatedly drawn attention to the inadequacy of built-in fire safety systems. The 2019 fire at the Accountant General's Office in Abuja is a well-documented case in point (Adewole 2026). Yet it is far from isolated. Across the country, public office buildings continue to be designed, constructed, and maintained with insufficient attention to passive fire protection, those architectural and structural measures that operate automatically during a fire event without human intervention or activation.

Passive fire protection encompasses fire-resistant materials, compartmentalization strategies, structural fire ratings, and protected egress routes (Salako, and Eze 2024). These differ fundamentally from active systems such as sprinklers and alarms, which depend on detection and triggering mechanisms (Li, *et al.*, 2022). In public office buildings, settings characterised by high occupancy densities, complex spatial layouts, and the presence of critical government functions, the reliability of passive measures is not optional; it is foundational (Wang, *et al.*, 2025).

Despite the existence of the Nigerian Building Code, which prescribes minimum fire safety standards, enforcement remains inconsistent and compliance is rarely independently verified (Goodluck, *et al.*, 2025). This gap between regulation and practice is not merely procedural, it has direct consequences for occupant safety, asset preservation, and the continuity of government operations.

Abuja, as the seat of federal government and home to numerous ministries, parastatals, and legislative and judicial facilities, presents an important context for this appraisal. Its buildings range widely in age, size, and construction quality, making the city a useful test case for understanding how passive fire protection performs across the public sector estate. This paper pursues three objectives: to identify defects in passive fire protection systems in Abuja's public office buildings; to evaluate compliance with the Nigerian Building Code; and to propose evidence-based recommendations for improving safety outcomes.

LITERATURE REVIEW

Passive Fire Protection: Concepts and Significance

Passive fire protection refers to the integration of fire-resistive features directly into a building's fabric, such that they function continuously without external activation (Dormohamadi, *et al.*, 2025), distinguishes passive systems from active systems like sprinklers and smoke detection, which require triggering to operate (Tello, *et al.*, 2026). The key components of passive fire protection include structural fire resistance, fire compartmentalization, fire-resistant openings (doors and glazing), and protected egress pathways.

Structural fire resistance refers to the capacity of a building's load-bearing elements; beams, columns, slabs, and walls to maintain their integrity under fire conditions for a specified duration (Chaturvedi, *et al.*, 2022). This rating is typically expressed in minutes (60 or 90 minutes of fire resistance) and is determined through standardised laboratory testing, most commonly ASTM E119 or its equivalents. Inadequate structural fire resistance can lead to early collapse, severely shortening the time available for evacuation and fire-fighting.

Compartmentalization is a design strategy that subdivides a building into discrete fire-resistant zones, limiting the spread of fire and smoke and confining emergencies to manageable areas (Mohammed and Abdulrahman, 2023).

Research has consistently shown that effective compartmentalization can reduce fire fatalities by 40–60%, making it one of the highest-impact passive fire protection measures (Wu, *et al.*, 2026). However, compartmentalization is also particularly vulnerable to degradation: penetrations for services such as pipes, cables, and ducts create gaps in fire barriers that must be carefully sealed, and frequently are not (Rana, and Shuvo, 2024).

Fire-resistant openings, particularly doors and glazing systems, represent critical junctions in the passive protection envelope. Self-closing fire doors, when correctly certified, installed, and maintained, prevent fire and smoke from spreading between compartments during evacuation. The Grenfell Tower disaster highlighted the catastrophic consequences of non-compliant cladding and opening systems in residential high-rise buildings, and similar vulnerabilities have been documented in office contexts (Huang 2025).

Egress route protection is the final and perhaps most operationally visible component of passive fire protection. It encompasses the design, sizing, signage, and structural protection of corridors, stairwells, and emergency exits. Emergency lighting is a critical element: without it, occupants cannot navigate unfamiliar escape routes in smoke-filled or darkened conditions (Chen, *et al.*, 2024). Studies in high-occupancy buildings have found that obstruction of egress routes, through storage, unauthorised installations, or deferred maintenance, dramatically increases evacuation risk.

Passive Fire Protection in the Nigerian and Sub-Saharan Context

The Nigerian Building Code establishes minimum requirements for fire safety in both residential and commercial construction, including provisions for structural fire ratings, compartmentalization, and egress. However, the gap between code provisions and on-the-ground compliance has been widely acknowledged in the literature (Lu, *et al.*, 2022). Enforcement is episodic, inspection cycles are irregular, and penalties for non-compliance are rarely applied consistently.

Research in comparable Sub-Saharan contexts has identified a recurring set of structural barriers to fire safety compliance: weak institutional capacity, chronic underinvestment in building maintenance, limited availability of qualified fire safety professionals, and procurement systems that prioritise upfront cost over lifecycle performance (Barua 2025). In Nigeria specifically, studies have noted a pattern of progressive deterioration in older public buildings, where fire protection features installed at construction are rarely maintained or upgraded over the building's life (Yacob, *et al.*, 2022).

Van Roosmale, *et al.*, (2024), evaluated passive fire protection strategies in high-rise architecture across urban African environments, finding that effectiveness was closely tied to the technical capacity of facility management teams and the regularity of inspection and maintenance regimes. van Gestel, *al.*, (2024), examined passive design fire protection specifically in Abuja's high-rise residential buildings, identifying challenges in sustainable implementation that closely mirror those expected in the public office sector. Together, these studies suggest that the deficiencies observed in Nigerian public buildings are systemic rather than incidental, requiring structural interventions in regulation, capacity, and funding.

Compliance Assessment Frameworks

Internationally, compliance rates in developed nations with mature building regulatory systems typically fall in the 80–95% range (Ghafoor, *et al.*, 2025). Systematic assessment frameworks, combining technical inspection, materials testing, and stakeholder engagement, have been shown to effectively diagnose fire safety weaknesses and catalyse targeted interventions (Barua 2025). This study adopts such a framework, adapted to the Nigerian regulatory context and applied specifically to the public office building typology in Abuja.

METHODOLOGY

Research Design

This study employed a cross-sectional mixed-methods design, combining quantitative compliance assessment with qualitative stakeholder inquiry. The approach was structured to produce both measurable compliance data and contextual understanding of why deficiencies persist. A purposive sampling strategy was used to select six public office buildings within Abuja's Central Business District (CBD), chosen to represent a range of building ages (5 to 24 years) and floor areas (3,500 to 18,200 m²). The buildings house federal ministries, parastatals, legislative, and judicial facilities, high-occupancy environments where fire safety failures carry significant public consequence.

Data Collection

Data were collected through four complementary methods:

- i. Technical inspections: Each building was inspected using a standardised protocol based on Nigerian Building Code requirements, covering all four passive fire protection domains.
- ii. Compliance scoring: A 100-point scoring instrument was developed, allocating 25 points to structural fire resistance, 30 points to compartmentalization, 25 points to fire-resistant openings, and 20 points to egress protection. Points within each domain were assigned based on observed performance against code-prescribed standards.
- iii. Material testing: Samples from structural elements and barrier materials were tested in the laboratory following ASTM E119 standard procedures, to determine actual fire resistance periods and compare them to specified ratings.

iv. Semi-structured interviews: A total of 50 interviews were conducted across four stakeholder groups: facility managers (n=12), fire safety officers (n=8), building occupants (n=24), and regulatory officials (n=6). Interviews explored operational challenges, resource constraints, maintenance practices, and perceptions of fire risk.

Data Analysis

Quantitative data from compliance scores and material tests were analysed using SPSS, with descriptive statistics and Pearson correlation used to examine the relationship between building age and compliance performance. Qualitative interview data were transcribed and thematically coded using NVivo, with codes derived both inductively from the data and deductively from the study's conceptual framework. Member-checking with two facility managers and one fire safety officer was used to validate thematic interpretations.

FINDINGS

Overall Compliance Status

The most immediate finding is stark: only 33% of the six assessed buildings achieved full compliance with passive fire protection requirements under the Nigerian Building Code. The mean compliance score across all buildings was 68.2 ± 15.4 out of 100, indicating that on average, approximately one-third of required passive fire protection measures were either absent, deficient, or degraded. Correlation analysis confirmed a significant inverse relationship between building age and compliance score ($r = -0.79$, $p < 0.05$): as buildings age, compliance deteriorates.

These aggregate figures, however, mask important variation between buildings. The highest-scoring building, a ministry facility less than eight years old, achieved 91 points, while the lowest-scoring, a 22-year-old parastatal office, recorded just 48 points. This range illustrates both the potential for high compliance in newer construction and the extent to which older buildings have been allowed to deteriorate.

Structural Fire Resistance

Structural fire resistance emerged as the most severely deficient category: 52% of buildings failed to meet code requirements. Across steel-framed buildings, 80% lacked adequate fire-resistant coatings, with surface treatments found to be either absent or significantly degraded. Among concrete-framed structures, 67% presented inadequate cover depths, the concrete layer protecting steel reinforcement from heat (Murugan, and Srinivasan 2022).

Laboratory testing under ASTM E119 conditions revealed a troubling pattern: actual fire resistance periods averaged only 35 to 45 minutes across the tested samples, substantially below the 60- or 90-minute ratings specified at design stage. This discrepancy between specified and real-world performance represents a latent but serious risk, particularly given the high occupant densities typical of government office buildings.

Fire Compartmentalization

Compartmentalization defects were both the most common and among the most consequential findings. 74% of buildings had inadequate compartmentalization systems, with 83% presenting visible gaps or cracks in their fire barriers. The condition of service penetrations, where pipes, conduits, and cables pass through walls and floors, was particularly poor: 89% of penetrations had either inadequate sealing materials or deteriorated systems (Gurmu, and Mudiyansele 2023). In 50% of buildings, the floor area of individual office compartments exceeded the maximum sizes permitted for office occupancy under the Building Code.

These findings are especially significant in light of fire modelling evidence from (YUN 2025), which indicates that buildings with compartmentalization deficiencies of this severity could experience full floor involvement within 10 to 15 minutes of ignition, compared to 30 to 60 minutes in adequately protected buildings. The implications for evacuation time are severe.

Table 1. Compliance Scoring Summary Table

Building	Age Group (yrs)	Structural Fire Resistance	Compartmentalization	Fire-Resistant Openings	Egress Protection	Total Compliance Score
B1	<10	23	27	22	19	91
B2	<10	21	26	21	18	86
B3	11–15	18	21	18	15	72
B4	11–15	17	20	17	14	68
B5	>15	12	15	12	12	51
B6	>15	10	13	11	10	44

Table 1 summarizes the compliance performance of the six assessed public office buildings across the four passive fire protection categories.

Fire-Resistant Opening Systems

67% of buildings had glazing systems and fire-resistant doors that did not comply with applicable standards. Among the specific deficiencies recorded: 72% of doors at required locations lacked functional self-closing mechanisms, 78% of positions requiring fire-rated glazing lacked it entirely, and only 45% of fire doors present in the buildings retained

valid certification and labelling (To, *et al.*, 2025). Several fire doors were found wedged open, a common but dangerous practice driven by occupant convenience rather than safety awareness.

Egress Route Protection

43% of buildings presented deficiencies in egress route protection serious enough to constitute evacuation risks. In 67% of buildings, at least one egress route failed to meet the width or headroom requirements specified for office occupancy. Physical obstructions, stored materials, installed equipment, partitioning, blocked or restricted egress routes in 67% of buildings. Emergency lighting was either absent or inadequate in 83% of the surveyed buildings, a finding that is particularly alarming given that power disruptions frequently accompany fire events (Naser, and Kodur 2025).

Age-Related Compliance Patterns

Building age proved to be a strong predictor of compliance performance, consistent with the broader literature on building deterioration (Ghafoor, *et al.*, 2025). Buildings under 10 years old achieved mean compliance scores of 84.5%, while those aged 11 to 15 years averaged 69.8%, and those exceeding 15 years averaged only 50.4%. This gradient reflects not simply the age of installed systems, but the absence of systematic maintenance and upgrading programmes. Older buildings were not necessarily poorly designed; they were poorly maintained.

Stakeholder Perspectives

Interviews with facility managers, fire safety officers, building occupants, and regulatory officials produced a consistent and mutually reinforcing account of systemic failure (Meacham 2023). Facility managers pointed to inadequate maintenance budgets, limited in-house fire safety expertise, and insufficient occupant training as their primary operational constraints (Akinwusi 2024). Fire safety officers highlighted the poor integration between passive and active fire protection systems, with the two often specified and managed by separate contractors with no coordination (Barua, *al.*, 2024).

Occupants displayed significant knowledge gaps: 42% could not identify the location of the nearest emergency exit, and 67% were unaware of the fire safety features installed in their building (Meacham 2023). Regulatory officials were candid about resource limitations: current inspection intervals exceed the two-to-three-year cycle recommended by professional standards, with some buildings not receiving formal inspections for five or more years. The officials attributed this directly to staffing shortfalls and the absence of a dedicated inspection budget.

Figure 1 Mean Compliance Scores by Building Age Group

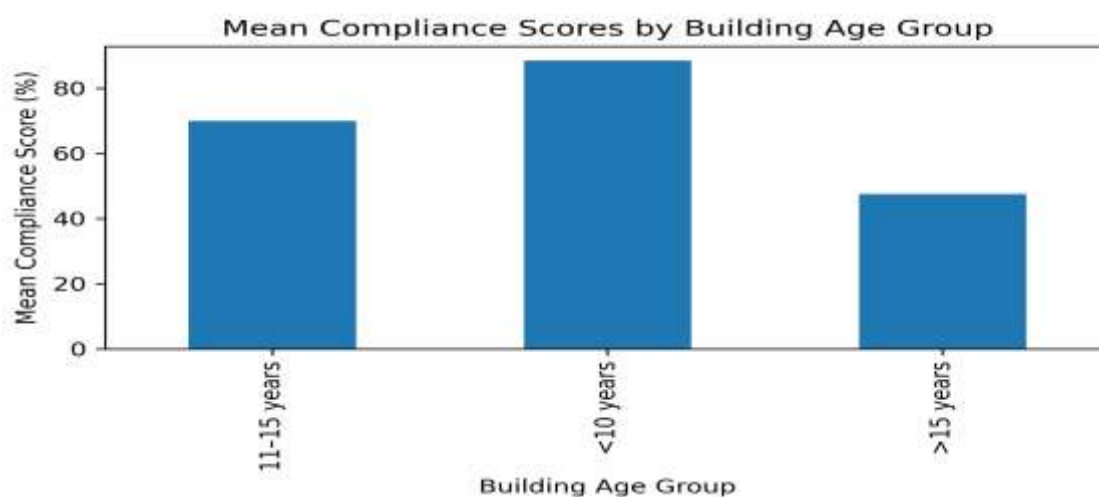


Figure 1 illustrates the relationship between building age and overall passive fire protection compliance. The chart demonstrates a clear decline in compliance performance as building age increases, consistent with the manuscript findings regarding maintenance deterioration and regulatory enforcement gaps.

DISCUSSION

Contextualising the Findings within Abuja

The 68.2% mean compliance score recorded in this study stands in sharp contrast to the 80–95% benchmark typical of developed nations with mature regulatory systems (Galane, *et al.*, 2025). In the context of Abuja specifically, this gap matters for reasons beyond statistics. Abuja's public office buildings house thousands of civil servants and members of the public daily, making fire safety in these buildings a matter of direct public interest. The fact that two-thirds of assessed buildings are non-compliant, in the federal capital, signals that even where institutional capacity and resources are comparatively better than in other Nigerian cities, compliance remains structurally problematic.

The 74% compartmentalization deficiency rate is particularly concerning when placed in the context of fire spread modelling. (Alam, *et al.*, 2022), demonstrate that deficient compartmentalization can reduce available evacuation time from over 30 minutes to as little as 10 to 15 minutes, a difference that may be the difference between life and death in a large-floor-plate office building. Given Mohammed and Abdulrahman (2023). finding that effective compartmentalization reduces fire fatalities by 40–60%, the neglect of this system in Abuja's public buildings represents a measurable and preventable increase in occupant risk.

Systemic and Institutional Factors

The four contributing factors identified through stakeholder engagement, institutional failures, economic constraints, technical capacity gaps, and problematic procurement practices, are not independent. They reinforce one another in ways that make the problem resistant to piecemeal solutions. Weak enforcement creates a permissive environment in which cost-cutting in procurement is rarely penalised. Cost-cutting procurement degrades the quality of installed systems. Degraded systems are not maintained because maintenance budgets are insufficient and technical expertise is lacking. And without consequences for non-compliance, the cycle continues.

This pattern has parallels in other Sub-Saharan African contexts (Ayeni, *et al.*, 2025), but it is not inevitable. Countries that have improved fire safety compliance rates have typically done so through a combination of stronger regulatory institutions, mandatory regular inspections with published outcomes, and financial incentives, such as insurance premium reductions, tied to demonstrated compliance (Cordes, *et al.*, 2022).

CONCLUSION

This study has appraised the state of passive fire protection in six public office buildings in Abuja, Nigeria. The findings are clear and concerning: only 33% of the buildings assessed are fully compliant with the Nigerian Building Code, with systemic deficiencies recorded across structural fire resistance, compartmentalization, fire-resistant openings, and egress protection. The depth of these deficiencies is not primarily a function of poor initial design; it is the product of inadequate maintenance, weak regulatory enforcement, limited technical capacity, and chronic underfunding, conditions that are mutually reinforcing and deeply embedded in the institutional culture of public building management in Nigeria (Gado 2025). The age-related deterioration pattern is particularly instructive. Newer buildings can and do achieve high compliance scores, demonstrating that the knowledge and materials for effective passive fire protection exist within the Nigerian construction sector. The challenge is sustaining compliance over a building's operational life. Without mandatory inspection cycles, adequate maintenance budgets, and genuine regulatory consequence, even well-designed buildings deteriorate into hazardous ones.

This study is subject to limitations inherent in its scope: a six-building sample drawn from a single district limits generalisability, and the cross-sectional design captures only a single moment in each building's lifecycle. Future research should pursue broader multi-city surveys, longitudinal tracking of system performance degradation, and systematic evaluation of cost-effective retrofit strategies for Nigeria's existing public building stock.

Recommendations

Immediate Interventions

The most urgent need is to address deficiencies that directly endanger occupants in the event of fire. This means clearing and maintaining egress routes, ensuring fire doors are functional and uncorrected, and repairing visible gaps in fire barriers. These actions do not require legislative change or major capital expenditure; they require facility management commitment and basic maintenance funding.

Policy and Regulatory Reform

The Nigerian Building Code should be reviewed and updated to incorporate current international standards on passive fire protection, with attention to the specific conditions of Nigerian construction practice and the urban environments of rapidly growing cities like Abuja.

Capacity Building

The technical knowledge gap identified among facility managers is not a personal failing; it reflects underinvestment in professional development across the public sector estate. Structured training programmes for facility managers, building inspectors, and fire safety officers should be developed and funded at both federal and state levels. The integration of Building Information Modelling and digital twin technologies into facility management practice could improve predictive maintenance capabilities and reduce the risk of undetected deterioration.

Economic and Financial Strategies

Economic modelling undertaken in this study suggests that comprehensive passive fire protection upgrades, estimated at ₦150–300 million per building, could avert losses exceeding ₦2–8 billion, yielding benefit-cost ratios of between 8:1 and 25:1. This is a compelling case for investment, but it requires long-term funding commitments rather than sporadic capital allocations. Annual allocations of 2–4% of building replacement cost for fire safety maintenance, a standard benchmark in facilities management practice, would provide the financial predictability needed to sustain

compliance over time. Insurance incentives tied to verified compliance offer an additional mechanism for encouraging private owners and public building managers alike to prioritise fire safety.

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Passive Security Strategies for Sustainable Redevelopment of Abuja Metro Station: An Overview

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ABSTRACT

Metro stations are critical public transportation hubs, yet their high foot traffic and open accessibility make them inherently vulnerable to criminal activity, including theft, vandalism, and terrorism. As urbanisation accelerates, redeveloping transit infrastructure with a strong focus on safety and security becomes increasingly essential. This study investigates the integration of passive security design, rooted in the principles of Crime Prevention Through Environmental Design (CPTED), in the redevelopment of Abuja Metro Station. By shaping the built environment through spatial planning, access control, and visibility enhancements, passive design not only discourages criminal behaviour but also improves passengers' perception of safety. Using a qualitative case study approach, the research gathers data through field observations, stakeholder interviews, and document reviews, while also analysing international metro systems to identify best practices applicable to Abuja's context. Findings reveal persistent challenges, such as petty crime, unauthorised access, and overcrowding, which threaten both passenger safety and operational efficiency. The study demonstrates that strategic implementation of passive security measures, including natural surveillance, territorial reinforcement, and controlled pedestrian flows, can significantly enhance both real and perceived safety. These findings inform a series of recommendations tailored to the study area, offering a framework for designing safer, more resilient public transportation systems in rapidly growing cities.

Keywords: Transportation Hubs, Passive Security Design, Crime Prevention, Passenger Safety, CPTED, Urban Planning, Transit Security

INTRODUCTION

The rapid pace of urbanisation in developing countries has transformed public transportation, placing increased demands on metro systems and their supporting infrastructure. Metro stations serve as the arteries of urban mass transit, facilitating the movement of millions of passengers daily while simultaneously acting as sensitive security targets (Alam et al., 2024). Their high pedestrian density, multiple entry points, and around-the-clock accessibility create conditions that heighten vulnerability to various forms of criminal activity, including theft, vandalism, and unauthorised access (Abdullahi, 2021). Ensuring passenger safety encompasses both physical protection and psychological comfort, extending beyond traditional security measures such as surveillance cameras and personnel (Schuitema, 2025). Consequently, environmental and architectural design strategies have become essential tools for mitigating risk, promoting natural surveillance, and enhancing user confidence in public transportation systems. In Abuja, Nigeria's administrative capital, recurring incidents of petty crime, overcrowding, and gaps in monitoring underscore the urgent need for security-sensitive station design (Adejoh, 2013).

Passive security design, grounded in the principles of Crime Prevention through Environmental Design (CPTED), offers a proactive approach to enhancing safety by shaping the built environment to discourage criminal activity (Yoade et al., 2023). Unlike active measures that rely primarily on surveillance or personnel, passive strategies integrate safety into spatial layout, lighting, material selection, and wayfinding. These interventions not only reduce crime opportunities and occurrence but also foster a perception of security that encourages responsible use of transit spaces. This study investigates the integration of passive security design principles in the redevelopment of Abuja Metro Station.

While global transit systems have successfully institutionalised Crime Prevention through Environmental Design (CPTED), however, there is still a marked deficiency in applying these principles within the unique socio-spatial context of West African urban centres. Previous research, such as that by Badiora and Adeyemi (2021), highlights that high-traffic hubs in developing nations remain vulnerable to theft and vandalism due to a reliance on resource-intensive, reactive security rather than preventative design. Consequently, there is a critical shortage of evidence-based frameworks addressing localised challenges such as high-density informal commerce and climate-induced visibility issues. This research study is positioned at the intersection of architecture and urban safety, shifting the paradigm from high-cost active surveillance to design-led passive security. By evaluating the Abuja Metro Station's current CPTED adherence which stands at a critical rating, this research provides a local redevelopment framework that leverages architectural transparency, natural surveillance, and territorial reinforcement to foster a more resilient and secure transit environment.

LITERATURE REVIEW

The concept of Crime Prevention through Environmental Design (CPTED) emerged in the 1970s as a multidisciplinary strategy to reduce crime by reshaping the built environment. Developed by C. Ray Jeffery and expanded by Oscar Newman, CPTED posits that the physical environment can be designed to reduce both crime opportunities and the fear of crime (Mihiniac & Saville, 2019). The framework operates on four core principles: natural surveillance, natural access control, territorial reinforcement, and maintenance (Goren, 2023). Within transportation infrastructure, these passive security measures are integrated directly into the physical layout. This involves using strategic lighting, open

sightlines, and durable materials to embed security into architectural decisions, making safety less intrusive and more sustainable than active policing (Ikani, 2021). Comparative international experiences, such as the redesign of the London Underground and the Singapore MRT, demonstrate that passive strategies like open station layouts and intuitive wayfinding significantly enhance operational efficiency and passenger safety (Izak, 2025; Li et al., 2024).

However, critics of CPTED argue that the strategy can lead to fortress architecture, potentially displacing crime to adjacent areas rather than eliminating it, or creating exclusionary public spaces that marginalise vulnerable populations (Parnaby, 2006). Furthermore, scholars suggest that over-reliance on physical design often ignores the underlying socio-economic drivers of crime, potentially providing a false sense of security if not paired with social interventions. In the context of the Abuja Metro Station, the adoption of passive security offers distinct advantages in cost-effectiveness and cultural resonance. Integrating CPTED principles during redevelopment mitigates the high recurring costs of active surveillance technology, which is often hampered by Nigeria's inconsistent power supply. Culturally, the use of communal seating and local transit-oriented commerce leverages the Nigerian concept of communal guardianship, turning commuters into active participants in station security.

Conversely, the strategy faces localised limitations. Abuja's tropical climate and Harmattan dust require specialised material resilience to prevent environmental degradation that could lead to the Broken Windows effect. Moreover, the station's location in a high-density zone necessitates a modular design that can accommodate informal commercial activities without compromising sightlines. Ultimately, while passive design reduces the burden on formal law enforcement, its success in Abuja is contingent upon a robust maintenance culture and the flexibility to adapt to rapid urban growth. When examined against international best practices, the challenges at Abuja Metro Station highlight the importance of adapting global lessons to local contexts. Singapore's open design philosophy, which emphasises sightlines and spatial transparency, offers an effective model for improving natural surveillance.

Similarly, London's extensive use of integrated lighting systems provides lessons for addressing safety concerns related to illumination in high-density transit environments. Mexico City's gender-sensitive approaches, such as women-only train cars and strategically placed retail outlets, are particularly relevant in Abuja, where gendered safety concerns are pressing and where socio-cultural similarities make such strategies transferable. However, successful adaptation of these practices requires careful consideration of Abuja's tropical climate, limited maintenance resources, and socio-economic realities to ensure long-term sustainability (Gadiaga et al., 2025).

METHODOLOGY

Abuja Metro Station, a station which serves as a central multi-modal hub within Nigeria's Federal Capital Territory, strategically situated in the Central Business District (CBD) adjacent to the World Trade Centre (See Figure 1), managed by the Federal Capital Territory Administration (FCTA) and the Nigerian Railway Corporation (NRC). The station is a vital component of the city's regional transit network, connecting the metropolitan core to outlying areas such as Kubwa and Idu as its primary purpose is to facilitate the daily movement of approximately 1.4 million commuters, offering a sustainable rail alternative to the city's significant road traffic congestion.

This study adopts a qualitative case study approach to investigate the integration of passive security design principles in the redevelopment of the Abuja Metro Station. This design is appropriate for gaining an in-depth understanding of user interactions within the built environment and evaluating the impact of spatial interventions on safety. The study area is situated in the Federal Capital Territory (FCT), Nigeria, as shown in the map in Figure 1. This site was selected due to its strategic importance and the documented architectural challenges regarding visibility and access control.

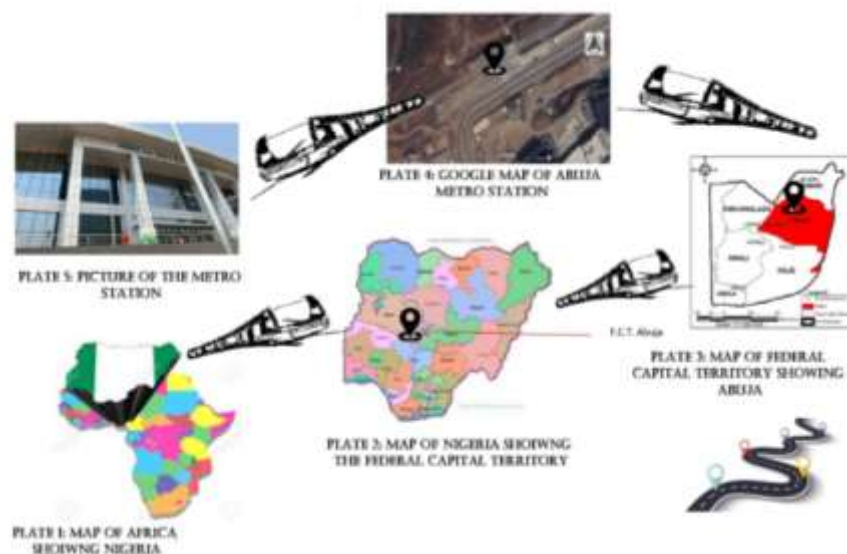


Figure 1: The Location of study

Participants were selected through purposive sampling to ensure a triangulation of technical expertise and lived experience. A total sample size of 20 participants was reached, comprising five (5) metro staff who provided insights into operational bottlenecks, five (5) security experts including transit police familiar with local crime trends, and ten (10) regular commuters to capture diverse perceptions of safety. Ethical approval was obtained from the Institutional Review Board of the Federal University of Technology, Minna, and ensuring informed consent across all groups.

Data collection utilised multiple methods to ensure validity. Semi-structured interviews were conducted with the ten (10) key stakeholders (staff and experts), while the ten (10) commuters provided data through guided field interactions. This sample size was justified by reaching data saturation, where no new thematic insights regarding the station's CPTED adherence were observed. Complementing these, field observational studies were conducted using a quantifiable Rating Scale (Table 1) and photographic documentation to record architectural vulnerabilities. Data were analysed using thematic analysis following the six-phase framework by Braun and Clarke (2006). This process involved rigorous coding and the synthesis of themes to interpret how environmental cues and user perceptions intersect.

Table 1: Quantifiable Rating Scale

SCALE	RATING	DETAILED ARCHITECTURAL CRITERIA
Extremely Adequate	5	The environment demonstrates a state-of-the-art integration of CPTED principles where passive security is seamlessly embedded into the architectural design. Design features provide 360-degree natural surveillance, unambiguous territorial reinforcement, and total access control without compromising commuter flow.
Exemplary	4	Best practices are fully implemented; the space is highly secure and functional with effective territorial reinforcement and no significant criminal incidents.
Strong	3	The space is designed with a high degree of adherence to CPTED principles, resulting in a well-maintained, secure environment with high user satisfaction.
Moderate	2	Most CPTED principles are applied, leading to a noticeable reduction in crime, but significant physical improvements are still required.
Minimal	1	CPTED principles are partially implemented but are insufficient to ensure a significant reduction in crime or the fear of crime.
Poor	0	The environment has little to no attention paid to CPTED principles, with little or no crime prevention design features present.

RESULTS AND DISCUSSION

Security at the Abuja Metro Station

The security assessment of the Abuja Metro Station identifies a significant disconnect between its high-visibility urban context and its internal architectural efficacy, the station fails to meet basic safety-by-design benchmarks. The research highlights that while the central concourse provides a semblance of safety, the under-performance in Territorial Reinforcement and Maintenance as shown in Table 2 creates blind spots that facilitate unauthorised access and theft. Consequently, the station remains a high vulnerability environment, requiring urgent architectural intervention to move beyond minimal safety adherence.

Evaluation of CPTED Performance Ratings

The summary of Qualitative Description of CPTED Performance as observed during the field work and ratings are presented in Table 2, the station operates primarily within the minimal to moderate range. While some structural foundations exist, they are currently insufficient to ensure a significant reduction in crime or the fear of crime.

Table 2: Summary of Qualitative Description of CPTED Performance Ratings for Abuja Metro Station

CPTED PRINCIPLES	RATING	QUALITATIVE DESCRIPTION (BASED ON TABLE 1)
Natural Surveillance	2.25	Moderate: Partial application but requires physical intervention.
Access Control	2.25	Moderate: Compromised by non-functional hardware and screening gaps
Territorial Reinforcement	1.00	Minimal: Insufficient implementation to reduce the fear of crime.
Activity Support	1.30	Minimal: Partial amenities present but lacks commercial integration.
Technology Integration	1.25	Minimal: Recording-only systems are insufficient for active prevention
Maintenance Culture	1.60	Minimal/Moderate: Visible neglect signals a need for significant improvement

Natural Surveillance and Visibility

The Abuja Metro Station's natural surveillance is rated 45% as seen in Table 3, supported primarily by a favourable Site Location (80%). However, this is undermined by a total failure in Gated Access (0%) and Defined Entry/Exit points (0%), which prevents effective spatial control. Architectural obstructions specifically massive opaque columns create dead zones by compromising Sightlines (60%) and Spatial Arrangement (60%). Despite some safety in the central concourse, the 40% Site Plan rating highlights a lack of integrated lighting and transparency. To address the performance deficit, the study recommends adopting open design philosophies to eliminate structural blind spots and ensure continuous visibility.

Table 3: Analysis of Natural Surveillance Principle of CPTED in Abuja Metro Station

NATURAL SURVEILLANCE	RATING	RATIO
SITE LOCATION	4	80%
SITE PLAN	2	40%
BOUNDARIES	2	40%
GATED ACCESS	0	0%
DEFINED ENTRY AND EXIT	0	0%
SIGHTLINES	3	60%
SPATIAL ARRANGEMENT	3	60%
DESIGN LAYOUT	3	60%
NATURAL SURVEILLANCE	2.25	45%

Access Control and Pedestrian Flow

The Abuja Metro Station's access control system operates at a 45% efficiency level according to Table 4 captured by a significant disparity between structural provision and operational functionality. Although entrance infrastructure is robust (80%), the system is undermined by a total lack of Wayfinding (0%) and compromised Platform Access (40%). The resulting non-sterile zones and overcrowding create high-vulnerability pockets. Academic analysis suggests that without restoring hardware functionality and implementing clear zoning, the station remains a soft target despite its substantial building envelope, which is essential to guide movement while maintaining a secure perimeter.

Table 4: Analysis of Access Control Principle of CPTED in Abuja Metro Station

ACCESS CONTROL	RATING	RATIO
BUILDING ENTRANCES AND EXIT	4	80%
ACCESS TO PLATFORM	2	40%
RESTRICTED ACCESS	3	60%
WAYFINDING	0	0%
ACCESS CONTROL	2.25	45%

Territorial Reinforcement and Activity Support

Territorial Reinforcement at the Abuja Metro Station is critically deficient (See Table 5) scoring only 20% in overall implementation. The research highlights a minimal application of proprietary cues, with 0% ratings in community-centric markers and public art. This lack of symbolic barriers, combined with poor Fencing and Landscaping (40%), leads to spatial inadequacies and the formation of activity neglect. The study concludes that the absence of commercial integration and community markers disproportionately impacts vulnerable demographics, specifically women, necessitating a shift toward gender-sensitive and community-integrated design to reclaim underutilised dead zones.

Table 5: Analysis of Territorial Reinforcement Principle of CPTED in Abuja Metro Station

TERRITORIAL REINFORCEMENT	RATING	RATIO
LANDSCAPE	2	40%
FENCING	2	40%
COMMUNITY INVOLVEMENT	0	0%
PUBLIC ART	0	0%
TERRITORIAL REINFORCEMENT	1	20%

Technology Integration and Maintenance Culture

The Abuja Metro Station's security resilience is hindered by a reactive technological framework and poor maintenance culture, scoring only 27% in Activity Support. Critical infrastructure gaps, including a 0% rating for commercial integration and a lack of real-time monitoring, create a passive security environment as shown in Table 6. The study finds that the absence of proactive technology, such as motion sensors and emergency helplines, leaves commuters vulnerable. Moreover, visible environmental neglect reinforces a perception of disorder, suggesting that the restoration of physical hardware and the transition to smart surveillance are vital to establishing a credible security deterrent.

Table 6: Analysis of Activity Support Principle of CPTED in Abuja Metro Station

ACTIVITY SUPPORT	RATING	RATIO
RETAIL OUTLET	0	0%
PUBLIC AREA	3	60%
INFORMATION DIRECTORY	1	20%
ACTIVITY SUPPORT	1.3	27%

Structural Vulnerabilities and Spatial Blind Spots

The primary structural vulnerability identified at the Abuja Metro Station is the prevalence of massive, opaque circular columns shown in Plate 1. These architectural elements act as significant visual barriers; field audits indicate the total floor area is shielded from direct sightlines. This spatial fragmentation has created 12 distinct 'dead zones' pockets

where criminal behaviour can occur shielded from both natural surveillance and electronic monitoring. The density and girth of these columns directly violate CPTED continuous sightline protocols, providing potential offenders with ample concealment and reducing the prospect of the station layout.



Plate 1: Circular columns and deep alcoves

Poor Lighting and Environmental Deterrence

Quantitative assessments using a lux meter revealed that illumination levels in critical exits and waiting zones average less than 50 lux, a sharp contrast to the 200-lux international safety standard required for high-traffic transit hubs. These dark zones function as a significant environmental deterrent, exacerbating passenger fear and reducing station utility during the Harmattan season or after dusk. Furthermore, this low illumination (See Plate 2) creates a technical failure point as it severely degrades CCTV footage quality, rendering electronic surveillance systems effectively blind, as the lack of visibility discourages legitimate eyes on the street and reinforces a perception of the station as an unmanaged, high-risk environment.



Plate 2: Part of the station lighting situation at noon

DISCUSSION OF FINDINGS

The discussion of findings reveals that safety at the Abuja Metro Station is a multifaceted issue where structural vulnerabilities specifically the shadow effect created by massive opaque columns directly exacerbate demographic and temporal anxieties. While the station's strategic urban location provides a foundation for eyes on the street, architectural blind spots and sub-standard lighting levels averaging below 50 lux transform high-potential zones into high-risk 'dead zones'. These areas disproportionately affect vulnerable groups, including women and senior citizens, particularly during off-peak hours when natural surveillance is at its lowest. These physical deficiencies are compounded by a systemic breakdown in maintenance culture, evidenced by the security fatigue commuters experience regarding non-functional access control hardware. Consequently, this study rejects a universal security model in favour of adaptive passive strategies. By integrating modular retail kiosks to maintain a consistent human presence and replacing opaque architectural obstructions with transparent barriers, the station can transition from minimal CPTED adherence to a resilient, inclusive transit hub.

RECOMMENDATIONS

Based on these results, a multi-phased approach to design intervention is recommended as immediate priorities such as lighting upgrades in high-risk areas, removal of architectural obstructions to improve sightlines, and re-organisation of

pedestrian circulation to minimise conflict points and improve flow. Medium-term strategies should involve spatial reconfiguration, including the redesign of station layouts to align circulation paths with natural surveillance opportunities and the strategic placement of retail and service functions to activate overlooked areas. Long-term strategies demand a holistic integration of CPTED principles into the station's redevelopment. This includes reinforcing territorial cues, optimising access control systems, maximising opportunities for natural surveillance, and embedding maintenance into design as an ongoing practice. Furthermore, technological innovations such as adaptive lighting, integrated communication systems, and responsive emergency facilities should be embedded within the architectural framework, enhancing passive security rather than substituting for it. These findings highlight that passive security strategies, when carefully integrated into the architectural and spatial planning of Abuja Metro Station, can not only mitigate current risks but also transform the facility into a safer, more user-centred transit environment.

FUTURE RESEARCH DIRECTIONS

While this study has provided critical insights into the role of passive security strategies in the redevelopment of Abuja Metro Station, future research is needed to extend and validate these findings. Collectively, these directions point to a growing need for interdisciplinary research that bridges architecture, planning, security studies, and urban technology in order to create safer, more inclusive, and sustainable metro systems. One important direction involves the use of quantitative techniques to complement qualitative results. Large-scale user surveys and systematic analysis of crime statistics could provide measurable evidence of how architectural design interventions influence both perceived and actual safety outcomes. Such approaches would also allow for the assessment of the financial implications of passive security enhancements, thereby informing cost-benefit evaluations that are vital for policymakers and urban planners (Lamoreaux & Sulkowski, 2021).

Another area for further investigation lies in comparative studies across metro systems in developing countries. Cross-cultural analyses of design preferences, safety perceptions, and crime prevention strategies could reveal how socio-cultural and economic contexts mediate the effectiveness of CPTED principles. Benefits derived from comparable urban environments in Africa, Asia, and Latin America would help identify scalable and adaptable design strategies for Abuja and other rapidly urbanising cities in sub-Saharan Africa (Ahmed et al., 2025).

Finally, future studies should investigate the integration of specific emerging technologies that reinforce passive security frameworks. Research should prioritise the architectural and operational implications of Smart Lighting Systems (SLS), which utilise motion sensors to adapt illumination levels to pedestrian flow, and Video Content Analytics (VCA), which provides predictive analytics to detect suspicious behaviour patterns before they escalate. Additionally, the role of Geographic Information Systems (GIS) in mapping crime hotspots for spatial optimisation and the use of Building Information Modelling (BIM) to simulate natural surveillance sightlines during the design phase offer significant potential. Rather than replacing physical interventions, these digital tools including Internet of Things (IoT)-enabled emergency pillars and Mobile Wayfinding Applications complement CPTED principles by providing real-time data that enhances the resilience and responsiveness of transit environments (Chen et al., 2024).

CONCLUSION

This research underscores that passive security design is both a technical and policy imperative for the sustainable redevelopment of transit systems in rapidly urbanising regions. By evaluating the Abuja Metro Station, the study demonstrates that CPTED-based interventions specifically enhanced natural surveillance, robust territorial reinforcement, and optimised spatial layouts can effectively mitigate recurring challenges such as theft and overcrowding while significantly improving passenger psychological comfort. The findings reveal three core insights, which include safety perceptions that are fundamental to a system's operational success, spatial design which directly dictates opportunities for informal guardianship and security as the most effective when passive architectural features are seamlessly integrated with active technological systems and rigorous operational management. The study advocates for embedding security into the initial design phases of infrastructure projects, ensuring that international best practices are contextually adapted to local socio-cultural and environmental realities to provide a resilient blueprint for inclusive public transportation across sub-Saharan Africa.

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Sustainable Housing Solutions: A Review of Climate-Responsive Architectural Approaches for Abuja's Urban Growth

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ABSTRACT

Abuja the Nigeria's administrative capital, faces rapid urbanization, exacerbating demand for sustainable housing. Many contemporary developments neglect climate-responsive design, leading to high energy consumption and poor thermal comfort. This study evaluates the implementation of passive design strategies in Abuja's housing sector and quantifies their impact on energy performance and occupant satisfaction. A mixed-methods approach was employed, including detailed environmental monitoring of five case studies (n=45 residential units), semi-structured interviews with stakeholders (architects, developers, planners; n=26), and occupant surveys (n=24). Results revealed that only 23% of developments integrated core climate-responsive principles. Critically, the study also found a strong correlation between design choices and performance: projects with unshaded, east-west oriented façades and high window-to-wall ratios ($WWR > 40\%$) consumed 35-45% more energy for cooling ($180\text{-}220\text{ kWh/m}^2\text{/year}$) than those with strategic shading and north-south orientations. Furthermore, 67% of units in conventional designs exceeded 30°C during peak dry season, leading to low occupant satisfaction with thermal comfort (2.8/5.0). The study concludes that a shift from aesthetic-driven to performance-based design is imperative. The study therefore proposes a practical framework centered on mandatory climate-responsive zoning, enhanced building codes with performance metrics, and the integration of cost-effective vernacular strategies like deep overhangs and cross-ventilation to ensure sustainable urban growth in Abuja and similar tropical cities.

Keywords: Climate-Responsive Design, Sustainable Housing, Passive Cooling, Energy Efficiency, Thermal Comfort, Tropical Architecture, Abuja

INTRODUCTION

The population of Abuja has increased dramatically from 107,000 in 1991 to over 3.5 million today, creating an unparalleled need for housing (Emmanuel, 2024). This quick expansion has frequently put cost and speed ahead of environmental performance, which has led to a housing stock that is not appropriate for the city's tropical savanna climate (Lubogo, 2022). The climate of Abuja, which is characterized by high solar radiation and distinct wet and dry seasons, necessitates particular architectural responses in order to prevent excessive cooling energy use and guarantee occupant comfort (Kalyoncuoglu, & Guerrou, 2022).

This paper moves beyond theoretical discussion to present the needed evidence-based analysis of current housing performance in Abuja (Ahmad, 2025). This study offers architects, developers, and policymakers in West Africa a clear, practical framework for incorporating climate-responsive principles into Abuja's urban fabric by calculating the energy and comfort costs of bad design and identifying implementation obstacles.

METHODOLOGY

Research Design

In order to ensure triangulation and a thorough grasp of the research problem, this study used a convergent mixed-methods design, combining quantitative environmental data with qualitative insights from stakeholders (Vivek, 2023).

Case Study Selection

Five housing estates in Abuja were selected as case studies to represent a spectrum of typologies, densities, and stated design approaches (Table 1).

Table 1: Case Study Characteristics

Estate Name	Typology	Year	Units Sampled	Stated Design Approach	Features
Millennium City	High-density Condos	2018	10	Contemporary	Glazed facades, minimal shading
Guzape District	Mixed-income	2015	12	Hybrid	Partial shading, mixed materials
Lifecamp	Private Estate	2012	8	Conventional	Brickwork, punched windows
Kubwa New Town	Public Housing	2009	29	Basic	Minimal design consideration
Jabi Lake	High-rise	2020	6	"Green"	Balconies, some sunscreens

2.3 Data Collection

Quantitative Data

Using calibrated HOBO MX110 data loggers, indoor environmental quality (IEQ) parameters (dry-bulb temperature, relative humidity, and illuminance) were recorded at 30-minute intervals over a 6-month period (Jan-Jun 2024) in the living areas of sampled units (Khovalyg, 2020). Estate management provided the 2023 annual energy consumption data for lighting and cooling, which were then normalized per square meter ($\text{kWh/m}^2\text{/year}$).

Qualitative Data: Semi-structured interviews were conducted with 12 architects, 8 developers, and 6 urban planners. An interview protocol focused on design philosophy, perceived barriers (cost, knowledge, regulation), and implementation challenges (Hanbury, 2012). Additionally, 24 residents across the estates completed satisfaction surveys, using a 5-point Likert scale to assess thermal, visual, and overall comfort.

Data Analysis

The quantitative data were analysed using ANOVA to check for performance differences between case studies, correlation analysis between design features (orientation, WWR) and energy use, and descriptive statistics using SPSS 28.0 (Dagiyan, 2024). To find reoccurring themes and obstacles, qualitative data from interviews was coded and transcribed using NVivo 12.0 for thematic analysis (Iqbal *et al.*, 2024).

RESULTS AND ANALYSIS

Quantitative Performance Findings

The data revealed stark contrasts in performance directly linked to design strategies.

Energy Consumption

Buildings with extensive unshaded glazing (Millennium City, Jabi Lake) had the highest energy intensity for cooling, averaging 210 kWh/m²/year. In contrast, developments with strategic shading and lower WWR, like Guzape District, consumed 35% less (135 kWh/m²/year). WWR and cooling energy consumption were found to be strongly positively correlated ($r = 0.82$).

Thermal Comfort

About 67% of units in east-west oriented buildings without shading continuously exceeded 30°C during the busiest dry season (March), falling short of ASHRAE comfort standards for 78% of occupied hours (Osman, 2019). For more than 65% of the time, temperatures below 28°C were maintained by north-south oriented units with deep overhangs.

Design Implementation

According to an analysis of the case studies, 68% of them maximized undesired solar heat gain by orienting their primary façades within 30° of east-west (Wu, 2025). The majority relied on ineffective internal blinds, while only 20% used efficient external shading devices.

Stakeholder Perspectives (Qualitative Themes)

Thematic analysis of interviews revealed critical implementation barriers:

Architects

The cited client demand for "modern" (glassy) aesthetics and a lack of expertise in advanced climate simulation tools as major constraints.

Developers

This group identified higher initial costs (5-15% for integrated shading) and a lack of market valuation for energy efficiency as primary disincentives. One developer stated, "Homebuyers look at marble floors, not sun-shading angles."

Planners

The sampled planner highlighted weak enforcement of existing building codes and the absence of specific performance-based regulations for residential energy use.

Occupant Satisfaction

Environmental data and survey results were triangulated. Thermal comfort received a low rating of 2.8 out of 5.0, whereas satisfaction with amenities was high at 78% (Aghniaey, 2019). Significantly, 72% of respondents in glazed-unit buildings said they kept their blinds permanently closed, which negated the potential benefits of daylighting and increased the energy consumption of lighting. This finding is in line with research conducted in mixed-use buildings.

DISCUSSION

Interpreting the Performance Gap

The results demonstrate a significant performance gap driven by a fundamental misalignment between design intent and climatic reality (Adeniji, 2021). In Abuja's tropics, the preference for large, unshaded glazing — a direct import from temperate climates—is a major cause of discomfort and energy inefficiency. This is consistent with research on mixed-use buildings that found that unshaded glazing above 40% WWR was a significant predictor of high cooling loads.

A Framework for Climate-Responsive Housing in Abuja

To close this gap, we propose a multi-tiered framework:

Design Strategies

Give priority to north-south orientation, restrict WWR on east/west façades to 30–40%, and require fixed external shading (vertical fins for east/west, 1.5–2.0m overhangs for south). For deep plan units, incorporate light wells and courtyards.

Policy and Regulation

The Abuja Master Plan and National Building Code must be updated to include performance-based metrics like Spatial Daylight Autonomy (sDA) and annual carbon emissions limits for cooling. Fast-track permitting processes for projects that demonstrate compliance through simulation.

Economic and Market Incentives

Provide property tax breaks for energy-efficient homes and green mortgage programs. Energy performance must be valued by appraisers, which will motivate developers financially.

Capacity Building

Include training in simulation software and climate-responsive design as required courses for engineers and architects.

CONCLUSION

This study assesses the implementation of passive design strategies in Abuja's housing sector and computes their effect on energy performance and occupant satisfaction. This study thus provides empirical evidence that the current trajectory of housing design in Abuja is environmentally and economically unsustainable. The over-reliance on mechanical cooling to compensate for poor design is a costly failure to adapt to the local climate (Cortiços and Duarte, 2025). The results also demonstrate how well-established, reasonably priced passive strategies can significantly lower energy use and enhance liveability.

The suggested framework is not just theoretical; it is an essential call to action for cooperation between developers, policymakers, and designers. (Haliru, 2024). Abuja can make its housing sector a model of resilient and sustainable urban growth for tropical Africa by adopting a performance-based design culture that prioritizes environmental intelligence over imported aesthetics.

In order to give more precise design guidance, determine whether new technologies are feasible, and assess policy measures, the study recommends more research on microclimate studies, post-occupation evaluation of climate-responsive housing projects, technology assessment, and policy impact assessment (Hafizi, 2022). With an emphasis on climate-responsive design, sustainable housing solutions are required due to Abuja's urban expansion. Setting an example for African cities, cooperation between developers, lawmakers, architects, and residents is essential to success.

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