

## Integrating Fire Safety Strategies to Enhance Occupant Safety in Mixed-Use Buildings in Kaduna, Nigeria

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### Abstract

*Access to adequate fire safety remains a significant challenge for many mixed-use buildings in Kaduna, Nigeria, where systems are often compromised by generator-dependent power, informal retail layouts, and low municipal water pressure. This study evaluates the integration of fire safety strategies in such buildings to enhance occupant safety and promote resilient design. A mixed-methods approach was adopted, combining quantitative data from 50 architectural and engineering professionals with qualitative case-study observations and photographic documentation. Nine fire safety strategies were examined, including compartmentation, pressurized stairwells, fire-rated doors, refuge floors, protected means of escape, zoned detection with battery backup, solar-powered detection, gravity-fed hose reels, and dry-pipe sprinkler systems. While compartmentation and pressurized stairwells recorded the highest knowledge levels (Means = 3.82 and 3.56 respectively), overall integration remained low across all strategies (all Means < 3.0). Cost implications and developer priorities emerged as the strongest barriers (Means = 4.72 and 4.64), whereas occupant safety and regulatory enforcement ranked highest among success factors (Means = 4.94 and 4.68). The study recommends strengthened code enforcement, capacity building on passive-first and context-adapted systems, and demonstration projects that quantify life-safety and lifecycle benefits. These findings contribute to the growing body of knowledge on fire safety in tropical urban contexts and provide practical guidance for architects, engineers, and policymakers seeking to enhance occupant safety in mixed-use buildings.*

**Keywords:** Active strategies, Fire safety, Kaduna, Mixed-use buildings, Occupant safety, Passive strategies.

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### 1.0 Introduction

Kaduna is one of Nigeria's faster-growing secondary cities, driven by economic expansion, population growth, and its strategic location along major transportation corridors (Qurix et al., 2024; United Nations Human Settlements Programme [UN-Habitat], 2024). In this rapidly

urbanizing context, mixed-use buildings combining residential, commercial, and retail functions have become central to development due to their land-use efficiency and economic vitality. However, this typology introduces compounded fire risks arising from heterogeneous fuel loads, complex compartmentation, high occupant densities, and varying levels of user awareness (National Fire Protection Association [NFPA], 2023; Buchanan & Abu, 2017). The combination of residential units with commercial spaces creates complex fire dynamics that demand comprehensive, well-integrated fire safety strategies (Drysedale, 2011; Torero, 2023).

According to Alfakhry (2026), fire safety profoundly influences architectural design, requiring architects to balance aesthetic, functional, and safety considerations. The interplay between passive strategies—such as compartmentation, fire-resistant materials, and egress design—and active systems—including sprinklers, smoke control, and detection—significantly shapes building form and spatial organization while ensuring life safety. Despite this established knowledge, recent fire incidents in Kaduna underscore the grave consequences of inadequate safety integration. The 2021 Kaduna State University mini-market fire and the 2024 Panteka timber market fire caused substantial economic losses, with the Kaduna State Fire Service recording hundreds of outbreaks attributed to electrical faults, improper storage of flammable materials, and blocked escape routes (Premium Times, 2024; Vanguard, 2021; Kaduna State Fire Service [KSFS], 2025; Adamu et al., 2020). Many buildings rely on generator power due to unreliable electricity, creating additional ignition risks, while informal retail activities storing flammable goods further elevate hazards (Adamu et al., 2020; Qurix et al., 2024). Low municipal water pressure compounds these challenges, undermining the effectiveness of active suppression systems.

The Nigerian National Building Code (Federal Republic of Nigeria, 2006) and National Fire Safety Code (Federal Ministry of Works and Housing, 2013) mandate fire-rated separation, pressurized stairwells, and automatic sprinklers for high-rise mixed-use buildings. However, enforcement remains inconsistent, with many structures erected without proper fire safety provisions (Adamu et al., 2020; Qurix et al., 2024). As Nigerian media reports highlight, while codes and regulations exist on paper, they are rarely enforced, and regulatory authorities tend to be reactive rather than proactive. The absence of effective enforcement mechanisms for building codes and space standards contributes to widespread non-compliance, creating conditions that exacerbate fire risks.

### **1.1 Research Gap and Justification**

Existing studies from other Nigerian cities have identified critical deficits in regulatory adherence regarding building space, plot coverage, and setbacks, yet there is a pronounced absence of empirical research specifically examining the knowledge, integration, barriers, and success factors associated with fire safety strategies in Kaduna's mixed-use buildings. While general challenges—such as weak enforcement and infrastructure deficits—are acknowledged, no study has systematically quantified professionals' awareness of specific passive and active measures, assessed the actual extent to which these strategies are integrated into practice, or ranked the contextual barriers (e.g., cost implications, developer priorities) and success drivers (e.g., occupant safety, regulatory enforcement) that influence adoption. Understanding these factors is essential for developing targeted, evidence-based interventions to enhance occupant safety. This study therefore bridges that gap by employing a mixed-methods approach to evaluate nine fire safety strategies, offering practical guidance for architects, engineers, and policymakers seeking to promote resilient, fire-safe design in Kaduna's rapidly evolving urban landscape.

## **2.0 Literature Review**

### **2.1 Fire Dynamics and Behavior in Buildings**

Understanding fire dynamics—encompassing ignition, growth, flashover, fully developed fire, and decay—is fundamental to fire safety design. In mixed-use buildings, diverse occupancies create heterogeneous fuel loads that produce complex fire scenarios requiring tailored strategies (Drysdale, 2011; Torero, 2023). Fire resistance, expressed as the duration a building element can withstand exposure, is critical for preventing spread (Buchanan & Abu, 2017). Compartmentation addresses both internal spread (via conduction and boundary failure) and external spread (via convection and hot gases), as Majdalani et al. (2024) explain—a dual threat especially relevant in mixed-use buildings with vertical openings and occupancy interfaces. Meta-analyses confirm that fire behavior depends on ventilation, fuel characteristics, and boundary thermal properties. Given the variety of fuel types across residential and commercial spaces, uniform approaches are inadequate; comprehensive, context-adapted design strategies are essential for addressing the full spectrum of potential fire scenarios in buildings.

### **2.2 Passive Fire Safety Strategies**

Passive fire safety strategies form the foundation of fire safety, working continuously without mechanical or electrical systems (Buchanan & Abu, 2017; Hopkin et al., 2022). According to Alfakhry (2026), passive fire safety methods encompass compartmentation, fire-resistant materials, and egress design, and these strategies fundamentally influence the shape and flow of buildings. Passive strategies are considered the first line of defence against fire spread and are critical for protecting occupants and property.

#### **2.2.1 Compartmentation**

Compartmentation divides buildings into fire compartments using fire-resistant walls, floors, and doors to limit fire and smoke spread (Buchanan & Abu, 2017). Hopkin et al. (2022) demonstrated effective compartmentation can reduce fire spread by up to 70% in high-rise buildings. Majdalani et al. (2024) emphasize that compartmentation is primarily concerned with preventing destructive internal spread potential, but external convective spread through windows and facade systems represents a potentially more effective route for fire propagation.

The effectiveness of compartmentation depends on the continuity of fire-resistant construction and the proper installation and maintenance of fire-rated elements. In mixed-use buildings, different occupancy types may require different levels of fire resistance, creating complex compartmentation requirements. Research has shown that compartmentation failures often occur at service penetrations and around fire doors, indicating the need for careful detailing and quality control during construction. A bibliometric analysis of fire prevention and mitigation technologies in high-rise buildings classified passive technologies into preventive tools, including façade retrofitting aimed at eliminating primary fire risk and the implementation of fire compartmentation using fire-resistant materials in cladding. This classification highlights the importance of compartmentation as a fundamental passive strategy for high-rise and mixed-use buildings.

#### **2.2.2 Fire-Rated Doors and Intumescent Seals**

Fire-rated doors and intumescent seals are essential components of compartmentation. Fire doors are designed to resist the passage of fire and smoke for a specified period, maintaining the integrity

of fire compartments. Intumescent materials expand when exposed to heat, sealing gaps around doors and other openings to prevent smoke and flame spread.

Research has demonstrated that intumescent seals are effective in stopping cold and hot smoke spread, with visual observations indicating that cold smoke seals in silicone and intumescent strips around door frames provide efficient smoke containment. However, studies have also identified vulnerabilities: post-earthquake fire performance research has shown that fire door effectiveness can be compromised by distorted door geometry, loosened hinges, and damaged intumescent seals. The proper specification, installation, and maintenance of fire doors and seals are critical to their performance. ISO 12472:2002 specifies test methods for determining the effective sealing capability of intumescent materials in timber door assemblies, providing a standardized approach to evaluating these critical components. In the Nigerian context, where quality control is often weak, the issue of fire door integrity is likely to be even more significant.

### **2.2.3 Protected Means of Escape**

Protected means of escape provide safe exit routes, including protected stairwells, corridors, and lobbies (HM Government, 2023). These routes are separated from the rest of the building by fire-resistant construction, ensuring they remain usable during a fire emergency. The width, length, and configuration of escape routes are determined based on the occupancy, number of occupants, and travel distances. In high-rise mixed-use buildings, complex evacuation strategies such as phased evacuation and refuge floors may be required. Research by Ma et al. (2012) demonstrated that refuge floors play an important part in evacuation strategies, providing not only a place for temporary stop but also for transition from stair evacuation into elevator evacuation. The interval design of refuge floors has a direct relation with the characteristics of elevators and building occupants. Studies have shown that travel distances and wayfinding significantly affect evacuation times, highlighting the importance of clear signage and familiarization with escape routes for building occupants. Phased evacuation strategies can reduce evacuation times while also reducing occupant exposure to fire hazards.

### **2.2.4 Pressurized Stairwells**

Pressurized stairwells prevent smoke ingress and maintain stairwells as safe evacuation routes (Buchanan & Abu, 2017). These systems are designed to create a smoke-proof barrier, preventing the ingress of smoke into staircases within buildings. In tall buildings over 25 meters, evacuation strategies can utilize phased or simultaneous evaluation of multiple storeys.

Lee and Lau (2023) examined the performance of stair pressurization systems with differing numbers of doors open. Their simulations using Fire Dynamics Simulation (FDS) showed that a system passing commissioning requirements allows smoke in the shaft if more than four doors are open simultaneously. The required airflow to prevent smoke ingress was found to be above an average flow speed of 0.7 m/s, and beyond this limit, smoke leakage into staircases continues to increase as more doors open. The study suggested that standards regarding stair pressurization systems should be updated to account for realistic evacuation scenarios, including system cascade settings, number of storeys, and expected evacuation time. Ionescu et al. (2026) further analyzed smoke control strategies in high-rise building stairwells, finding that natural ventilation alone is ineffective, while single-point mechanical pressurization improves conditions only during the early fire stage. These findings contribute to better-informed decision-making regarding stairwell conditions during fire emergencies.

In the Nigerian context, where electricity supply is unreliable, backup power systems are essential for maintaining pressurization during fires. Solar-powered backup systems offer a sustainable alternative to grid-dependent systems.

### **2.2.5 Refuge Floors and Phased Evacuation**

Refuge floors provide protected areas where occupants can wait during a fire emergency, and phased evacuation strategies involve evacuating occupants in stages (Ronchi et al., 2022; Purser, 2022). Ma et al. (2012) demonstrated that refuge floors play an important role in evacuation strategies, providing both temporary stopping places and transition points from stair evacuation to elevator evacuation. The interval design of refuge floors has a direct relation with the characteristics of elevators and building occupants. Research found that when a proper ratio of building occupants is transported to ground level by fast elevators while others are evacuated by stairs, the evacuation process can reach an optimized state. This is particularly relevant for mixed-use buildings where diverse occupant populations—including elderly, disabled, and visitors—may have varying evacuation capabilities. Studies have shown that phased evacuation can reduce occupant exposure to fire hazards by up to 40% compared to simultaneous evacuation. The effectiveness of refuge floors and phased evacuation strategies depends on clear communication, occupant training, and robust fire safety management systems.

## **2.3 Active Fire Safety Strategies**

Active fire safety strategies require mechanical or electrical systems to detect and suppress fires, alert occupants, and facilitate evacuation (NFPA, 2023; Buchanan & Abu, 2017). According to Alfakhry (2026), active fire safety methods comprise sprinklers, smoke control, and detection systems, and these systems offer the flexibility needed for architectural creativity while ensuring life safety. Active systems work in conjunction with passive strategies to provide comprehensive fire protection.

### **2.3.1 Fire Detection and Alarm Systems**

Fire detection and alarm systems identify fires early and warn occupants of the need to evacuate. Detection devices include smoke detectors, heat detectors, flame detectors, and combination units. The type and placement of detectors should be tailored to the specific risks and occupancy characteristics of each building. In generator-dependent contexts, battery backup for detection systems is essential to maintain functionality during power outages. Solar-powered detection systems offer a sustainable and reliable alternative to grid-dependent systems in areas with unreliable electricity supply. Research has demonstrated the development of solar-powered fire detection systems that use solar energy and batteries to operate autonomously and sustainably. A solar-powered IoT-based home fire early warning and protection system has been developed, integrating detection with automated response capabilities. These systems can provide reliable performance with minimal maintenance requirements, making them particularly suitable for contexts with unreliable grid electricity.

### **2.3.2 Automatic Sprinkler Systems**

Automatic sprinkler systems are one of the most effective fire safety measures, providing active fire suppression (NFPA, 2023). Dobrowolskis et al. (2025) evaluated the effectiveness of sprinkler fire protection systems, noting that automatic water fire-extinguishing systems operate

continuously and without human intervention, responding quickly to fires at any time. These systems automatically detect the origin of fire and begin extinguishing it at an early stage, significantly reducing damage and protecting human lives. The study found that automatic water fire-extinguishing systems are effective fire safety means that significantly reduce the threat of fire spreading and ensure building safety if operational capacity is regularly maintained and tested. Research has also examined how the response time of sprinkler systems varies depending on the year of production, providing recommendations for improving operational capability. Despite their effectiveness, sprinkler systems require reliable water supply and pressure, which may be challenging in many Nigerian cities. Gravity-fed systems that use overhead tanks to provide water pressure offer a context-appropriate alternative where municipal water pressure is inadequate.

### **2.3.3 Dry-Pipe Sprinkler Systems**

Dry-pipe sprinkler systems use pressurized air with water held back by a valve that opens when a fire is detected (NFPA, 2023). These systems are particularly suitable for areas where freezing is a concern, but also offer advantages where water pressure is intermittent or where pipes are exposed to high ambient temperatures.

Cablé (2018, 2019) conducted numerical studies of transient two-phase flow within sprinkler fire protection systems filled with pressurized air at idle state (dry pipe). The research concerned the reliability and efficient design of full-scale automatic sprinkler systems for fire protection of industrial facilities and process plants.

Research has shown that a reduction of initial pressure from 3.50 to 0.82 bar can reduce water delivery time by up to 40%. In the Nigerian context, where ambient temperatures are high, dry-pipe systems may offer advantages over wet-pipe systems in terms of reducing the risk of pipe corrosion and water damage, while also addressing challenges related to intermittent water pressure.

### **2.3.4 Standpipe and Hose Reel Systems**

Standpipe and hose reel systems provide a means for firefighters and trained occupants to apply water to fires (NFPA, 2023). Class I standpipes provide connections for fire hoses, while Class II systems provide hose reels for use by building occupants. NFPA 14 provides standards for the installation of standpipe and hose systems.

OSHA regulations require that reels and cabinets provided to contain fire hose be designed to facilitate prompt use of hose valves and be conspicuously identified and used only for fire equipment. Gravity-fed hose reels, which rely on overhead water tanks for pressure, offer a context-appropriate solution in areas with unreliable municipal water pressure.

Standpipe systems for fire protection are comprehensively addressed in the International Building Code, municipal fire codes, and the National Fire Code of Canada, with guidance on design, installation, inspection, and maintenance. In the Nigerian context, where municipal water pressure is often inadequate, gravity-fed systems and dedicated water storage tanks are essential for reliable standpipe operation.

## **2.4 Theoretical Framework**

According to Goyol (2019), a theoretical framework guides research by relying on a formal theory. This study adopts the Systems Theory of Fire Safety, which conceptualizes fire safety as an integrated system of interconnected components working together to protect life and property

(Buchanan & Abu, 2017). The theory emphasizes that fire safety requires coordinated integration of passive and active strategies, human factors, and management systems.

Systems Theory provides a lens for understanding the interrelationships between different fire safety strategies and how their integration contributes to overall safety. It recognizes that fire safety is an emergent property of the whole system, not simply the sum of individual strategies. This theoretical framework enables architects and engineers to create integrated fire safety solutions addressing the unique challenges of the Nigerian context.

Alfakhry (2026) supports this systems approach, demonstrating that passive strategies influence the shape and flow of buildings while active systems offer flexibility for architectural creativity. Rather than limiting design, fire safety acts as a driving force for innovation when properly integrated into the design process. This framework enables the creation of buildings that balance safety, aesthetics, and sustainability in modern design.

### 3.0 Methodology

#### 3.1 The Study Area: Kaduna City

The study was conducted in Kaduna metropolis, comprising the core urban area of Kaduna State. Kaduna is located in northern Nigeria. Kaduna State is generally located at the coordinates 10°20'N 7°45'E approximately 160 km south-west of Kano and 200 km north of Abuja. The city Kaduna city, more precisely situated at approximately 10.52°N 7.44°E has a tropical climate with mean annual temperatures ranging from 25°C to 35°C. The population continues to grow rapidly, driven by rural-urban migration (Qurix et al., 2024; UN-Habitat, 2024). Selected mid-to-high-rise mixed-use buildings were examined, representing varied occupancy mixes, heights, generator dependence, and informal retail layouts.

Kaduna's urban development pattern reflects broader Nigerian trends where rapid urbanization has outpaced regulatory capacity. Studies from other Nigerian cities have documented similar challenges: non-compliance with planning regulations, buildings constructed contiguously on fragmented plots, and inadequate setbacks that negate provisions of the National Building Code.



These conditions create environments where fire can spread rapidly between buildings, as observed in recent Kaduna fire incidents.

**Figure 1:** Map of Kaduna State, Nigeria

*Source: Adopted from Qurix et al., (2024)*

### 3.2 Research Design

A mixed-methods design was adopted, combining quantitative survey data with qualitative case study observations, photographic documentation, and semi-structured interviews (Creswell & Creswell, 2023; Tashakkori & Teddlie, 2022). The mixed-methods approach was selected because it allows for both breadth and depth in data collection, providing quantitative data on professional knowledge and perspectives while also capturing qualitative insights from case studies.

The quantitative component involved a structured questionnaire administered to architectural and engineering professionals. The qualitative component involved structured observations and semi structured interviews at selected case-study buildings. This triangulation of methods enhances the validity and reliability of findings by corroborating quantitative data with qualitative insights.

### 3.3 Data Sources

Primary data were obtained through structured questionnaires, direct observations, photographic documentation, and detailed case studies. The questionnaire employed a five-point Likert scale to assess knowledge, integration levels, barriers, and success factors. Secondary data were sourced from journals, books, institutional reports, and professional handbooks, including the National Building Code (2006), National Fire Safety Code (2013), and NFPA codes.

The use of multiple data sources enables comprehensive analysis of fire safety integration from both professional and empirical perspectives. Secondary data provided theoretical grounding and contextual relevance for interpreting primary findings.

### 3.4 Population and Sample

The target population comprised construction industry professionals (architects and engineers) practicing in Kaduna metropolis. According to the Architects Registration Council of Nigeria (ARCON, 2012), of the 840 registered architectural firms nationwide, 190 are in the North Central Zone, with 63 located in Kaduna (Ola-Adisa et al., 2019; Qurix et al., 2024). This served as a reliable framework for identifying qualified respondents, with considerations given to gender, professional experience, and projects completed within the last 15 years.

### 3.5 Sample Size

The finite population of professionals involved in mixed-use building design in Kaduna is unknown. Consequently, Cochran's formula (1977) was used to determine the initial sample size for an infinite population, at a 95% confidence level ( $Z=1.96$ ), with a 5% margin of error ( $e=0.05$ ), and a conservative estimated proportion of the population with the attribute ( $p=0.5$ ):

$$n_0 = \frac{Z^2 \cdot p \cdot q}{e^2}$$

...(Equation 1)

Where:

- $n_0$  = initial required sample size

- $Z = 1.96$  (Z-score for 95% confidence)
- $p = 0.5$  (estimated proportion)
- $q = 1 - p = 0.5$
- $e = 0.05$  (margin of error)

Substituting the values:

$$n_0 = \frac{(1.96)^2 \times (0.5) \times (0.5)}{(0.05)^2} = \frac{(1.96)^2 \times (0.5) \times (0.5)}{0.0025}$$

$$n_0 = \frac{3.8416 \times 0.25}{0.0025} = \frac{0.9604}{0.0025}$$

$$n_0 = \frac{0.9604}{0.0025} = 384.16$$

$$\therefore n_0 = 384.16 \therefore n_0 = 384.16$$

Thus, the initial calculation yielded a statistically representative sample of approximately 384 professionals. However, given the practical limitations of professional registers in Kaduna—which are neither fully accessible nor centrally maintained—a census was not feasible. Therefore, a sample of 50 professionals was considered appropriate for this exploratory study. This sample size, while modest, aligns with precedent in similar exploratory research contexts and proved adequate for generating meaningful quantitative and qualitative insights, particularly given the 100% response rate achieved. The sample size calculation ensured statistical validity while remaining practical given the constraints of professional registers in the study area.

### 3.6 Sampling Technique

Purposive sampling was used to select case-study buildings based on height (mid-to-high-rise), functional mix (residential + commercial), and accessibility. Stratified random sampling was applied to professional respondents based on professional affiliation and years of experience. This combination of sampling techniques ensures representation of different professional perspectives and building types, enhancing the generalizability of findings.

### 3.7 Data Analysis

Quantitative data were analyzed using the Statistical Package for Social Sciences (SPSS) version 27. Descriptive statistics, including means, standard deviations, and rankings, were computed. One-way ANOVA was used to identify significant differences between professional groups. Qualitative observations and interview responses were analyzed thematically, with key themes coded and presented as case descriptions. This rigorous analytical approach ensures that findings are both statistically robust and contextually meaningful.

## 4.0 Data Presentation, Analysis and Discussion of Results

### 4.1 Sample Characteristics

Fifty professionals participated. Respondents were predominantly architects (48%) and structural engineers (26%), with building services engineers (16%) and facilities managers (10%). Most had 5-10 years' experience (44%), followed by 10-20 years (28%), less than 5 years (20%), and more than 20 years (8%). This distribution reflects the professional landscape in Kaduna's construction industry and ensures representation of different experience levels and perspectives.

**Table 1: Demographic Profile of Respondents (N = 50)**

| Characteristics          | Frequency (n) | Percentage (%) |
|--------------------------|---------------|----------------|
| Professional Affiliation |               |                |
| Architect                | 24            | 48.0           |

| Characteristics            | Frequency (n) | Percentage (%) |
|----------------------------|---------------|----------------|
| Structural Engineer        | 13            | 26.0           |
| Building Services Engineer | 8             | 16.0           |
| Facilities Manager         | 5             | 10.0           |
| Total                      | 50            | 100.0          |
| Years of Experience        |               |                |
| Less than 5 years          | 10            | 20.0           |
| 5-10 years                 | 22            | 44.0           |
| 10-20 years                | 14            | 28.0           |
| More than 20 years         | 4             | 8.0            |
| Total                      | 50            | 100.0          |

Source: Field survey, 2025

#### 4.2 Objective 1: Knowledge of Fire Safety Strategies

Nine strategies were assessed for knowledge. Compartmentation recorded the highest mean ( $3.82 \pm 0.612$ ), followed by Pressurized Stairwells ( $3.56 \pm 0.598$ ) and Fire-Rated Doors ( $3.40 \pm 0.701$ ). Zoned Detection with Battery Backup scored  $2.36 \pm 0.688$ , while Solar-Powered Detection ( $1.74 \pm 0.663$ ), Gravity-Fed Hose Reels ( $1.62 \pm 0.602$ ), and Dry-Pipe Sprinkler Systems ( $1.48 \pm 0.505$ ) recorded the lowest means. These findings indicate that professionals have greater familiarity with established passive strategies that are emphasized in professional education and building codes. The lower knowledge scores for context-adapted active systems suggest a gap in professional awareness of strategies that could address local infrastructure constraints. This aligns with Alfakhry's (2026) observation that while passive strategies are well-understood, the integration of active systems requires additional attention in professional practice.

**Table 2: Knowledge of Fire Safety Strategies (N = 50)**

| S/No | Strategy                             | M    | SD    | Rank |
|------|--------------------------------------|------|-------|------|
| 1    | Compartmentation                     | 3.82 | 0.612 | 1    |
| 2    | Pressurized Stairwells               | 3.56 | 0.598 | 2    |
| 3    | Fire-Rated Doors / Intumescent Seals | 3.40 | 0.701 | 3    |
| 4    | Refuge Floors / Phased Evacuation    | 3.18 | 0.784 | 4    |
| 5    | Protected Means of Escape            | 2.94 | 0.731 | 5    |
| 6    | Zoned Detection with Battery Backup  | 2.36 | 0.688 | 6    |
| 7    | Solar-Powered Detection              | 1.74 | 0.663 | 7    |
| 8    | Gravity-Fed Hose Reels               | 1.62 | 0.602 | 8    |
| 9    | Dry-Pipe Sprinkler Systems           | 1.48 | 0.505 | 9    |

Source: Field survey, 2025

#### 4.3 Objective 2: Level of Integration

All nine strategies recorded mean integration scores below 3.0. Compartmentation ranked highest ( $2.74 \pm 0.742$ ), followed by Pressurized Stairwells ( $2.42 \pm 0.611$ ) and Fire-Rated Doors ( $2.30 \pm 0.678$ ). Dry-Pipe Sprinkler Systems recorded the lowest ( $1.28 \pm 0.454$ ).

The low integration scores across all strategies confirm that even the most well-known passive strategies are inadequately implemented in existing mixed-use buildings. This disconnect between

knowledge and practice is concerning and suggests that factors other than technical knowledge—such as cost constraints, developer priorities, and weak enforcement—are more significant determinants of fire safety integration. The findings are consistent with observations from other Nigerian cities where non-compliance with building regulations is widespread.

**Table 3: Level of Integration (N = 50)**

| S/No | Strategy                             | <i>M</i> | <i>SD</i> | Rank |
|------|--------------------------------------|----------|-----------|------|
| 1    | Compartmentation                     | 2.74     | 0.742     | 1    |
| 2    | Pressurized Stairwells               | 2.42     | 0.611     | 2    |
| 3    | Fire-Rated Doors / Intumescent Seals | 2.30     | 0.678     | 3    |
| 4    | Protected Means of Escape            | 2.18     | 0.725     | 4    |
| 5    | Refuge Floors / Phased Evacuation    | 1.96     | 0.812     | 5    |
| 6    | Zoned Detection with Battery Backup  | 1.58     | 0.701     | 6    |
| 7    | Solar-Powered Detection              | 1.44     | 0.541     | 7    |
| 8    | Gravity-Fed Hose Reels               | 1.36     | 0.485     | 8    |
| 9    | Dry-Pipe Sprinkler Systems           | 1.28     | 0.454     | 9    |

*Source: Field survey, 2025*

#### 4.4 Objective 3: Barriers to Integration

Ten barriers were assessed. Cost Implications ( $4.72 \pm 0.454$ ) and Developer Priorities ( $4.64 \pm 0.485$ ) ranked highest. Regulatory Gaps ( $4.52 \pm 0.505$ ), Knowledge and Expertise ( $4.48 \pm 0.542$ ), and Generator Dependence ( $4.30 \pm 0.580$ ) followed. Space Efficiency was lowest-ranked ( $3.76 \pm 0.822$ ). These findings align with broader Nigerian challenges where regulatory authorities are more reactive than proactive, and property developers often compromise standards to reduce costs. The high ranking of cost implications and developer priorities reflects the commercial orientation of real-estate decision-making, where short-term financial considerations override long-term safety concerns. Regulatory gaps reflect the inconsistent adoption and enforcement of building codes across Nigerian states.

**Table 4: Barriers to Integration (N = 50)**

| S/No | Barrier                                    | <i>M</i> | <i>SD</i> | Rank |
|------|--------------------------------------------|----------|-----------|------|
| 1    | Cost Implications                          | 4.72     | 0.454     | 1    |
| 2    | Developer Priorities                       | 4.64     | 0.485     | 2    |
| 3    | Regulatory Gaps                            | 4.52     | 0.505     | 3    |
| 4    | Knowledge and Expertise                    | 4.48     | 0.542     | 4    |
| 5    | Generator Dependence / Power Unreliability | 4.30     | 0.580     | 5    |
| 6    | Maintenance Challenges                     | 4.18     | 0.661     | 6    |
| 7    | Low Municipal Water Pressure               | 4.12     | 0.689     | 7    |
| 8    | Informal Retail Overcrowding               | 4.04     | 0.705     | 8    |
| 9    | Harmattan Dust & Wind Effects              | 3.96     | 0.742     | 9    |
| 10   | Space Efficiency                           | 3.76     | 0.822     | 10   |

*Source: Field survey, 2025*

#### 4.5 Objective 4: Critical Success Factors

Eleven factors were assessed. Occupant Safety ( $4.94 \pm 0.240$ ) ranked highest, followed by Regulatory Enforcement ( $4.68 \pm 0.471$ ), Indoor Comfort ( $4.60 \pm 0.495$ ), and Architectural Expertise ( $4.56 \pm 0.501$ ). Adaptive Detection Systems was lowest-ranked ( $3.88 \pm 0.745$ ).

The high ranking of occupant safety indicates that professionals recognize the fundamental importance of protecting building occupants from fire risks. This aligns with research emphasizing that fire safety measures help prevent tragedies and save lives by quickly detecting and responding to fires. The strong support for regulatory enforcement reflects recognition that effective enforcement mechanisms are essential for driving compliance with fire safety codes. In the Nigerian context, strengthening enforcement is critical given the current reactive approach of regulatory authorities.

**Table 5: Critical Success Factors (N = 50)**

| S/No | Factor                                  | <i>M</i> | <i>SD</i> | Rank |
|------|-----------------------------------------|----------|-----------|------|
| 1    | Occupant Safety                         | 4.94     | 0.240     | 1    |
| 2    | Regulatory Enforcement                  | 4.68     | 0.471     | 2    |
| 3    | Indoor Comfort / Life Safety            | 4.60     | 0.495     | 3    |
| 4    | Architectural Expertise                 | 4.56     | 0.501     | 4    |
| 5    | Lifecycle Cost Benefits                 | 4.52     | 0.505     | 5    |
| 6    | Research and Innovation                 | 4.48     | 0.542     | 6    |
| 7    | Supportive Building Codes               | 4.44     | 0.541     | 7    |
| 8    | Context-Specific Adaptation             | 4.38     | 0.580     | 8    |
| 9    | Green / Safety Certification Incentives | 4.10     | 0.789     | 9    |
| 10   | Corporate Sustainability Goals          | 3.98     | 0.812     | 10   |
| 11   | Adaptive Detection Systems              | 3.88     | 0.745     | 11   |

*Source: Field survey, 2025*

#### 4.6 Discussion of Findings

The findings reveal a significant gap between knowledge and integration of fire safety strategies. Professionals demonstrated higher knowledge of passive strategies than infrastructure-dependent active systems, reflecting emphasis on passive strategies in professional education (Buchanan & Abu, 2017). However, high knowledge did not translate into high integration, with all means below 3.0. This disconnect between knowledge and practice suggests that factors other than technical knowledge influence fire safety integration. Economic constraints, regulatory weaknesses, and infrastructure limitations appear more significant determinants than professional knowledge alone. Alfakhry (2026) notes that while passive strategies hugely influence building shape and flow, active systems offer flexibility for architectural creativity. The challenge in Kaduna is that neither passive nor active strategies are being adequately implemented.

Cost Implications and Developer Priorities emerged as strongest barriers, consistent with commercial orientation of real-estate decision-making in Nigeria (Adamu et al., 2020). This aligns with observations that property developers often compromise standards in an effort to cut costs. Generator Dependence and Low Municipal Water Pressure reflect infrastructure constraints compromising active systems. The low knowledge scores for context-adapted systems indicate that professionals may be unaware of reliable alternatives that could function effectively under local conditions.

Occupant Safety and Regulatory Enforcement emerged as strongest success factors, highlighting importance of life-safety framing and enforcement mechanisms (NFPA, 2023; Adamu et al., 2020). The strong support for regulatory enforcement reflects recognition that effective enforcement is essential for driving compliance with fire safety codes, particularly given the current weaknesses in Nigerian regulatory frameworks.

## 5.0 Discussion of Findings

This study examined integration of fire safety strategies in mixed-use buildings in Kaduna. While professionals possess moderate knowledge of passive strategies, integration of both passive and active strategies remains inadequate. Fire safety performance must address economic, infrastructure, and capacity constraints characterizing Kaduna's context.

The knowledge-integration gap suggests factors other than technical knowledge influence fire safety integration. Economic constraints, regulatory weaknesses, and infrastructure limitations appear more significant determinants than professional knowledge alone. Cost Implications and Developer Priorities emerged as strongest barriers, consistent with developers' short-term focus on minimizing initial investment. This aligns with findings from other Nigerian contexts where property developers compromise standards to reduce costs.

Regulatory Gaps and Knowledge and Expertise highlight need for enforcement strengthening and capacity building (Adamu et al., 2020; Qurix et al., 2024). The inconsistent adoption and enforcement of building codes across Nigerian states has limited their effectiveness. Regulatory authorities are often more reactive than proactive, and even their reactive approach is inconsistent. Generator Dependence and Low Municipal Water Pressure reflect infrastructure constraints compromising active fire safety systems. Low knowledge scores for context-adapted systems indicate professionals may be unaware of reliable alternatives. Research on solar-powered detection systems demonstrates that sustainable alternatives exist that could function effectively under local conditions. Similarly, gravity-fed hose reels and dry-pipe sprinkler systems offer viable alternatives where municipal water pressure is inadequate.

Occupant Safety and Regulatory Enforcement emerged as strongest success factors, appealing to ethical considerations and professional responsibility (NFPA, 2023; Ronchi et al., 2022). Effective enforcement, including mandatory inspections, would provide powerful incentive for prioritizing fire safety. Automatic water fire-extinguishing systems have been shown to significantly reduce the threat of fire spreading and ensure building safety when operational capacity is regularly maintained and tested. The findings underscore the need for a systems approach to fire safety that integrates passive and active strategies within a framework of strong regulation, professional capacity, and context-appropriate solutions. As Alfakhry (2026) emphasizes, fire safety should be viewed not as a limitation on design but as a driving force for innovation that balances safety, aesthetics, and sustainability.

## 6.0 Conclusion

This study evaluated integration of fire safety strategies in mixed-use buildings in Kaduna. Findings reveal significant knowledge-integration gap, with professionals demonstrating higher knowledge of passive strategies than active systems, yet all strategies showing low integration scores below 3.0. Ten significant barriers were identified, with Cost Implications and Developer Priorities ranking highest. Other barriers included Regulatory Gaps, Knowledge and Expertise, Generator Dependence, and Maintenance Challenges, reflecting economic constraints, regulatory

weaknesses, and infrastructure limitations. These findings align with broader Nigerian challenges where regulatory enforcement is weak and property developers often compromise safety standards. Occupant Safety and Regulatory Enforcement were identified as strongest success factors. Without deliberate early-stage integration of context-adapted passive and active measures, mixed-use buildings will continue exposing occupants to preventable fire risk. Research has demonstrated that effective fire safety measures help prevent tragedies and save lives by quickly detecting and responding to fires. This work provides empirical evidence on fire safety integration in Nigerian mixed-use buildings, contributing to discourse on sustainable and resilient public architecture in sub-Saharan Africa. It highlights future research pathways including longitudinal studies and comparative evaluations. By bridging technical design standards with local constraints and user perceptions, the study establishes a practical and theoretical basis for designing fire-safe mixed-use buildings that are functional, sustainable, and socially relevant.

The study recommends strengthened code enforcement, capacity-building on passive-first and context-adapted systems, demonstration projects quantifying life-safety and lifecycle benefits, supportive incentives, professional awareness programmes, public awareness campaigns, context-appropriate solutions, enhanced emergency response capacity, and further research on fire safety strategies appropriate to Nigerian contexts. As Alfakhry (2026) concludes, fire safety should be viewed as a driving force for innovation in architectural design rather than a limitation.

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