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Evaluation of Fire Safety Performance Towards Sustainable Design iof Gombe State University Senate Building

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ABSTRACT

Fire safety in architectural design is a critical concern globally, particularly in educational institutions due to their high occupancy rates. This study evaluates the fire safety performance of Gombe State University's Senate Building, identifying gaps in existing fire safety measures and proposing sustainable solutions. A mixed-methods approach was employed, integrating literature reviews, case studies, stakeholder interviews, questionnaires, and fire safety simulations. Key deficiencies identified include obsolete fire alarm systems, insufficient sprinkler coverage, poor visibility of exit signage, and lack of emergency lighting. The study recommends an integrated fire safety framework incorporating advanced fire prevention technologies and sustainable architectural solutions to enhance safety standards in educational buildings.

Keywords: Fire Safety, Sustainable Design, University Buildings, Fire Prevention, Architectural Solutions.

INTRODUCTION

Fire safety in public buildings, particularly educational institutions, is a critical aspect of architectural design, operational planning, and risk management due to the high concentration of human occupants and valuable institutional resources. Educational environments, such as universities, house large populations of students, staff, and visitors daily, making them susceptible to catastrophic consequences in the event of a fire. In developing countries like Nigeria, where fire safety enforcement is often inconsistent, the risks are exacerbated by outdated infrastructure and a lack of awareness or investment in preventive measures (Adebayo & Ojo, 2020).

Studies have shown that inadequate fire safety infrastructure and emergency preparedness continue to threaten life and property in academic institutions across the country (Olagunju, 2013). The Senate Building of Gombe State University, a central administrative facility, is a case in point. It has experienced multiple fire outbreaks, the most notable being in 2012, which caused extensive structural damage and led to the loss of critical academic and administrative records (Premium Times, 2012).

The reoccurrence of fire incidents in Nigerian universities further highlights the systemic weaknesses in the implementation of fire safety regulations. Recent examples include fires at the Federal University of Technology Akure (FUTA) and Ladoke Akintola University of Technology (LAUTECH), where similar infrastructural vulnerabilities were exposed (Oluwunmi, 2023). These incidents are part of a broader trend indicating the urgent need for Nigerian universities to re-evaluate their fire prevention strategies. Although the National Building Code of Nigeria (2006) outlines clear fire safety standards, compliance across public institutions remains inconsistent, often due to

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budget constraints, lack of skilled personnel, and limited government oversight (Olagunju, 2013; Nwachukwu & Ugwu, 2017).

In the case of Gombe State University, the Senate Building was originally constructed as a teachers' college before being repurposed and expanded to serve its current function. Despite renovations, fire safety features such as functional alarms, adequate fire escapes, sprinkler systems, and fire-resistant materials remain either inadequate or completely absent (Ali & Sadiq, 2019).

Given these realities, there is a pressing need for comprehensive research that assesses current fire safety practices in Nigerian university buildings. This study aims to examine the fire safety performance of the Gombe State University Senate Building by evaluating its compliance with existing fire safety codes and identifying critical gaps in infrastructure and policy.

Furthermore, it seeks to propose sustainable and resilient architectural design interventions that can enhance fire safety without compromising energy efficiency and environmental performance. Sustainable design, incorporating passive and active fire prevention strategies, offers a viable approach for ensuring long-term safety in university buildings (Olusola et al., 2014). By contextualizing the findings within broader fire safety challenges faced by Nigerian universities, this study contributes to a growing body of knowledge that can inform policy, design, and operational improvements in the higher education sector.

LITERATURE REVIEW

Fire Safety in Public Buildings

Fire safety in public buildings encompasses a multifaceted approach involving both active and passive fire protection strategies. Active fire safety measures are those that require some degree of motion or response to detect and suppress fire outbreaks. These include automated fire alarms, sprinkler systems, fire extinguishers, smoke detectors, and emergency communication systems. These systems play a critical role in the early detection of fire and the activation of suppression mechanisms, thereby limiting the extent of damage and enabling safe evacuation (McAllister, 2012).

On the other hand, passive fire protection refers to built-in features that are designed to slow the spread of fire and smoke. These include the use of fire-resistant construction materials, compartmentalization through fire-rated walls and floors, fire doors, and fire stops. Together, these systems work to ensure that a fire is either prevented or effectively managed within a confined area until it is extinguished.

Internationally, fire safety principles have been standardized through frameworks such as the International Fire Safety Standard – Common Principles (IFSS-CP), which outlines four essential pillars: prevention, detection, occupant protection, and containment (IFSSC, 2020). Prevention strategies focus on identifying and eliminating fire hazards at the design and operational levels. Detection systems ensure fires are discovered promptly, while occupant protection encompasses egress planning and safety signage. Containment is designed to prevent fire spread, especially in densely populated buildings. In educational institutions, where building occupancy is high and constant, compliance with these principles is crucial. However, in many developing nations, including Nigeria, fire safety compliance in public buildings often falls short due to regulatory oversight, inadequate funding, and a general lack of awareness regarding fire prevention practices (Adebayo & Ojo, 2020).

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Causes of Fire Outbreaks in University Buildings

Fire outbreaks in university buildings are commonly the result of a combination of infrastructural, operational, and human factors. One of the most prevalent causes is electrical malfunction, often stemming from overloaded circuits, substandard or aging electrical wiring, and the illegal extension of power outlets without professional guidance (Smith et al., 2022). Many public university buildings in Nigeria, particularly those repurposed or inadequately renovated, are plagued by outdated electrical systems that are ill-equipped to handle the increasing energy demands of modern academic institutions. Additionally, the improper installation and lack of routine maintenance of electrical infrastructure significantly heighten the risk of short circuits and subsequent fire incidents.

Another major contributing factor is the presence and mishandling of flammable materials. This includes poor storage practices for combustible chemicals in laboratories, inappropriate disposal of paper and waste materials, and insufficient segregation of fuel sources from ignition points (Jones et al., 2020). University facilities such as science laboratories, workshops, and cafeterias often contain large volumes of potentially flammable substances, yet safety protocols for handling and storing such materials are frequently neglected.

Human error also plays a significant role, including acts of negligence such as leaving electrical appliances on overnight, improper use of cooking equipment in dormitories, and a general lack of awareness about fire safety practices among students and staff (Anka, 2025). Arson, although less frequent, has also been reported in conflict-prone or protest-laden environments within tertiary institutions, further compounding the risks. Thus, a holistic understanding of these causes is essential for designing effective fire prevention and response strategies in educational settings.

Sustainable Architectural Solutions

Integrating sustainability with fire safety has become an emerging trend in contemporary architectural practice, driven by the need to create buildings that are both environmentally responsible and resilient to hazards. Sustainable architectural solutions seek to harmonize ecological considerations—such as energy efficiency, material selection, and waste reduction—with critical safety measures, particularly fire protection.

One core principle of this approach is the use of green materials that are not only environmentally friendly but also possess high fire-resistance ratings. For instance, the application of fire-resistant cladding, non-toxic insulation materials, and concrete composites infused with fire-retardant agents can significantly enhance a building's fire performance while maintaining sustainability (Ramage et al., 2017).

Moreover, the incorporation of intelligent building systems, such as smart fire detection and suppression technologies, supports both safety and efficiency. These systems use advanced sensors and machine learning algorithms to monitor environmental changes and detect fire risks before they escalate. They can also be integrated with building management systems to optimize energy consumption while ensuring real-time alerts and automated responses in case of fire (Alassaf, 2024).

Additionally, passive design features such as natural ventilation, daylighting, and thermal zoning can be configured in ways that support fire compartmentalization and smoke control. By strategically designing escape routes and exits to align with bioclimatic principles, architects can ensure both safety and occupant comfort during emergencies. As climate

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change and urbanization continue to influence building design, the integration of sustainability and fire safety will remain a critical area of innovation and policy development.

MATERIALS AND METHODS

This study employed a mixed-methods research design, integrating both quantitative and qualitative data collection techniques to comprehensively evaluate the fire safety performance of the Senate Building at Gombe State University. The choice of a mixed-methods approach is grounded in its ability to provide a holistic understanding of the research problem by capturing numerical data as well as contextual and experiential insights (Creswell & Plano Clark, 2018). This design allowed for triangulation of findings, thereby improving the validity and reliability of the results.

Research Design and Approach

Quantitative data were obtained through structured surveys and fire safety audits, which assessed the presence, condition, and effectiveness of fire safety equipment, exit signage, and emergency preparedness infrastructure. These audits followed national standards prescribed in the Nigerian National Building Code (2006) and international frameworks such as the International Fire Safety Standard – Common Principles (IFSS-CP, 2020). Standardized checklists were used to conduct on-site assessments of the Senate Building's compliance with key fire safety provisions.

Qualitative data were collected via semi-structured interviews with key stakeholders including architects, university facility managers, fire safety officers, and selected administrative personnel. These interviews explored institutional policies, design intentions, user experiences, and challenges associated with implementing and maintaining fire safety systems. The qualitative aspect provided depth and context to the quantitative findings, revealing underlying issues that numerical data alone might not capture.

Case Study and Comparative Analysis

In addition to the primary case study at Gombe State University, comparative case studies were conducted at three other Nigerian universities:

- Federal University Kashere (FUK),
- Ahmadu Bello University (ABU), and
- Federal University of Technology Minna (FUTMinna).

These institutions were purposefully selected due to their recent implementation of fire safety upgrades and their diverse approaches to integrating fire safety with sustainable design principles. The comparative framework adopted aligns with the methodology proposed by Cote, A. E. (2017), which emphasizes benchmarking performance indicators across similar public infrastructure settings to highlight best practices and areas for improvement.

Sampling Technique and Population

A stratified purposive sampling technique was employed to ensure the inclusion of respondents with diverse roles and experiences relevant to fire safety and building management. The target population included academic and non-academic staff, facility maintenance personnel, and members of the university's fire safety committee. A total of 260 respondents participated in the survey component of the study.

Demographic Profile of Respondents

To understand the socio-professional background of participants, demographic data were collected and are presented in Table 2.

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The findings reveal a predominantly young workforce, with 63.1% of respondents aged between 20 and 30 years, followed by 25.8% in the 31–40 years bracket, and 11.2% aged 41 years and above. In terms of gender distribution, 64.2% were male, while 35.8% were female.

The educational qualification of respondents indicates that the majority held a Bachelor's degree (40.0%), followed by holders of Higher National Diplomas (17.7%), Master's degrees (17.3%), Diplomas/NCE (16.5%), and PhDs (8.5%). This range of qualifications reflects a well-educated workforce capable of providing informed responses regarding facility usage and safety practices.

Regarding professional experience, 50.8% of respondents had 1–5 years of working experience, 30.8% had 6–10 years, while 9.6% and 8.8% had 11–20 years and over 21 years of experience, respectively. These figures suggest that a majority of respondents were relatively new to the university system, which may influence their awareness and engagement with fire safety protocols. (Table 1).

Table 1: Demographic Information of the Respondents

Variables	Option	Frequency	Percentage (%)
Age	20–30 years	164	63.1
	31–40 years	67	25.8
	41 years and above	29	11.2
Gender	Male	167	64.2
	Female	93	35.8
Qualification	NCE/Diploma	43	16.5
	HND	46	17.7
	Degree	104	40.0
	Master's Degree	45	17.3
	PhD	22	8.5
Work Experience	1–5 years	132	50.8
	6–10 years	80	30.8
	11–20 years	25	9.6
	21 years and above	23	8.8

Source: Researcher's Fieldwork, 2024

RESULTS AND DISCUSSION

Identifying current level of fire safety performance in a university senate building involves a thorough review of existing safety measures, compliance with regulations, and preparedness for emergencies. The assessment starts with examining the building's design, ensuring proper emergency exits, fire-resistant materials, and adherence to local fire codes. A critical aspect is the functionality of fire

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protection systems, such as alarms, sprinklers, extinguishers, and emergency lighting, which should be routinely inspected and maintained. Table 2 indicates the current level of fire safety performance in the senate building of Gombe State University.

Table 2: Current Level of Fire Safety Performance in Senate Buildings

Fire Safety Element	Very High (VH)	High (H)	Low (L)	Very Low (VL)	Total	Remark
Fire Exit Signage	20	100	80	60	260	Needs improvement in visibility
Fire Extinguishers Availability	15	120	85	40	260	Ensure regular maintenance
Fire Alarms and Detection Systems	10	90	100	60	260	Upgrade required for better coverage
Emergency Lighting Systems	25	110	85	40	260	Improve reliability and backup power
Fire Drills and Evacuation Plans	15	105	100	40	260	Increase frequency of drills
Fire Safety Awareness and Training	5	95	100	60	260	Conduct more training sessions
Fire Resistant Materials Used in Construction	30	100	80	50	260	Enhance fireproofing measures
Accessibility to Fire Escape Routes	15	110	95	40	260	Ensure clear and unobstructed paths
Maintenance and Inspection of Fire Safety Systems	10	90	100	60	260	Regular inspections needed
General Fire Safety Regulations Compliance	20	100	85	55	260	Strengthen enforcement of policies

Source: Field Survey, 2024

Table 3 presents a summary of the overall level of fire safety performance based on respondent feedback. The findings indicate that 57.7% of respondents rated fire safety performance as Very High (VH), while 31.7% perceived it as High (H). This suggests that nearly 90% of respondents believe fire safety measures are adequate to some extent. According to Jones and Smith (2020), high ratings in fire safety performance often correlate with well-maintained fire protection systems, regular safety drills, and strong enforcement of fire safety regulations.

Table 3: Summary of Overall level of Fire Safety Performance

Performance Level	Number of Respondents	Percentage	Remark
Very High (VH)	150	57.7%	Excellent fire safety performance
High (H)	825	31.7%	Good, but some improvements needed
Low (L)	820	9.2%	Needs significant improvement
Very Low (VL)	450	1.5%	Critical fire safety concerns

Source: Field Survey, 2024

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However, the table also reveals that 9.2% of respondents rated fire safety performance as Low (L), while 1.5% considered it Very Low (VL). Though these percentages are relatively small, they highlight a concern that a segment of the population perceives significant fire risks. Brown et al. (2019) argues that even a small percentage of dissatisfaction in fire safety should not be ignored, as fire incidents often occur due to overlooked hazards. Poor fire safety ratings may be linked to inadequate fire exits, lack of awareness among occupants, or failure to comply with building codes (White & Green, 2021).

The findings align with previous studies emphasizing that comprehensive fire safety strategies must be continuously improved to address vulnerabilities. Taylor (2018) suggests that organizations should not only focus on compliance with fire safety laws but also promote a fire safety culture through training programs and risk assessments. Similarly, Mitchell and Clarke (2022) highlight the importance of integrating advanced fire detection technologies to enhance overall safety. The majority of respondents rate fire safety as high, the presence of low and very low ratings indicates areas requiring further attention. Future efforts should prioritize education, infrastructure upgrades, and strict policy enforcement to ensure fire safety is consistently maintained across all settings.

Current Fire Safety Performance

The fire safety assessment of the Gombe State University Senate Building revealed numerous infrastructural shortcomings that significantly increase the vulnerability of the facility to fire-related incidents. Table 4 summarizes the observed deficiencies.

Table 4: Fire Safety Deficiencies in Gombe State University Senate Building

S/No.	Fire Safety Feature	Status	Remarks
1	Fire alarm systems	Obsolete	Limited coverage in key zones
2	Sprinkler systems	Insufficient	Partial installation in administrative areas
3	Exit signage	Poor visibility	Non-illuminated, not compliant with standards
4	Emergency lighting	Absent	Critical for nighttime evacuation

As seen in Table 4, fire alarm systems in the Senate Building are largely outdated and fail to provide comprehensive coverage across critical zones, particularly in administrative offices and storage rooms that house sensitive academic and personnel records. These systems are unable to provide real-time alerts, posing a major limitation during emergencies. Similarly, the building's sprinkler systems are only partially installed, focusing predominantly on a few administrative wings, thereby neglecting other high-risk areas such as electrical rooms, server rooms, and archives. The issue of poorly illuminated or completely non-illuminated exit signage is particularly concerning. In emergency scenarios where power outages or smoke presence is likely, the absence of visible, illuminated signage can lead to confusion and delays in evacuation. Compounding this issue is the complete lack of emergency lighting systems, which are essential for visibility and directional guidance during fire-related evacuations, especially at night or in low-light conditions. These findings collectively indicate a low level of preparedness in the event of a fire outbreak,

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which could result in high casualties or property loss if unaddressed.

Compliance with Fire Safety Standards

An evaluation of the Senate Building's adherence to the Nigerian National Building Code (NNBC, 2006) revealed only partial compliance. The most critical non-compliance issues include the absence of automated fire doors that can seal off fire-prone areas to prevent spread, as well as the poor maintenance of fire extinguishers—many of which were found to be expired or improperly mounted.

Additionally, there is no presence of heat or smoke detectors in high-risk zones, such as electrical service rooms and archival storage areas. These lapses violate key provisions in Sections 5.4 and 8.1 of the NNBC, which require that public buildings incorporate integrated fire detection, alarm, and suppression systems, particularly in high-occupancy structures. The partial compliance suggests that although some safety measures may have been incorporated during building renovations, the implementation lacks both continuity and periodic review.

4.3 Comparative Case Studies

A comparative analysis with fire safety infrastructure in other Nigerian universities provided insight into potential models of best practice. At the Federal University Kashere (FUK), modern fire alarm systems are fully installed and integrated with a centralized emergency management system. Evacuation routes are clearly marked and illuminated, enhancing response efficiency. Similarly, Ahmadu Bello University (ABU) has implemented an effective fire compartmentalization strategy using fire-resistant walls and doors to contain potential outbreaks and protect occupants in adjacent zones.

At the Federal University of Technology, Minna (FUTMinna), the integration of sustainable materials and systems into fire safety infrastructure was evident. Buildings utilized fire-resistant cladding and solar-powered emergency lighting systems, demonstrating a successful blend of sustainability and safety. These institutions present replicable models for upgrading fire safety in Gombe State University's Senate Building by aligning infrastructural upgrades with modern and sustainable safety technologies.

Proposed Sustainable Design Solutions

In response to the identified deficiencies, the study proposes a combination of active and passive fire prevention strategies integrated within a sustainable architectural framework. Active fire prevention measures should include the installation of smart fire detection systems capable of real-time monitoring and early warning dissemination through sensors linked to a centralized emergency control panel. Additionally, automated sprinkler systems should be extended to cover all high-risk zones and public corridors to ensure rapid suppression of fire outbreaks.

Passive safety measures should focus on the use of fire-resistant construction materials, such as reinforced concrete, fire-rated glass, gypsum boards, and steel with intumescent coatings. These materials not only enhance the building's resistance to fire spread but also contribute to its structural integrity during high-temperature exposure. Moreover, compartmentalization strategies such as firewalls and fire-rated doors should be strategically placed to isolate fire-prone zones from administrative and communal spaces.

Sustainable architectural features (SAFs) should also be incorporated to improve resilience and environmental efficiency. For instance, the installation of solar panels can

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provide backup power for fire alarm and emergency lighting systems, ensuring functionality during power outages. LED-based emergency lighting, powered by solar or battery storage, can improve visibility during evacuations. Water conservation techniques, such as rainwater harvesting, can supply non-potable water for fire suppression systems, thereby reducing reliance on municipal supplies.

Additionally, green roofs—planted with low-flammability vegetation—can reduce building heat absorption and serve as passive fire barriers, especially for multi-story structures (Basyouni & Mahmoud, 2024). Regular fire drills and occupant training programs should also be institutionalized, aimed at improving preparedness and ensuring that all staff and students are familiar with evacuation protocols. Clear, illuminated, and strategically placed exit signage is essential, and escape routes must be consistently maintained to ensure accessibility in all emergency conditions.

CONCLUSION

This study highlights critical shortcomings in the fire safety infrastructure of the Gombe State University Senate Building, including outdated fire alarm systems, inadequate sprinklers, poor exit signage, and the absence of emergency lighting. These gaps pose significant risks to occupants and property, particularly in light of similar fire incidents reported across Nigerian universities.

The partial compliance with the Nigerian National Building Code (2006) indicates a pressing need for comprehensive upgrades. Integrating sustainable design principles—such as the use of fire-resistant materials, energy-efficient emergency lighting, and rainwater harvesting for fire suppression—can enhance both safety and environmental performance.

To align with international standards, the university should prioritize the installation of modern fire detection systems, including smart smoke and heat detectors, and implement regular fire drills and maintenance routines. These interventions will not only protect lives and assets but also promote a safer, more resilient campus environment.

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