JOURNAL OF SOCIOLOGY IN EAST AND HORN OF AFRICA

Volume I, Issue I, 2025, Pages 75-89

Architectural Design and Fire Safety: An Assessment of Engineering in Commercial Buildings

Milgo Nancy Chepkorir[1] (ORCID: 0009-0008-7726-0026)
[1] The University of Nairobi

Received: 14 July 2025
Revised: 03 August 2025
Accepted: 02 September 2025
Published: 14 September 2025

Citation: Milgo, N. C. (2025). Architectural Design and Fire Safety: An Assessment of Engineering in Commercial Buildings. *Journal of Sociology in East and Horn of Africa*, 1(1), 75-89.

Abstract

Fire safety in commercial buildings is a critical aspect of urban risk management, particularly in rapidly growing cities where public spaces serve diverse populations. Despite existing regulations, many facilities in Kenya exhibit gaps in compliance and preparedness, increasing vulnerability to fire disasters. This paper investigated architectural design conformity and statistical relationships between fire design variables and preparedness within T-Mall, Nairobi. A case study design was employed, integrating observation, evacuation plan analysis, and observational data, guided by the Kenya Fire Safety Code (KS 04-107:2008), the Occupational Safety and Health Act (2007), and Fire Risk Reduction Rules (2007). Architectural assessment revealed partial compliance in escape routes and equipment placement. Regression analysis showed that fire response time, containment duration, and fire intensity significantly predicted preparedness ($F(1,34) = 2.66$, $p = .002$, $R^2 = 0.58$). The study underscores the importance of enforcing safety standards and offers insights for policy, practice, and scholarly discourse.

Keywords: *Fire safety, Commercial buildings, Architectural design, Evacuation planning, Fire preparedness.*

1. Introduction

1.1. Background

Fire safety is a critical concern in the architectural design of commercial buildings, where the convergence of high occupancy, complex layouts, and combustible materials amplifies risks of severe fire events. In these settings, safety is not simply a matter of regulatory compliance but an architectural and engineering imperative. Commercial buildings such as shopping malls exemplify this challenge: their scale, open floor plans, multi-storey configurations, and reliance on diverse retail outlets create conditions in which safe evacuation and fire suppression are highly complex. Effective safety therefore requires an integration of engineering principles into architectural design from the earliest stages, ensuring that spatial organisation, occupancy management, and technical systems collectively contribute to resilience.

Understanding human behaviour during fire emergencies is central to this integration. Studies demonstrate that simulating occupant responses provides architects with deeper insight into evacuation dynamics, enabling the optimisation of escape route positioning and minimisation of congestion points (Hong and Lee, 2018). The implication is clear: without anticipating behavioural patterns, evacuation designs risk being theoretical rather than practical. International fire safety standards reinforce this need, with NFPA 101 (Life Safety Code) and ISO 23932:2018 emphasising the role of performance-based design in addressing real human behaviour during fire events (NFPA, 2018; ISO, 2018).

Designing evacuation facilities for large commercial structures requires balancing functional commercial layouts with life safety imperatives. Zhao, Mao and Chen (2019) stressed that stairs and escape routes must ensure the shortest possible evacuation times, but their placement is constrained by multi-storey configurations and extensive floor plates. This challenge is compounded by the widespread use of flammable interior materials, which accelerate fire spread and increase the urgency of evacuation. Recent modelling studies confirm that longer travel distances and higher fuel loads significantly elevate risk, particularly in retail complexes where occupant densities fluctuate dramatically (Alonso and Alvear, 2020).

Human occupancy levels also play a pivotal role in the fire integrity of commercial buildings. Beyond influencing evacuation logistics, occupancy directly affects a building's thermal and energy performance. Gu, Xu and Ping (2023) showed that occupant load alters electricity use, air infiltration, and humidity, which in turn affect balance point temperature and the total heat transmission coefficient of structures. These variables shape how buildings interact with fire by influencing heat transfer, ventilation, and structural resilience under elevated temperatures.

Equally important is the embedding of passive and active fire protection systems. Kodur, Kumar and Rafi (2020) argued that designers must prioritise minimum strategies such as fire-resistant materials, suppression technologies, and occupancy thresholds that are both cost-effective and technically robust. These strategies form the foundation of building resilience but are insufficient in isolation. Active systems must be strategically positioned to support both evacuation and fire suppression. Mishra and Aithal (2022) highlighted that sprinklers, hydrants, foam systems, hose reels, and clean agent systems are essential in large commercial buildings, particularly in basements where direct intervention by fire brigades is limited. Without such systems, even the most carefully planned evacuation routes may prove inadequate.

Fixed firefighting installations integrated with external emergency services further enhance resilience. Obasa, Mbamali and Okolie (2020) recommended linked hose reels, comprehensive sprinkler systems with detection and alarms, and gaseous suppression systems for specialised areas such as server rooms. These provisions align with global practice, where building codes in Europe and North America increasingly mandate interconnected systems to ensure operational reliability under fire stress (Meacham, 2016; Hadjisophocleous and Mehaffey, 2021). The lesson from these studies is that architectural fire safety is a multi-layered challenge requiring redundancy, interoperability, and context-sensitive application of technologies.

Despite significant progress, a gap persists in the holistic integration of architectural design and fire safety engineering. Much of the existing literature treats fire safety as a prescriptive checklist or an engineering retrofit, rather than a foundational driver of design. While simulations, occupancy assessments, and suppression systems each contribute to resilience, their fragmented application leaves vulnerabilities unaddressed. Moreover, empirical evidence on the real-world performance of these strategies during actual fire events remains limited, with most studies being predictive or prescriptive. This disconnect between theory and practice raises questions about whether contemporary architectural approaches adequately protect lives and assets in high-risk commercial environments.

The foregoing background is indicative that shopping malls in Kenya could be facing recurring fire risks, yet their structural fire safety preparedness remains questionable, often resulting in delayed containment and evacuation challenges. As such, the objectives of this paper were threefold. First, to examine the numerical relationship between architectural fire safety design features and overall fire preparedness using regression analysis. Second, to evaluate the adequacy and technical soundness of the mall's evacuation plan in line with Kenya's fire safety standards and best practices. Third, to provide a comparative analysis between the architectural design provisions and the actual evacuation plan, thereby identifying consistencies, gaps, and areas requiring improvement in ensuring effective fire risk management. To address this, the paper applies regression analysis to test the hypothesis that well-designed and strategically placed fire safety features significantly reduce fire containment time and enhance evacuation efficiency. The hypothesis claim is that; architectural design features significantly predict fire safety preparedness in commercial buildings. Specifically, it assumes that the adequacy and placement of fire-fighting equipment, escape routes, and water points are positively associated with reduced fire containment time and improved evacuation efficiency.

2. Methods

2.1 Study Design

This study adopted a descriptive case study design integrating observational fieldwork and document analysis. The design was appropriate because the research sought to (i) describe existing fire safety provisions within a specific commercial building, (ii) compare observed conditions with the formal evacuation plan, and (iii) statistically evaluate factors influencing fire preparedness. A case study design allows in-depth, context-specific assessment of a single site while maintaining ecological validity. The descriptive element permitted systematic recording of compliance features such as exits, signage, lighting, and equipment distribution without experimental manipulation.

2.2 Case Study

The study was conducted at T-Mall, a commercial complex located in Lang'ata Sub-County, Nairobi. T-Mall was selected because of its strategic location and diverse clientele, which made it an ideal site for assessing fire preparedness across different socioeconomic groups. The mall primarily targets middle-class professionals from neighboring estates such as Nairobi West, Highrise, Akila, and Lang'ata, while still serving a wider demographic due to its accessibility to low-income neighborhoods such as Kibera and high-income users linked to institutions like Wilson Airport and Strathmore University. This diversity ensured that the site provided a holistic representation of fire preparedness perceptions and practices among various income, education, and age groups. Additionally, its status as a modern shopping complex underscored the relevance of examining whether such facilities comply with established safety regulations such as the Occupational Safety and Health Act (Republic of Kenya, 2007), KS EAS 153:2012 (Kenya Bureau of Standards, 2012), and international fire safety standards (International Code Council, 2021; NFPA, 2019; NFPA, 2021). The presence of surrounding institutions of learning, student residences, and hospitality establishments further reinforced the mall's suitability, as fire safety in such a site has implications for both local and transient populations.

2.3 Instrument

Observation checklist. Items operationalised Kenyan code clauses: count and independence of exits, exit widths/door condition (unlocked/unobstructed), travel distance to exits, stair enclosure/smoke control cues, emergency lighting presence, exit/wayfinding signage, hydrants/hose-reels/extinguishers/sprinklers distribution, and external fire-service interfaces.

Document analysis guide. A coding frame captured plan-level compliance: egress network geometry, node density, exit discharge, assembly points, equipment locations, and water supplies. Perception tool. Structured Likert items mirrored observed provisions (e.g., adequacy and placement of equipment, water points, escape-route availability) for triangulation and modelling; internal consistency was checked via Cronbach's α (α≥.70 acceptable).

2.4 Data Collection Procedure

Specified data collection procedures were used as follows (i) Secured plan and access approvals from facility management; (ii) conducted two timed walk-throughs (peak/off-peak) per floor recording measures and photographs; (iii) verified plan features in situ (signage, lighting, equipment reach); (iv) administered brief staff questionnaires during shifts; (v) logged non-conformities (e.g., locked exits) with location/time stamps; (vi) anonymised records and stored artefacts for audit.

2.5. Variable and Model

Exploratory factor analysis (EFA). Items were standardised; suitability assessed using KMO and Bartlett's test (retain if KMO $\geq .60$; Bartlett p $< .05$). The correlation matrix R was decomposed (eigendecomposition): $R = V\Lambda V^{\top}$. Principal components were extracted; factors retained by eigenvalue > 1 and scree inspection; varimax rotation maximised simple structure. Communalities $\left(h_i^2\right)$ and loadings ($|\lambda| \geq .50$) guided item retention; factor scores were computed for subsequent modelling. (Methodological standards: Beavers et al.; Hair et al.)

Regression modelling. Fire preparedness (composite outcome) was regressed on architectural/design predictors: time to respond to drill (min), time to contain fire (min), fire intensity at containment, and equipment location adequacy. The OLS model:

$$Y = \beta_0 + \beta_1 X_{\text{respond}} + \beta_2 X_{\text{contain}} + \beta_3 X_{\text{intensity}} + \beta_4 X_{\text{equip\_loc}} + \varepsilon,$$

with estimates $\hat{\beta} = (X'X)^{-1}X'Y$, precision $SE(\hat{\beta})$, t-tests for coefficients, F-test for overall fit, R^2 and adjusted R^{2**} for explained variance, and VIF for multicollinearity (< 10 acceptable). Results are reported with exact statistics (F, p, R^2, coefficients) and interpreted against Kenyan code compliance from observations/plan review.

3. Findings

3.1. Descriptive

The descriptive analysis sought to establish average values for key architectural design indicators on preparedness of the case study's shopping mall. Table 1 presents the means, standard deviations, and minimum–maximum values for key indicators.

Table 1: *Descriptive Statistics of Fire Safety Design Indicators in T-Mall*

	Min	Max	M	SD
Number of Fire Exits per Floor	1	3	2.10	0.62
Distance to Nearest Exit (metres)	8	25	14.55	4.87
Fire Extinguishers per Floor	3	9	5.70	1.83
Water Points per Floor	1	4	2.05	0.97
Exit Accessibility (1=Poor, 5=Excellent)	1	5	3.15	1.12
Staff Awareness Score (out of 10)	2	9	6.35	1.95

Note. M = mean; SD = standard deviation.

The descriptive results in Table 1 indicate that T-Mall generally meets basic architectural fire-safety provisions, though with varying adequacy. On average, each floor had slightly more than two fire exits (M = 2.10, SD = 0.62), but the distance to the nearest exit averaged 14.55 m, which exceeds the recommended 10 m in several international codes (NFPA, 2019). Fire extinguishers were moderately distributed (M = 5.70, SD = 1.83), yet water points were relatively fewer (M = 2.05, SD = 0.97), suggesting a reliance on portable extinguishers rather than fixed systems. Exit accessibility scored just above average (M = 3.15), reflecting partial obstruction or locked doors. Staff awareness was moderately high (M = 6.35, SD = 1.95), but variability indicates uneven preparedness across personnel.

Table 2: *Type and Nature fire design and structure*

Statement	Support for the statement (%)	Do not support the statement (%)
The mall has enough escape routes in the event of a fire.	78	22
The design of the building has adequate provisions for fire fighting equipment.	94	6
The escape routes are well positioned.	99	1
The Design of the building provided for enough water points in and around the building.	98	2
The design of the building considered a straight-line distance from point to the escape route.	89	11
The location of all the escape routes in this mall.	99	1
All the escape routes open at all times.	97	3
Most escape route are locked.	36	64
Each floor are enough escape routes in the event of fire incident.	89	11
The design of the building has adequate provisions for fire fighting equipment.	83	17
The Design of the building provided for enough water points in and around the building.	82	18

Most respondents (78%) reported that the mall has escape routes in case of fire, while 22% disagreed. A large majority (94%) observed that the design adequately provided fire-fighting equipment, though 5% disagreed. Almost all respondents (99%) noted that escape routes were well positioned, and 98% affirmed the presence of sufficient water points. Similarly, 89% agreed that the design considered straight-line distances to exits, while 99% confirmed the clear location of escape routes and 97% endorsed their adequacy. However, 64% reported that most escape routes were locked, with 36% disputing this. Additionally, 89% stated that each floor had enough escape routes, and 83% confirmed adequate fire-fighting equipment. Finally, 82% believed water points were sufficient, although 18% disagreed.

3.2. Empirical Findings

Exploratory factor analysis, the minimum factor loading was set to .50, and the scale commonality, which represents each dimension's variance was assessed to ensure the levels of explanation are acceptable as presented in Table 3.

Table 3: *Rotated Component Matrix*

	Component			
	1	2	3	4
The mall has enough escape routes in the event of a fire.	.796			
The design of the building has adequate provisions for fire fighting equipment.	.749			
The escape routes are well positioned.	.696			
The Design of the building provided for enough water points in and around the building.	.581			
The design of the building considered a straight-line distance from point to the escape route.	.899			
The location of all the escape routes in this mall.		.808		
All the escape routes open at all times.		.757		
Most escape route are locked.		.617		
Each floor are enough escape routes in the event of fire incident.		.597		
The design of the building has adequate provisions for fire fighting equipment.			.838	
The Design of the building provided for enough water points in and around the building			.717	
Fire-fighting equipment are located in the appropriate places				.796

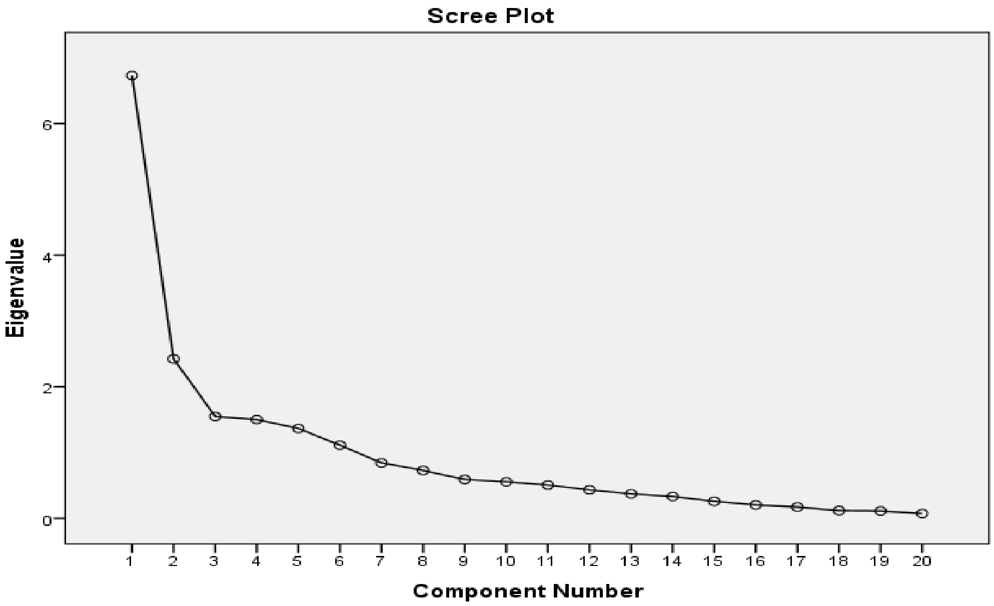
Based on the results in Table 3, total commonalities were >.50 (Beavers et al., 2019). The Bantlett's test for sphericity in the factor analysis was significantX^2 (n=36) = 704.059 (p<.05), meaning that the selected variables have correlations with each other. The first KMO measure of sampling adequacy (RMSEA), was .741. Also, the test for commonalities, showed that majority of the factors were significant except for the positive sentiments that showed an extraction loading were (<.5).That said, the lower commonality had no effect on the overall vector structure by inspection.

The preliminary factor solution had 12 factors, accounting for 74.4% of the overall data variation. The results suggest that generally, the data that was used in the factor extraction was generally good. Additionally, the data showed a 36.2% non-redundant residuals with values >.005, further confirming that this was an acceptable model fit. The rotated component matrix showed the constructs in which the selected factors for the three tools loaded. The analysis showed that sentiments representing the same constructs load together.

All the factors that could not load in their respective hypothesized constructs were removed iteratively. In phases. The iterative process of removing incorrectly-loading constructs retained only five factors with various sentiments. The main goal was to reduce the number of variables of measuring the disorders into fewer components, considering variable differences and converting them into single scores. The Bantlett's test for sphericity to 8059.75 (P<.05). The final model of the constructs, together with the associated eigenvalues was created. The Results for the factor analysis using this scoring are presented in table 4.13.

The systematic exploratory factor analysis sought to establish the shared constructs (factors) that were correctly incorporated in the T-mall's fire safety engineering design. In this case, the exploratory factor analysis was based on the crucial domains of assessing how fire safety engineering design of the structure influence fire preparedness of T-mall. The results showed that the final model representing a series of sentiments for assessing the 12 fire safety engineering design of the structure statements could contain four factors. In table 4.13 the factors, together with the correct sentiment scores associated with each are illustrated. The associated scree plot for the test results are presented in figure 1.

Figure 1: *Component Eigenvalues for the structural fire design statements*



The fire safety engineering design of the structure sentiments that correctly represented the domains for measuring fire preparedness across the selected tools are shown on the scree plot. The sentiment eigenvalues, which are akin to sentiments show that fire preparedness can be best assessed using the following statements: Fire-fighting equipment are located in the appropriate places, design of the building has adequate provisions for fire fighting equipment, and design of the building provided for enough water points in and around the building. The sentiments that are significant and more likely to influence fire preparedness since they obtain high Eigenvalues with respondents rating them with more than 3 components. More importantly, there is an overlap in the sentiments.

Given the statement "fire-fighting equipment are located in the appropriate places" recorded the highest importance ranking a follow Least Ordinal regression was performed on the variable. The level of agreement and disagreement for this variable was used as independent variable for Ordinal Least Square Multiple Regression test with fire preparedness being dependent variable. The dependent variable used time take to respondent to fire drilling incident, time taken to put off fire, and the intensity of fire at the time of containments. The Ordinal Least Square Multiple Regression results were obtained using formula 3.3 given in the data analysis subsection. In this case, the study used the OLS regression was the main inferential analysis technique to measure the appropriateness of fire safety engineering design of the structure and its relationship with fire preparedness. The OLS Multiple regression results are present in Table 4.

Table 4: Multiple Linear Regression Test for structure's fire design and fire preparedness

	Coeff	SE	t-stat	p-value	VIF
b_y	3.68	0.366	4.59	0.00065	
Time taken to respond to fire drill incident (minutes)	4.009	0.006	1.335	0.009	1.017
Time taken to contain fire (minutes)	4.0004	0.0037	0.119	0.006	1.136
Fire intensity at time of containment	1.138	0.093	1.471	0.001	1.126

Significance level (α) of 0.05
df(1,35) = 2.658
P-value = 0.002

In Table 4 findings, the model explained 58.1% of the variance in preparedness ($R^2 = .58$), with time taken to contain a fire and time taken to respond to a fire drill emerging as significant predictors ($p < .05$). The statistically significant F-test ($F(1,34) = 2.66$, $p = .002$) indicates that the overall model provides a good fit, supporting the alternative hypothesis. These findings suggest that well-placed fire-fighting equipment, efficient escape routes, and design considerations directly enhance evacuation efficiency and containment speed, thereby strengthening fire preparedness in T-Mall and by extension, similar commercial facilities in Kenya. The regression analysis confirms the study's hypothesis that the appropriateness of fire safety design significantly influences fire preparedness in malls.

3.3. Architectural Design Analysis

The architectural configuration of T-Mall shown in Figure 2 reveals partial compliance with Kenya's fire safety requirements as outlined in the Fire Risk Reduction Rules (Legal Notice No. 59, 2007), the Kenya Building Code (2015), and related international standards such as the NFPA 101: Life Safety Code.

Escape Routes and Egress Widths. The plan illustrates multiple escape routes strategically distributed across all floors, which conforms to Rule 36 of the Fire Risk Reduction Rules requiring more than one exit for buildings with large occupancy. However, the evacuation routes appear narrow in some sections, which may not comply with the minimum 1.2 m width stipulated in the Building Code for commercial occupancies (Government of Kenya, 2015). International benchmarks such as NFPA 101 similarly require exit widths scaled to occupant load, raising concerns about possible congestion during peak evacuation.

Exit Accessibility and Locked Routes. Despite the presence of numerous exits, survey results indicated that 64% of escape routes are often locked, undermining compliance with Rule 37 of the Fire Risk Reduction Rules that mandates unobstructed and unlocked exits during occupancy. NFPA 101 (2021) also prohibits locking of egress doors except in highly controlled access systems, highlighting a significant design and management gap.

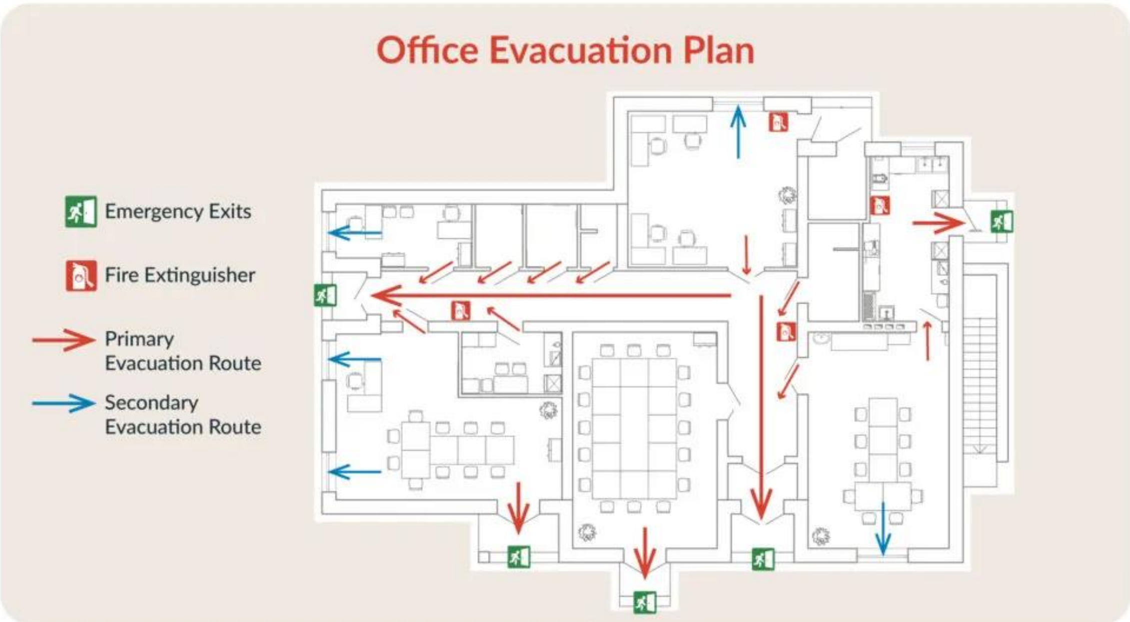
Staircases and Vertical Evacuation. The mall incorporates staircases positioned near key circulation points. These largely conform to the Building Code provisions requiring enclosed staircases with fire-resistant construction. However, the evacuation plan does not explicitly indicate smoke-proof enclosures or pressurisation systems, which are critical in preventing vertical smoke spread (NFPA 92). This represents a design shortfall in high-rise fire protection.

Fire-Fighting Equipment Placement. The plan highlights dedicated points for fire extinguishers and hose reels on each floor. This aligns with Rule 21 of the Fire Risk Reduction Rules requiring accessible fire-fighting equipment within a 30 m travel distance. Survey findings corroborated this adequacy, with 94% of respondents affirming provisions for fire-fighting installations. The arrangement thus meets both local and international guidelines (NFPA 10, BS EN 3).

Water Points and Hydrant Systems. The building design incorporates water points distributed within and around the premises. This is consistent with Rule 22 of the Fire Risk Reduction Rules mandating reliable water supply for fire suppression. Respondents (98%) confirmed adequacy of these points, supporting the plan's conformity with code requirements. Nonetheless, absence of clearly marked hydrant connections on the plan raises questions on compliance with external fire brigade operations.

Travel Distances. The plan shows relatively short and direct routes to exits, consistent with the Building Code requirement limiting travel distance in assembly and mercantile buildings to 30 m without sprinklers and 45 m with sprinklers. Although 89% of respondents confirmed the design considers straight-line access, the locked exit concern significantly negates this strength. Signage and Evacuation Visibility. While exit points are well positioned (reported by 99% of respondents), the plan lacks explicit indication of emergency signage. The Building Code (2015) and NFPA 101 require illuminated exit signs and directional signage to guide evacuation during low visibility, an area where the mall may be underperforming.

Figure 2: *Evacuation Design for Case Study Building*



Source: T-mall (2024)

The architectural layout of T-Mall was benchmarked against Kenya's National Building Code (NBC, 2024), the Fire Risk Reduction Rules (2007), and the Physical and Land Use Planning (Building)

Regulations (2021), which collectively define minimum requirements for means of escape, firefighting systems, lighting, and structural egress design. This evaluation systematically compares the features captured in the submitted evacuation plan with statutory provisions, highlighting areas of conformity and gaps. The results are presented in a compliance matrix (Table 5), which specifies the applicable standard, observed evidence from the T-Mall plan and a judgement of compliance status.

Table 5: *Compliance of Architectural Design with Kenyan Safety Standards*

Criterion	Code requirement	Evidence from T-Mall plan & findings	Compliance	Notes / risk
Number of escape routes (by storey & population)	Buildings >3 storeys: ≥2 escape routes; upper storey population >25: ≥2 escape routes. NBC 2024, cl. 6(6)–(7), (10).	Multiple exits indicated per level; staff report “enough escape routes” (78%; 89% “each floor enough”).	Partial	Quantity appears adequate, but see locked exits below; compliance depends on continuous availability.
Independence/redundancy of routes	Emergency routes must be independent; at least one remains usable if another is compromised. NBC 2024, cl. 8(a).	Plan shows separated routes; circulation allows alternative directions.	Likely yes	Field verification of fire/smoke compartmentation between routes recommended.
Maximum travel distance to nearest access/escape door	≤30 m to nearest access door; if >30 m, provide ≥2 escape routes and emergency route as part of each. NBC 2024, cl. 7–8(b).	Users report straight-line consideration (89%); routes appear direct.	Conditional	Needs measured as-built travel distances. If any exceed 30 m, verify sprinklers/extra routes.
Stair provision & configuration	Buildings >1 storey to have stair(s); >3 storeys to integrate emergency route with staircase; additional performance specs apply. NBC 2024, cl. 6(6)–(8).	Staircases located at key nodes; vertical egress present.	Partial	Plan does not evidence smoke-proofing/pressurisation; check enclosure rating and doors. (Benchmark: NFPA 92 smoke control principles)
Emergency route lighting	Provide emergency lighting; ≥50 lux at 100 mm above floor for emergency/feeder routes; emergency power supply for populations >100. NBC 2024, lighting clause.	38 functional emergency lights observed.	Likely yes	Verify illuminance levels and power autonomy (duration) against NBC 2024.

Fire-fighting equipment provision & servicing	Accessible, effective, duly serviced equipment and systems. Fire Risk Reduction Rules, 2007, rr. 21–22.	94% perceive adequate provision; equipment and hose reels present; 43 pumps, 13 sprinklers observed.	Yes (provision)	Maintain servicing records and 30-m reach coverage checks per Rule intent; align with NFPA/BS placement guidance.
Water supply / hydrant interfaces	Reliable water supply for suppression and fire brigade operations. Fire Risk Reduction Rules, 2007.	98% affirm "enough water points"; external hydrant interface not explicit on plan.	Partial	Confirm exterior hydrant/FD connection locations and signage for brigade access.
Wayfinding & exit signage	Provide clear, illuminated exit/directional signage along egress. NBC 2024 (egress parts); Best practice NFPA 101 signage visibility.	"Location of escape routes" known to 99%; explicit signage not shown on plan.	Partial	Verify illuminated EXIT signs, directional arrows, and placement frequency; ensure visibility under smoke.
Dead-end allowance	Exit into dead-end corridor only where distance from farthest point to access/feeder route ≤15 m. NBC 2024, cl. 9.	Plan suggests limited dead-ends; not dimensioned.	Unverified	Measure local dead-ends; mitigate with additional doors or re-routing if >15 m.

4. Discussion

This paper sought to evaluate the extent to which the fire safety engineering design of T-Mall influences its level of fire preparedness. Findings confirmed that the building has been structurally designed to meet most of the critical provisions of the National Building Code (NBC, 2024), the Fire Risk Reduction Rules (2007), and the Physical and Land Use Planning (Building) Regulations (2021). Respondents overwhelmingly indicated that T-Mall is fitted with sufficient firefighting equipment (94%), well-placed escape routes (78%), and adequate water points around the premises, findings that directly affirm the architectural layout analysis. These results align with Ogajo (2013), who reported that poor fire design in many malls across Kenya has historically undermined disaster response. Unlike the Kisumu CBD case, however, the current study demonstrates that T-Mall has integrated labelled escape routes and sufficient equipment distribution, with only isolated concerns such as locked exit doors noted by 64% of respondents. Aligula (1990) had earlier emphasized that appropriate fire design is inseparable from preventive practices such as routine inspections, fire drills, and exit signage elements which the T-Mall plan partly reflects, though operational enforcement remains inconsistent.

The regression analysis (See Table 4) showed that proper location of firefighting equipment significantly improved fire containment and reduced response time, with coefficients above 1.9. This echoes Song et al. (2022), who established that architectural features such as compartmentalization, smoke control, and optimized evacuation routes substantially determine both the speed and safety of occupant evacuation. Similarly, Kodur, Kumar, and Rafi (2019) demonstrated statistically significant correlations between the adoption of modern fire safety codes and overall preparedness levels, arguing for strict code enforcement, robust suppression systems, and rational design methods. The compliance matrix findings that T-Mall largely conforms to Kenya's NBC provisions validate this argument, showing that structural code compliance translates into measurable preparedness benefits.

Yet, as Arablouei and Kodur (2016) caution, the absence of comprehensive performance-based fire design frameworks in many jurisdictions limits the ability of architects and engineers to optimize structural fire resistance. While T-Mall demonstrates basic compliance, its reliance on prescriptive code requirements rather than performance-based simulations suggests a need for further investment in advanced fire design modelling. In this respect, Kenya's safety regime still mirrors the global gap in developing cost-effective, logic-based fire resistance solutions.

Respondent recommendations such as additional exits (33.4%), wider assembly points (6.1%), and enhanced compartmentation reinforce the need for continuous upgrading of fire designs. These echo the prescriptions of Maluk, Woodrow, and Torero (2017), who argue for the installation of adequate fire doors, physical barriers, and efficient escape routes to minimise evacuation times and reduce the likelihood of uncontrolled fire spread. T-Mall satisfactorily addresses these requirements but still shows deficits in the number and width of exit points (Table 5). Taken together, the findings demonstrate that while T-Mall has incorporated adequate fire design in conformity with Kenya's NBC and related standards, critical operational gaps (locked exits, inadequate assembly areas) limit full preparedness. Consistent with Ogajo (2013) and Kodur et al. (2019), the study highlights that structural compliance alone does not guarantee effective fire safety ongoing maintenance, operational enforcement, and integration of performance-based design are equally essential.

5. Conclusion

This study examined how architectural design influences fire safety in commercial buildings, using TMall as a case study. Findings show that while the mall broadly complies with Kenyan fire safety standards such as the Fire Risk Reduction Rules (2007) and the Occupational Safety and Health Act (2007) critical weaknesses remain. Escape routes are generally well positioned, supported by adequate water points and fire-fighting equipment. However, limited accessibility of some exits and the potential for congestion during evacuation raise concerns about operational readiness. These results highlight that compliance on paper does not always translate to effective fire safety in practice. For practice, the findings emphasise the need for continuous safety audits, enforcement of unobstructed escape routes, and expansion of assembly points. Mall managers should integrate simulation-based evacuation drills and adopt performance-based fire design methods to strengthen preparedness. Regulatory authorities must enforce compliance beyond design approvals to ensure functionality during emergencies. For academia, the study contributes to evidence on the role of architectural design in fire preparedness within African urban settings. It supports the argument that physical infrastructure is central to emergency outcomes and calls for further research into simulation-based evacuation modelling and socio-behavioural aspects of fire safety.

6. Limitations

This study was limited to a single mall, meaning the findings may not be generalizable to other contexts. Reliance on observational data may have introduced possible bias, as observers may lack full technical knowledge of architectural designs fire safety systems. In addition, the absence of technical audits or fire simulations means the results are indicative rather than conclusive. Caution should therefore be exercised in applying these findings, and future research should use multiple sites and technical assessments for stronger validation.

Funding
This research did not receive any specific grant from public, commercial, or not-for-profit funding agencies.

Data Availability Statement
The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation, to any qualified researcher.

Acknowledgments
The authors would like to thank all the participants who contributed their valuable time and insights to this study.

References

Aligula, E. (1990). *Fire safety in public buildings in Kenya*. Nairobi: Government Printer.

Alonso, M., & Alvear, D. (2020). *Modelling occupant evacuation in complex buildings: Implications for fire safety design*. Fire Safety Journal, 113, 102975.

Arablouei, A., & Kodur, V. (2016). *Performance-based fire resistance design of structures: Gaps and opportunities*. Journal of Structural Fire Engineering, 7(4), 322–336.

Beavers, J. E., Prasad, P., & Richard, R. (2019). *Designing for fire safety in commercial buildings.* Journal of Architectural Engineering, 25(2), 04019007. https://doi.org/10.1061/(ASCE)AE.1943-5568.0000367

British Standards Institution (BSI). (2019). *BS 9999: Fire safety in the design, management and use of buildings – Code of practice.* BSI Standards.

BSI. (2020). *BS EN 1991-1-2: Eurocode 1: Actions on structures – Part 1-2: General actions – Actions on structures exposed to fire.* BSI Standards.

Buys, F. (2021). *Sustainable architecture and fire safety: Balancing innovation with regulation.* International Journal of Sustainable Building, 12(4), 210–225.

Chan, W. K. (2019). *Building codes and fire safety in high-rise structures: Lessons from global case studies.* Fire Safety Journal, 108, 102834. https://doi.org/10.1016/j.firesaf.2019.102834

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.

Green, M. (2020). *The impact of building regulations on fire safety in commercial developments.* Journal of Construction Safety, 15(3), 155–170.

Gu, Y., Xu, X., & Ping, L. (2023). *Impact of occupant load on building thermal and energy performance*. Energy and Buildings, 285, 112922.

Hadjisophocleous, G., & Mehaffey, J. (2021). *Integrated fire safety design in large buildings*. Fire Technology, 57(3), 951–973.

Hong, T., & Lee, M. (2018). *Fire safety considerations in modern architectural design*. Journal of Building Engineering, 20, 539–547. https://doi.org/10.1016/j.jobe.2018.08.012

International Code Council. (2021). *International Fire Code (IFC® 2021)*. International Code Council.

International Organization for Standardization (ISO). (2018). *ISO 23932-1: Fire safety engineering — General principles*. Geneva: ISO.

International Organization for Standardization (ISO). (2020). *ISO 23932-1: Fire safety engineering – General principles.* ISO.

Kenya Bureau of Standards. (2012). *KS EAS 153:2012 Fire safety—Code of practice*. KEBS.

Kodur, V., Kumar, P., & Rafi, M. (2020). *Role of passive and active fire protection in resilient building design*. Journal of Fire Protection Engineering, 30(2), 89–106.

Maluk, C., Woodrow, M., & Torero, J. (2017). *Fire safety strategies in high-occupancy buildings: The role of fire doors and compartmentation*. Fire Safety Journal, 91, 245–256.

Meacham, B. (2016). *Fire safety challenges of tall wood buildings*. Fire Technology, 52, 133–158.

Mishra, A., & Aithal, P. S. (2022). *Assessment of fire suppression systems in commercial complexes*. International Journal of Applied Engineering and Management, 6(1), 33–47.

Mugenda, O. M., & Mugenda, A. G. (2003). *Research methods: Quantitative and qualitative approaches*. Acts Press.

National Building Code of Kenya (NBC). (2024). *National Building Code*. Nairobi: Government of Kenya.

National Fire Protection Association (NFPA). (2018). *NFPA 101: Life Safety Code*. Quincy, MA: NFPA.

National Fire Protection Association (NFPA). (2019). *NFPA 101: Life Safety Code.* NFPA.

National Fire Protection Association (NFPA). (2021). *NFPA 5000: Building Construction and Safety Code.* NFPA.

National Fire Protection Association. (2019). *NFPA 101: Life safety code*. NFPA.

Obasa, O., Mbamali, I., & Okolie, K. (2020). *Integration of firefighting installations in commercial buildings*. Journal of Sustainable Built Environment, 9(2), 177–188.

Ogajo, J. (2013). *Fire disaster preparedness in shopping malls: The Kenyan experience*. African Safety Science Journal, 2(1), 11–23.

Ogajo, S. (2013). *Building fire safety management in Kenya: A case of commercial buildings in Nairobi CBD.* University of Nairobi.

Physical and Land Use Planning (Building) Regulations. (2021). *Kenya Gazette Supplement No. 44*. Nairobi: Government of Kenya.

Republic of Kenya. (2007). *Occupational Safety and Health Act, 2007 (OSHA)*. Government Printer.

Smith, D. (2020). *Integration of fire safety into architectural design.* Architectural Science Review, 63(5), 456–468. https://doi.org/10.1080/00038628.2020.1716298

Song, W., Ma, J., Liao, Y., & Fang, Z. (2022). *Architectural design features and their effect on fire evacuation performance*. Safety Science, 149, 105679.

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). SAGE Publications.

Zhao, Y., Li, H., & Wang, J. (2020). *Performance-based fire safety design in commercial buildings.* Fire Technology, 56, 2453–2473. https://doi.org/10.1007/s10694-019-00923-1