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Containing the Risk: Architectural Strategies for Fire Compartmentalization in Retail Complexes

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Abstract
Retail complexes present significant fire safety challenges due to their large open-plan layouts, high occupant densities, and substantial combustible contents. Compartmentalization, the division of buildings into fire-resisting zones remains a fundamental passive strategy for limiting fire and smoke spread, protecting escape routes, and reducing damage. However, its effective application in retail design is often constrained by commercial preferences for spatial openness and, in many developing contexts, by weak enforcement and maintenance practices. This study examines architectural strategies for effective fire compartmentalization in retail complexes. A qualitative approach combining critical literature synthesis with comparative case study analysis of three retail facilities (Jabi Lake Mall and Ikeja City Mall Nigeria, and Dubai Mall in the United Arab Emirates) was adopted. Findings revealed that, while physical compartmentation elements are being frequently provided, their performance is often undermined by the poor maintenance, obstructed exits, and also, unregulated tenant modifications, particularly in the Nigerian cases. In contrast, there is a stronger integration of passive barriers with active systems and rigorous operational management, as demonstrated in the international case, significantly enhancing the fire containment. The study concludes that compartmentalization must be treated as a core architectural strategy rather than just a mere compliance requirement. An effective design requires early integration of fire-rated elements, a clear functional zoning of high-risk areas, robust detailing, and a coordination with means of escape and active protection systems. Priority should be given to a simple and maintainable solutions that can withstand operational realities, contributing to a more resilient and context-sensitive approaches to fire-safe retail design.

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Keywords: Fire compartmentalization; Retail complex design; Passive fire protection; Fire safety architecture; Risk containment

Introduction

Retail complexes are one of the most fire-vulnerable building typologies due to their high occupant densities, extensive open-plan layouts, diverse combustible contents, and also, their multipurpose functions. These characteristics tend to create conditions in which fire can spread very rapidly, producing a large volume of toxic smoke, and severely compromising evacuation routes (Majdalani, 2015; Drysdale, 2011). In environments like this, compartmentalization, which is the strategic division of a building into different zones using walls, floors, doors, and related barriers, is one of the most effective passive fire protection measures that could be used. Compartmentalization provides an adequate time for occupants to evacuate the building and also for emergency response while limiting the overall structural damage and property loss, by containing fire and smoke within limited areas for a prescribed period which is typically 30–120 minutes (British Standards Institution, 2017; NFPA, 2021).

In many developing countries, including Nigeria, the application of compartmentalization principles in retail design is quite inadequate. Recurrent fire incidents in traditional markets and modern shopping complexes have resulted in substantial losses of life, destruction of goods, and also, the disruption of economic activities (Arowolo et al., 2021; Ejale, 2021; Aderonmu & Eghobamien, 2021). Studies of markets such as Abubakar Rimi Market in Kano and Tejuosho Ultra Modern Market in Lagos consistently identifies the absence or a poor implementation of fire-resistant barriers, functional zoning, and a protected means of escape as major contributors to fire severity. An open-plan preferences driven by commercial visibility and customer circulation further complicates the integration of an effective compartmentalization (Arowolo et al., 2021; Aderonmu & Eghobamien, 2021).

Although international codes such as NFPA 101, BS 9999, and the Nigerian National Building Code provides a clear requirement for fire resistance ratings, egress design, and passive protection. But the enforcement and contextual adaptation remain very weak in many Nigerian urban centres (Olagunju et al., 2014). Consequently, there is a pressing need for design-oriented research that translates an established fire safety principle into a practical architectural strategy that is perfectly suited to the realities of Nigerian retail environments, characterized by a mixed formal and informal trading, limited maintenance culture, and varying levels of regulatory compliance.

This study therefore pursues three interrelated objectives:

(1) to synthesise the theoretical and practical principles of fire compartmentalization as an architectural strategy;

(2) to examine, through comparative case-study analysis, how these principles are applied (or compromised) in selected Nigerian and international retail complexes; and

(3) to derive concise, context-sensitive architectural design strategies that balance commercial openness with effective fire and smoke containment.

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The significance of this research lies in its potential to be able to reduce the fire-related risks in high-occupancy commercial buildings, support the development of context-sensitive fire safety guidelines and contribute to a safer, and more sustainable retail environments in Nigeria and similar contexts. The scope is limited to architectural design strategies, with a particular attention to spatial planning, passive fire protection elements, and their coordination with the means of escape. The construction detailing beyond architectural control, active firefighting operations, and post-occupancy management systems fall outside the primary focus of this paper.

Literature Review

Theoretical Framework

This study is framed by the principles of performance-based design (PBD) and risk-informed performance-based fire protection design (Meacham et al., 2005; Meacham & Alvarez-Rodriguez, 2015). In architectural terms, PBD shifts emphasis from rigid prescriptive compliance toward the achievement of explicit performance goals, life safety, property protection, and business continuity, under defined fire scenarios. Within this framework, compartmentalization is understood not merely as a code requirement but as a core spatial and organisational strategy that structures the building-occupant system.

Complementing this is the classic compartment-fire framework (Kawagoe, Thomas, and subsequent developments summarised by Majdalani, 2015; Drysdale, 2011). The framework conceptualises fire behaviour within enclosures as governed by geometry, ventilation, and fuel load, and it underpins the rationale for subdividing large retail volumes into discrete fire-resisting zones. By integrating these two complementary perspectives, performance goals at the building-system level and the physics of enclosure fire behaviour, the study positions compartmentalization as an architectural design generator that must be coordinated from the earliest stages with functional zoning, means of escape, and active systems. This theoretical stance directly informs the case-study analysis and the derivation of design strategies that remain robust under the operational realities of Nigerian retail complexes.

Fire Safety Challenges in Retail Complexes

Retail complexes present a unique fire safety challenges due to their very large floor plates, high occupant loads, mixed-use functions and a substantial fire loads arising from combustible merchandise, packaging, and the interior finishes (Ramachandran & Charters, 2011; Meacham et al., 2005). Open-plan layouts, atria, and interconnected spaces, while commercially desirable for visibility and circulation, tends to facilitate a rapid horizontal and vertical spread of fire and smoke if not properly controlled (Bryan, 2008; Karlsson & Quintiere, 2000). In such environments, the primary design objectives of fire safety architecture, life safety, property protection, and business continuity, becomes so difficult to achieve without a deliberate spatial control strategy.

Building Fire Dynamics and Implications for Design

Understanding fire dynamics is very fundamental to an effective architectural response. A typical enclosure fire progresses through ignition, growth, fully developed, and decay phases (Quintiere, 2006; Drysdale, 2011). Heat transfer occurs through conduction, convection, and radiation, while smoke and toxic gases (notably carbon monoxide and hydrogen cyanide) often pose the greatest

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threat to the occupants (Purser, 2002). Phenomena like a flashover and backdraft can really increase fire severity most especially in spaces that have a high fuel load and a limited ventilation control (Drysdale, 2011).

In retail settings, these dynamics are intensified by large volumes, vertical openings (escalators, atria), and continuous fuel packages. Architectural form therefore directly influences the fire behaviour: high ceilings and open connections can help to promote smoke logging and rapid-fire growth, while strategic barriers can interrupt heat and smoke pathways (Meacham et al., 2005).

Compartmentalization as a Core Passive Fire Protection Strategy

Compartmentalization is a foundational principle of passive fire protection. It involves the sub-division of a building into discrete fire-resisting compartments with the use of walls, floors, doors, and associated seals that maintain a very high level of integrity for specified periods, commonly 30, 60, 90, or 120 minutes (British Standards Institution, 2017; NFPA, 2021). The primary aims are to limit fire incidents and smoke spread, protect the means of escape, provide tenable conditions for evacuation and reduce the area that requires an active fire suppression (Ramachandran & Charters, 2011).

Key elements of an effective compartmentalization include:

- Fire-rated walls and floors that extend fully from the structural floor to the ceiling or the roof;
- Fire doors that are being fitted with self-closers and intumescent seals;
- Penetration seals around the services;
- Fire dampers in the ducts; and
- Coordination with the smoke control measures (Drysdale, 2011; NFPA, 2021).

Horizontal compartmentation controls often spread across the entire floor area, while the vertical compartmentation (via fire-rated floors, shafts, and stair enclosures) tends to limit the multi-level involvement. In atrium or multi-storey retail buildings, additional devices such as smoke curtains, baffles, or fire-resisting glazing are often required (Karlsson & Quintiere, 2000).

Functional zoning further strengthens compartmentation by helping to isolate higher-risk areas (kitchens, generator rooms, storage of flammable goods) from the public circulation and retail zones (Bryan, 2008). When properly coordinated with the means of escape, compartmentation ensures that the exit routes remain protected for the required evacuation time.

Integration with Active Systems and Means of Escape

Although compartmentation is a passive measure, its performance is significantly enhanced when integrated with an active fire protection system. Sprinklers, detection and alarm systems, and smoke control installations operates much more effectively when the fire is confined to limited areas (Meacham et al., 2005). Conversely, poorly maintained or compromised compartment boundaries (for example, fire doors wedged open) can undermine both the passive and the active provisions.

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Means of escape must be designed in tandem with the compartment boundaries so that protected corridors, stair enclosures, and refuge areas remain very tenable. Codes such as NFPA 101 and BS 9999 helps to provide a detailed requirement for travel distances, exit widths, and fire resistance of the escape routes (NFPA, 2021; British Standards Institution, 2017).

Implementation Challenges and Contextual Gaps

Despite the recognised importance of Compartmentalization, an effective execution of compartmentation faces several practical challenges in retail design. The commercial pressure for visual openness and flexible tenancy often conflicts with the need for physical barriers. The cost of fire-rated construction, inadequate maintenance of fire doors and seals, and unregulated fit-out alterations by tenants tends to frequently compromise the integrity of the building (Hasan & Islam, 2019; Olagunju et al., 2014).

In many developing contexts, including Nigeria, these challenges are compounded by a very weak code enforcement, limited technical capacity, and a predominance of informal or semi-formal retail environments (Olagunju et al., 2014; Oladokun & Emmanuel, 2014). While international literature extensively addresses compartmentation in high-rise residential, healthcare, and office buildings, relatively fewer studies focus specifically on large retail complexes, and even fewer examine the adaptation of these principles to African urban markets and shopping centres. This constitutes a significant gap that the present study seeks to address by synthesising the established principles with the context-relevant design considerations.

Methodology

This study adopted a qualitative, exploratory research design aimed at developing architectural strategies for effective fire compartmentalization in retail complexes. The approach was considered appropriate because the research seeks to synthesise existing knowledge, examine real-world applications, and generate design-oriented principles rather than test hypotheses statistically (Groat & Wang, 2013; Creswell & Poth, 2018).

Research Approach

The study combined critical literature synthesis with comparative case study analysis. The literature component established the theoretical foundation of fire dynamics, compartmentalization principles, and passive fire protection. The case study component provided empirical insight into how these principles have been applied (or neglected) in actual retail environments.

Case Study Selection

Three retail complexes were purposively selected to represent different contexts and levels of fire safety performance:

- Jabi Lake Mall, Abuja (Nigeria): a modern formal shopping mall in a major Nigerian city;
- Ikeja City Mall, Lagos (Nigeria): a high-traffic urban mall with documented fire incidents and safety provisions;
- Dubai Mall, Dubai (United Arab Emirates): an internationally recognised large-scale retail complex noted for advanced fire protection systems.

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These cases were chosen to allow comparison between Nigerian practice and international best practice, thereby highlighting transferable lessons and contextual challenges (Yin, 2018).

Data Collection

The data were collected through two primary methods:

Document and Literature Analysis

Architectural drawings (where available), published reports, academic papers, and relevant fire safety codes (NFPA 101, BS 9999, and the Nigerian National Building Code) were reviewed so as to understand the design intentions, fire resistance provisions, and the regulatory requirements.

Observational Analysis

Structured observations were conducted in the Nigerian case studies, focusing on the presence and condition of fire-rated walls and doors, compartment boundaries, means of escape, signage, and evidence of maintenance or compromise of passive systems. Observation checklists were used to ensure consistency.

Data Analysis

Data from the literature and case studies were analysed thematically. Key themes included: effectiveness of physical compartmentation, functional zoning of high-risk areas, coordination with means of escape, integration with active systems, and practical implementation challenges. A SWOT analysis was applied to the case studies to systematically identify strengths, weaknesses, opportunities, and threats related to compartmentalization strategies (Kumar, 2019). Findings from the cases were then synthesised with the theoretical literature to formulate practical architectural strategies.

Limitations

The study is limited by its qualitative nature and the relatively small number of case studies. Access to detailed as-built drawings and maintenance records was restricted in some instances. Nevertheless, the combination of literature synthesis and comparative case analysis provides a robust basis for developing transferable design strategies applicable to retail complexes in similar contexts.

Results

Case Study Findings

The three selected retail complexes revealed different levels of commitment to compartmentalization, and the effectiveness of fire compartmentalization strategies.

Jabi Lake Mall, Abuja

The mall incorporates a basic passive and active fire safety provisions. This includes; smoke detectors, fire alarms, portable extinguishers, and sprinklers in some selected areas. However, observational data and secondary reports also indicated a few inconsistencies in the maintenance of fire doors and escape routes. Some exit doors were found locked or obstructed during peak periods, and staff awareness of fire safety procedures appeared limited (Oladokun & Adegoke, 2017). Compartmentalization was present in principle but compromised in practice due to a very poor operational management.

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Ikeja City Mall, Lagos
This high-traffic mall demonstrated a more comprehensive approach. The mall has a fire hydrant system, sprinklers, a central fire alarm control panel, and clearly marked emergency exits. A recorded electrical fire in 2016 was successfully contained through the combined action of the detection systems and some trained security personnel (Akinyele, 2018). Nevertheless, challenges remained in crowd management during emergencies and in preventing temporary obstructions of escape routes. Horizontal compartmentation between retail units was only partially effective due to the tenant modifications.

Dubai Mall, Dubai
The Dubai Mall exhibited an advanced integration of passive and active systems. High-pressure water mist systems, aspirating smoke detection (VESDA), gas suppression in critical areas, and a sophisticated Building Management System that is being enabled in real-time monitoring and rapid response. A kitchen fire in 2012 was contained effectively with a minimal disruption, demonstrating the value of a well-maintained compartment boundaries combined with the intelligent active systems (Al Nuaimi & Khan, 2014). Vertical and horizontal compartmentation appeared very robust and consistently maintained.

Comparative Insights on Compartmentalization
Across the cases, these are the several patterns that emerged:

A physical compartmentation (fire-rated walls and doors) was more consistently implemented in the international example more than it was in the Nigerian malls.

Functional zoning of high-risk areas (kitchens, storage, plant rooms) was better defined in Dubai Mall.

The greatest weaknesses in the Nigerian cases related not to the complete absence of compartmentation, but to its operational compromise through poor maintenance, locked exits, and unregulated tenant alterations.

Integration between passive compartmentation and active systems was strongest where real-time monitoring and regular testing were institutionalised.

SWOT Analysis of Case Studies

Strengths
There is a presence of fire-rated elements and escape routes in all the cases; advanced detection and suppression systems in Dubai Mall; successful containment of small incidents in the Ikeja City Mall.

Weaknesses
There is an inconsistent maintenance of fire doors and seals; obstructed or locked exits; limited staff training; tenant modifications compromising the compartment integrity (especially in the Nigerian malls).

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Opportunities
Retrofitting of the existing malls; improved staff training and drills; adoption of an intelligent monitoring system; A stronger enforcement of post-occupancy compliance.

Threats
Weak regulatory enforcement; commercial pressure for open-plan flexibility; electrical overload and informal modifications; inadequate public fire safety awareness.

Key Lessons Emerging from the Results

1. Compartmentalization is only as effective as its maintenance and management.
2. Physical barriers must always be supported by a clear functional zoning of high-risk activities.
3. Strong integration between the passive compartmentation and the active systems significantly improves performance.
4. Operational factors (locked doors, obstructed routes, tenant alterations) frequently undermines a well-intentioned design strategy, particularly in the Nigerian context.
5. Advanced monitoring and regular testing, as demonstrated in Dubai Mall, offer a transferable lesson for improving the reliability in large retail complexes.

Discussion
The findings of this study reinforce the critical role of compartmentalization as a primary architectural strategy for containing fire risk in retail complexes, while also revealing the significant gaps between design intention and operational reality.

Interpreting the Case Study Findings
The comparative analysis shows that the physical provision of fire-rated walls, floors, and doors is very much necessary, but it is insufficient on its own. In both Nigerian cases (Jabi Lake Mall and Ikeja City Mall), elements of compartmentation existed, yet their effectiveness was frequently undermined by the poor maintenance, locked or obstructed exits, and unregulated tenant alterations. This aligns with earlier observations by Olagunju et al. (2014) and Oladokun and Emmanuel (2014) regarding the weak enforcement and maintenance culture surrounding fire safety in the Nigerian public buildings.

In contrast, the Dubai Mall demonstrates that when compartmentation is rigorously maintained and intelligently integrated with an advanced active system and a real-time monitoring, fire incidents can be rapidly contained with a minimal disruption. This strongly supports the arguments of Meacham et al. (2005) and Ramachandran and Charters (2011) that an optimal performance is being achieved through the coordinated use of both the passive and the active measures rather than the total reliance on either approach in isolation.

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The Tension Between Openness and Containment

A recurring theme across the cases and the broader literature is the inherent tension between the commercial preference for open-plan, visually continuous retail environments and the technical requirements of effective compartmentation (Bryan, 2008; Karlsson & Quintiere, 2000). Architects are often under an immense pressure to always minimise physical barriers in order to maximise sightlines, customer flow, and leasing flexibility. The results suggest that this pressure frequently leads to a compromised compartment boundary, particularly at the post-occupancy stage.

This study indicates that a successful strategy does not necessarily require abandoning the openness altogether. Instead, they demand a more sophisticated design response, which is a strategic placement of fire-rated elements, the use of fire-resisting glazing and smoke curtains, a clear functional zoning of high-risk activities (kitchens, storage, plant rooms), and a careful coordination with clear means of escape. These approaches allow a degree of spatial continuity while still limiting the fire incidents and smoke spread.

Implications for Architectural Practice

Several practical implications emerge for architects that are designing retail complexes, particularly in the developing contexts:

Compartmentalization must be treated as a core design generator from the earliest stages, not treated just as a compliance exercise that is being added later.

Functional zoning should isolate the higher fire-load or the higher-risk areas from the primary public circulation and escape routes.

Design detailing of fire doors, penetration seals, and junctions requires a greater attention, as these are the points that are most vulnerable to failure when there is a fire incident.

Post-occupancy management and tenant control must also be anticipated in the design; robust, difficult-to-compromise solutions are preferable to those that rely heavily on a perfect human behaviour.

Integration with active systems (detection, suppression, and smoke control) should be planned concurrently with the passive compartmentation to create a layered protection.

Contextual Considerations for Nigeria and Similar Settings

In the Nigerian context, the challenges are being amplified by an inconsistent code enforcement, limited technical capacity among some practitioners and facility managers, and the prevalence of an informal modification after handover. The findings suggest that design strategies for such environments should prioritise robustness, simplicity, and ease of maintenance over a highly complex system that may not be sustained. At the same time, lessons from advanced facilities such as Dubai Mall, particularly regarding monitoring, regular testing, and staff preparedness, remain highly relevant and quite transferable.

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Towards More Effective Strategies

Overall, the discussion points to a shift in approach. The study changed the viewing of compartmentalization as a purely technical or regulatory requirement to understanding it as a very fundamental architectural strategy for risk containment. When it is thoughtfully integrated with spatial organisation, means of escape, and active systems, compartmentation can reconcile the competing demands of commercial openness and life safety. The result of this study provides a foundation for developing a clearer, context-sensitive design principles that can guide architects in achieving this balance.

Recommendations for Future Research

Based on the findings and limitations of this study, the following areas are being recommended for future research:

Performance-Based Evaluation of Compartmentation in Retail Buildings

An empirical study that measures the exact performance of fire compartmentation during real or simulated fire events in retail complexes are very much needed. Such research would move beyond just the design intentions and compliance checklists to assess how effectively the walls, doors, and seals contain fire and smoke under a realistic condition.

Post-Occupancy Evaluation of Fire Safety Systems

A longitudinal post-occupancy studies should examine how compartmentation provisions tend to deteriorate or are being compromised over time due to the maintenance practices, tenant modifications, and the operational management. This is particularly important in developing countries where enforcement is often very weak.

Balancing Open-Plan Design and Fire Containment

Further research is also required to develop and test the innovative architectural solutions that reconcile commercial demands for a visual openness and spatial flexibility with effective fire and smoke containment. Investigations into the use of fire-resisting glazing, automatic smoke curtains, and adaptive compartmentation systems would be very valuable.

Context-Specific Design Guidelines for Developing Countries

There is a strong need for more research that is focused on the unique challenges of retail environments in sub-Saharan Africa and similar contexts, including a mixed formal-informal trading, limited technical capacity, and inconsistent regulatory enforcement. Such studies should aim to produce a practical, robust, and maintainable design guideline.

Integration of Digital Technologies and Intelligent Systems

Future research should explore the potentials of Building Information Modelling (BIM), digital twins, and real-time monitoring systems so as to improve the design, inspection, and the management of fire compartmentation in large retail complexes.

Human Behaviour and Evacuation in Compartmentalised Retail Spaces

More studies are needed on how the occupants (shoppers and staff) should behave during fire incidents in large, compartmentalised retail environments, and how design features also influence wayfinding, decision-making, and evacuation efficiency.

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Conclusion

This study sets out to examine architectural strategies for an effective fire compartmentalization in retail complexes, with a particular attention to the challenges of balancing commercial openness with life safety. Through a synthesis of fire safety principles and a comparative analysis of some selected case studies, the research has demonstrated that compartmentalization remains one of the most reliable passive means of containing fire and smoke, also protecting escape routes, and limiting the fire damage in high-occupancy commercial environments.

The findings also revealed that while physical fire-rated elements are often provided, their performance is frequently undermined by a very poor maintenance, operational compromises, and unregulated alterations, particularly in the Nigerian context. In contrast, examples of best practice show that a robust compartmentation, when properly integrated with functional zoning, means of escape, and an active fire protection system, can significantly enhance the building's resilience.

The central contribution of this paper lies in reframing compartmentalization as not just a merely regulatory requirement, but as a core architectural strategy for risk containment. Effective design must always address the inherent tension between open-plan retail environments and the need for spatial separation, using a thoughtful zoning, appropriate detailing, and a coordinated passive and active measure. In developing contexts, strategies should prioritise robustness, simplicity, and ease of maintenance to ensure a long-term effectiveness.

Ultimately, containing the risk of fire in retail complexes demands more than just compliance; it also require a deliberate architectural decision-making from the earliest design stages through to the post-occupancy management. By treating compartmentalization as an integral part of spatial organisation rather than an afterthought, architects can now create retail environments that are both commercially viable and also fundamentally safer for the people who are going to use them.

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