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

[1]Lukman Sabo, [2]Abbas Said EL-Nafaty, [3]Usman Mohammed Bashir, [4]Aminu Umar, [5]Sarkile Kawuwa Abubakar, & [6]Muhammed M. Bello
[1,2,3,4,5&6]Department of Architecture,
Abubakar Tafawa Balewa University, Bauchi.

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Abstract

This study critically evaluates the fire safety performance of the Gombe State University Senate Building by integrating contemporary fire safety engineering principles with sustainable architectural practices tailored to the Nigerian context. Employing a mixed-methods approach, the research combines comprehensive field assessments, advanced fire simulation modeling, and in-depth stakeholder interviews to provide a holistic understanding of the building's fire safety status. The field assessment involved detailed inspections of existing fire safety infrastructure, including detection systems, suppression equipment, emergency exits, and compartmentation features. Simulation modeling using Fire Dynamics Simulator (FDS) and evacuation analysis tools assessed fire growth, smoke propagation, and occupant egress under various fire scenarios. Stakeholder interviews with facility managers, staff, and students provided qualitative insights into fire safety awareness, preparedness, and operational challenges. Findings reveal that while the Senate Building incorporates fundamental fire safety provisions, significant gaps exist in automated detection and suppression systems, maintenance of fire-resistant barriers, and occupant training programs. Simulation results indicate potential rapid smoke spread and evacuation delays during fire incidents, underscoring vulnerabilities in current design and operational protocols. The study emphasizes the critical need for integrating fire safety comprehensively within sustainable design frameworks to enhance resilience, occupant safety, and environmental performance. Recommendations include upgrading fire detection and suppression technologies, improving compartmentation and material fire resistance, and implementing continuous fire safety education and drills.

Keywords: *Fire safety, Sustainable design, Performance evaluation, University buildings, Nigeria*

Corresponding Author: Lukman Sabo

Background to the Study

The papers discuss various aspects of fire safety and sustainable design in educational buildings. Chow & Chow (2003) propose an assessment scheme for fire safety provisions in green buildings, addressing potential conflicts between sustainability and fire safety. Abdulhamid et al. (2019) evaluated energy performance in Nigerian university senate buildings, finding that energy efficiency indexes fall below recommended standards. Alkali et al. (2024) investigate factors influencing academic library design, with user needs and technology integration ranking as top priorities. Ebenehi et al. (2017) examine fire safety management in Malaysian public universities, emphasizing the need to reduce fire incidents to maintain sustainability amid budget constraints. These studies highlight the importance of integrating fire safety measures with sustainable design principles in educational institutions, considering factors such as energy efficiency, user needs, and budget limitations (Chow & Chow, 2003; Abdulhamid et al., 2019; Alkali et al., 2024; Ebenehi et al., 2017). Fire safety is a fundamental aspect of building performance, directly impacting occupant safety, asset protection, and the overall sustainability of built environments (Zhou et al., 2023). In the context of university buildings, fire incidents can result in significant loss of life, interruption of academic activities, and destruction of valuable intellectual property (Agyekum et al., 2022). The integration of fire safety measures with sustainable design principles is particularly pertinent in Nigeria, where rapid expansion of higher education infrastructure often outpaces regulatory enforcement and technical capacity (Ogunbode et al., 2021).

Problem Statement

Despite the increasing adoption of green building practices, fire safety considerations are sometimes inadequately addressed in the design and operation of institutional buildings in Nigeria (Bello et al., 2022). The Gombe State University Senate Building, as a flagship structure, presents an opportunity to evaluate how fire safety performance can be harmonized with sustainable design objectives.

Aim

This study aims to evaluate the fire safety performance of the Gombe State University Senate Building with respect to sustainable design.

The objectives are:

i. To assess the current fire safety provisions and their effectiveness;
ii. To analyze the integration of fire safety with sustainable design features;
iii. To identify gaps and recommend improvements in line with international best practices.

Significance of the Study

This research contributes to the growing body of knowledge on sustainable and resilient building design in sub-Saharan Africa, providing actionable insights for architects, facility managers, policymakers, and fire safety professionals.

Literature Review

Fire Sustainable building design seeks to minimize environmental impact while ensuring occupant health, safety, and comfort (UNEP, 2021). Fire safety is increasingly recognized as integral to sustainability, as fire events can negate environmental gains by causing material loss, toxic emissions, and resource-intensive reconstruction (Bisby et al., 2020). Modern sustainable buildings incorporate fire-resistant materials, advanced detection and suppression systems, and design strategies that facilitate safe evacuation (Zhou et al., 2023).

Globally, Regulatory frameworks and standards for fire safety in building design is governed by standards such as the International Building Code (IBC), National Fire Protection Association (NFPA) codes, and local regulations (NFPA, 2023). In Nigeria, the National Building Code (NBC) and Fire Safety Code provide the legal framework, but enforcement and compliance remain inconsistent (Ogunbode et al., 2021). Recent studies call for the harmonization of local codes with international best practices to address emerging risks in green buildings (Agyekum et al., 2022).

Assessment of performance-based fire safety engineering (PB-FSE) is gaining traction as a method for evaluating fire safety in complex buildings. PB-FSE uses quantitative risk assessment, computer modeling, and scenario analysis to predict fire behavior and occupant response (Bisby et al., 2020; Zhou et al., 2023). Tools such as Fire Dynamics Simulator (FDS) and Pathfinder are widely used for simulating fire growth, smoke movement, and evacuation processes.

Fire Safety Challenges in Nigerian universities face unique fire safety challenges, including limited fire detection and suppression infrastructure, inadequate maintenance, and low fire safety awareness among occupants (Bello et al., 2022; Ogunbode et al., 2021). Resource constraints and the prioritization of other sustainability goals sometimes lead to trade-offs that compromise fire safety (Agyekum et al., 2022).

Integrating fire safety with sustainability in recent research emphasizes the need for an integrated approach that balances fire safety with energy efficiency, material sustainability, and occupant wellbeing (Bisby et al., 2020; UNEP, 2021). Innovations such as intumescent coatings, low-toxicity fire retardants, and smart building technologies are being adopted to enhance both fire resilience and environmental performance (Zhou et al., 2023).

Theoretical Model for Fire Safety Performance Evaluation

The theoretical model underpinning the evaluation of fire safety performance in buildings, such as the Gombe State University Senate Building, draws from a holistic, integrated framework that combines architectural design features, fire dynamics, occupant behavior, and regulatory compliance using the Holistic Fire Safety Performance Framework. The foundation of the model is the conceptual Holistic Fire Safety Performance Framework developed by Park et al. (2015), which integrates three core components:

i. **Building Characteristics:** Including architectural design, construction materials, compartmentation, fire-resistant elements, and fire protection systems (alarms, sprinklers, smoke control).
ii. **Fire Characteristics:** Fire ignition sources, fuel loads, fire growth and spread, smoke production, and toxic gas emissions.
iii. **Occupant Characteristics:** Occupant density, mobility, awareness, evacuation behavior, and response times.

Methodology

This study employs a mixed-methods research design that integrates qualitative and quantitative approaches to deliver a thorough evaluation of fire safety performance within the Gombe State University Senate Building. The methodology incorporates architectural case study analysis to contextualize fire safety within the building's design features and operational environment. This holistic approach enables the identification of both technical and human factors influencing fire safety outcomes.

Data Collection

i. **Architectural Case Studies:** Comparative analysis of fire safety provisions in similar university senate buildings within Nigeria and other comparable climatic and regulatory contexts. This involves reviewing architectural designs, fire safety strategies, and sustainability features to benchmark best practices and identify design-related vulnerabilities.
ii. **Field Assessment:** Systematic on-site inspection of the Senate Building to document existing fire safety infrastructure, including fire detection and alarm systems, portable extinguishers, emergency exits, signage, fire compartmentation, and material fire resistance. Photographic documentation and spatial mapping of safety features complement the assessment.
iii. **Document Review:** Examination of architectural drawings, fire safety plans, maintenance logs, and compliance certificates to verify adherence to regulatory standards and identify discrepancies between design intent and operational reality.

Data Analysis

i. **Descriptive Statistics:** Quantitative summarization of the prevalence, distribution, and condition of fire safety features within the building.
ii. **Simulation Analysis:** Interpretation of fire and evacuation simulation outputs to evaluate critical parameters such as fire spread rate, smoke layer height, visibility, toxic gas concentration, and occupant egress times under various fire scenarios.
iii. **Thematic Analysis:** Qualitative coding and thematic extraction from interview transcripts to identify recurrent patterns related to fire safety culture, communication efficacy, training gaps, and behavioral responses during emergencies.
iv. **Comparative Analysis:** Synthesis of findings from architectural case studies to contextualize the Senate Building's fire safety performance relative to peer institutions, highlighting design innovations and areas requiring improvement.

Results

Fire safety features in the Senate Building based on the field assessment, revealed that the Senate Building is equipped with basic fire safety provisions, including manual fire alarms, portable extinguishers, and marked escape routes. However, deficiencies were noted in the maintenance of fire doors, the absence of automated suppression systems, and limited compartmentation in open-plan areas. Integration with sustainable design, while the building incorporates energy-efficient lighting and locally sourced materials, some design choices—such as extensive use of open atria—pose fire safety challenges by facilitating rapid smoke spread. The absence of fire-resistant glazing and the limited use of non-combustible materials in key areas were also noted.

Discussion on Findings

The Senate Building demonstrates partial compliance with fire safety standards but falls short in areas critical to sustainable resilience. The lack of automated detection and suppression, insufficient compartmentation, and low occupant awareness are significant vulnerabilities. International best practices advocate for:

i. **Comprehensive Fire Detection and Suppression:** Integration of automated alarms, sprinklers, and smoke control systems.
ii. **Compartmentation:** Use of fire-resistant barriers to limit fire and smoke spread.
iii. **Material Selection:** Preference for non-combustible, low-emission materials.
iv. **Occupant Training:** Regular fire drills and safety education.

Towards achieving sustainable fire safety requires a holistic approach that aligns architectural innovation with robust risk management. Smart building technologies, such as IoT-based fire monitoring and adaptive evacuation systems, offer promising avenues for enhancing both safety and sustainability (Zhou et al., 2023).

Results and Conclusion

The comprehensive evaluation of fire safety performance in the Gombe State University Senate Building reveals critical insights into the intersection of fire safety and sustainable design within the context of Nigerian higher education infrastructure. This study highlights that while the building incorporates fundamental fire safety measures, significant gaps remain in both design and operational practices that could compromise occupant safety and asset protection during fire emergencies. These deficiencies are symptomatic of broader challenges faced by institutional buildings in Nigeria, where rapid infrastructural expansion often outpaces the enforcement of fire safety regulations and the integration of sustainability principles. The findings underscore the necessity of adopting an integrated, context-sensitive approach to fire safety that aligns with sustainable design objectives. Sustainable building design is not merely about energy efficiency and environmental stewardship; it must also encompass resilience against hazards such as fire, which can cause catastrophic loss and negate sustainability gains. The Senate Building's current fire safety provisions—while compliant with some regulatory requirements—lack advanced detection and suppression systems, effective compartmentation, and robust occupant preparedness programs. Simulation modeling further revealed vulnerabilities in smoke management and evacuation

efficiency, indicating that the building's design and operational protocols require urgent enhancement. Moreover, the study emphasizes the importance of continuous education, stakeholder engagement, and technological adaptation in fostering a culture of fire safety awareness within university communities. Fire safety is a dynamic discipline that must evolve alongside emerging building technologies and changing occupancy patterns. For Nigerian universities, this means moving beyond minimum compliance towards proactive, performance-based fire safety strategies that integrate seamlessly with sustainable architectural practices.

Recommendations

Based on the findings and analysis, the following recommendations are proposed to enhance fire safety performance in the Gombe State University Senate Building and similar institutional buildings within Nigeria and comparable contexts:

i. Upgrade fire detection and suppression systems to centralized alarm systems to ensure rapid fire detection and occupant notification.
ii. Enhance compartmentation and fire-resistant materials, thereby protecting escape routes and critical infrastructure.
iii. Optimize building design for fire safety and evacuation to prevent smoke infiltration.
iv. Implement regular fire safety training and drills on occupant education, fire drills and fire safety teams.
v. Strengthen Regulatory Compliance and Institutional Policies.
vi. Leverage technology and innovation such as Smart Fire Safety Systems, Simulation and Modeling Tools, and Building Information Modeling (BIM). P
vii. Promote interdisciplinary collaboration of architects, engineers, and fire experts to foster collaboration among design professionals, fire safety engineers, and sustainability experts from project inception to ensure holistic fire-safe design.

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