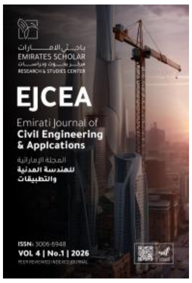

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Fire Safety Optimization in UAE High-Rise Buildings (A Mixed-Methods Evaluation of Fire Protection Systems)

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ABSTRACT

In the United Arab Emirates (UAE), it is exceptionally hard to keep high-rise buildings safe from fire because of the extreme weather, like heat, UV radiation, and sand in the air, which speeds up the wear and tear on façades and fire-resistant coatings. These stressors make materials less reliable and illustrate how crucial it is to develop standards that are appropriate to dry Gulf conditions. Grenfell Tower and Address Downtown are two big international occurrences that highlight how problems with suppression, compartmentalization, and coordination can make hazards worse. The rapid proliferation of high-rises in the UAE has led to the building of new buildings in a variety of forms and ways of life. The UAE Fire and Life Safety Code require stringent compliance, yet there is a lack of empirical research concerning the relationship between technological systems, regulatory enforcement, and organizational preparation in affecting safety results.

This research utilizes sequential mixed methods designed to rectify inadequacy. A stakeholder survey (N = 200) evaluates the roles of fire-resistant materials, construction regulations, and fire safety management systems (FSMS). We learn about maintenance discipline, evacuation performance, and system reliability via case studies and interviews that go together. The study enhances the existing knowledge by (i) evaluating the interplay of system functionality, compliance, and preparedness in enhancing safety, and (ii) providing recommendations for retrofitting, testing, and policy enhancement that consider climate change. The outcomes expand socio-technical perspectives on fire safety and establish a region-specific framework for resilience in UAE high-rises.

Keywords: *Fire safety optimization, Commercial high-rise structures, UAE Fire and Life Safety Code, Climatic resilience in fire protection, Mixed-methods study, Mediation analysis (response time).*

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Introduction and Literature Review

1) Introduction

2.1 Background and Research Gap

Managing fire safety in high-rise buildings is problematic since they are tall, have a lot of people living in them, and don't have many means to get out. These kinds of issues are widely documented in worldwide literature, but they are significantly worse in the United Arab Emirates (UAE) because the severe heat, UV radiation, and sand in the air make façades and fire-resistant coatings wear out faster. Two examples of how mistakes in compartmentation, suppression, and evacuation can lead to tragic effects are the Grenfell Tower fire in the UK in 2017 and the Address Downtown fire in Dubai in 2015.

The UAE Fire and Life Safety Code has very high criteria, but there isn't much real-world research on how fire protection systems, regulatory enforcement, and organizational readiness work together to effect outcomes in this particular setting. Previous studies have primarily focused on Western or Asian contexts, sometimes neglecting the synergistic effects of technical systems, regulatory procedures, and human preparedness in arid locations.

This study seeks to address these deficiencies by employing a mixed-methods approach to examine the interplay of system functionality, compliance, and emergency readiness on safety outcomes in high-rise buildings in the UAE. It will focus on how the time it takes to respond to an emergency influences these results.

2.2 Research Aim and Objectives

This study examines how fire prevention, regulatory compliance, and emergency preparedness improve UAE commercial high-rise fire safety.

Goals are specific:

- UAE high-rise active and passive fire protection systems are tested for reliability.
- UAE Fire and Life Safety Code comparison.
- Consider how communication, exercises, and training affect evacuations.
- Assess fire safety incident response time.
- Show climate-resilience in UAE high-rises.

Study ideas and premises assist these aims. Theory, method, and practice support this.

Global high-rise fire safety debates develop with a climate-resilient socio-technical framework for dry Gulf areas. Social-technical and resilience engineering models are commonly utilized in temperate and humid areas, but the cumulative impacts of severe heat, UV radiation, and airborne sand on façade systems and fire-resistant coatings have not been studied.

This survey and qualitative research employing climate-accelerated deterioration indicators shows material degradation's influence on UAE fire safety outcomes for the first time. Blockchain-based audits and IoT monitoring go beyond compliance.

Lacking international norms, digital technologies enable transparency and maintenance and enforcement alerts. The UAE results apply to dry megacities including Riyadh, Doha, and Perth. Climate-induced fire safety improves with scalable research.

Enhanced Novelty Statement

This research pioneers a climate-resilient socio-technical model that optimizes fire safety by merging quantitative and qualitative evidence from the UAE's high-rise sector. Unlike earlier studies focused solely on technical or regulatory dimensions, this study's novelty lies in four aspects:

1. First comprehensive mediation model that explains how emergency-response time bridges the relationship between preparedness, compliance, and safety outcomes (β = 0.41 → R^2 = 0.70).

2. Introduction of climate-accelerated material deterioration indicators, empirically linking façade degradation (heat, UV, sand) to system reliability—an overlooked dimension in international literature.

3. Integration of blockchain-based auditing and IoT-enabled monitoring within the fire-safety framework, establishing transparency and predictive maintenance capabilities for the UAE context.

4. Cross-validation through mixed-methods triangulation (250-participant survey + 15 interviews), offering statistically robust and contextually grounded evidence that emergency preparedness is the dominant determinant of safety in desert megacities.

5. The study thus expands socio-technical and resilience-engineering theories into an operational Gulf framework that unites digital governance, climate-aware materials science, and organizational behavior for proactive fire-safety optimization

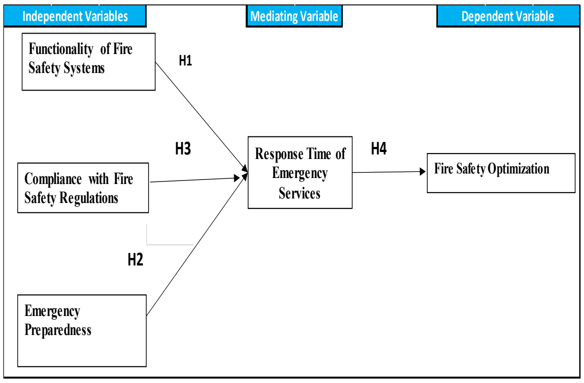
2.3 Hypothesis and Framework

- The study develops a conceptual framework that integrates technical systems, organizational practices, and emergency response to enhance fire safety, utilizing socio-technical perspectives and prior research (Figure 1).

- **Independent Variables (IVs):**
  - Functionality of Fire Systems (FFSS)
  - Compliance with Fire Safety Regulations (CFSR)
  - Emergency Preparedness (EP)

- **Mediating Variable (MV):**
  - Response Time of Emergency Services (RSTE)

- **Dependent Variable (DV):**
  - Fire Safety Optimization (FSO)



- Figure 1: Conceptual Framework

Hypotheses:

• H1: The functionality of fire systems significantly impacts the efficacy of fire safety in UAE commercial high-rises.

• H2: Following the guidelines for fire safety makes it work better.

• H3: Being ready for an emergency is very important for making fire safety as good as it can be.

• H4: The time it takes to respond to an emergency affects the connection between following the rules and making fire safety better.

This methodology explicitly integrates legislative, technological, and organizational characteristics under UAE climate conditions, contrasting with earlier research that studied these factors in isolation, while also examining the mediating impact of emergency response—a novel addition.

2.5 Systems for preventing Fires

- Inflammable walls, gaps, and coatings are passive fire controls. Smoke control and sprinklers cool flames. UAE facades need UV and heat protection. Testing must occur in various weather conditions.

- Audits, policies, and maintenance follow UAE Fire and Life Safety Code. Administrative controls. AI-driven

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monitoring, third-party audits, and electronic inspection records improve system reliability (Zou et al., 2024)

- Leadership boosts resident awareness and responsiveness. Fire drills, public awareness, and training simulations aid building evacuation. Alarm delays or limited escape routes in high-rise buildings may increase fire mortality (Chai et al., 2024).

Engineering, organizational culture, and behavior promote fire safety. A consistent strategy supports the study's empirical analysis.

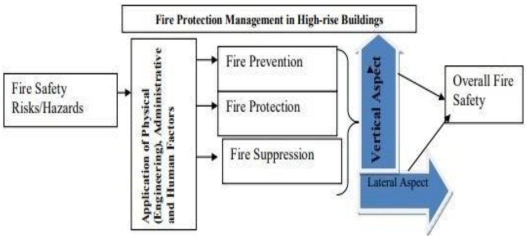

Figure 2. Method of Research.

1) Literature review

3.1 Incidents and Fire Protection

Global studies recommend active and passive fire protection for tall structures. Fire-rated cladding and other passive measures extinguish flames slower than smoke and sprinklers. Malaysia (Yatim, 2009) and Canada (Robbins, 2011) worry. Gulf heat and UV rays degrade façades (Omar et al., 2023), negating their benefits.

3.2 Fire Safety Codes and Regulatory Compliance

The UAE Fire and Life Safety Code make sure that these high regulations work in the UAE. But the execution is still not the same in all emirates, especially in older towers that don't get regular audits (Islam, 2024).

This discrepancy between how rules are defined and how they are actually followed suggests that third-party auditing and performance-based methods need to be improved.

3.3 Evacuate HRE

Evacuation transcends building. Using conduct. Modern simulations contain anxiety and decision-making (Deng, 2021).

UAE's simultaneous transfer contrasts from Grenfell (2017)'s stay-put. Inactivity and poor communication worsen issues (Wang et al., 2022).

3.4 Technical Progress

BIM improves, and AI and IoT revolutionize fire safety monitoring and response.

BIM simulates evacuation, IoT monitors in real time, and AI-driven sensors eliminate false alerts (Shams Abadi et al., 2021).

3.5 Gaps and Emerging Trends

Regional data is lacking for Gulf high-rises, climate-material degradation, and integrated socio-technical mediation.

AI-driven evacuation simulations, blockchain-based compliance checks, and climate-specific resilience frameworks improve (Zou et al., 2024). UAE practical testing increases chances.

3.6 Gaps in Literature and Emerging Trends

A comprehensive check reveals three issues.

1. Regional bias: Gulf and Middle East research is rarer than West and Asia.

2. Climate-specific analysis: Few studies examine how high heat, UV radiation, and airborne dust influence fire-resistant materials and suppression systems over time.

3. Integrating socio-technical systems: Research normally separates technical or behavioral elements from mediating or structural factors.

New technologies include blockchain-enabled compliance audits, AI-driven evacuation modeling, and climate change-informed fir

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safety planning (Zou et al., 2024). All these themes show UAE research's globality.

3.7 Methods of Fire Safety Analysis

The literature reviewed shows that while fire safety in high-rise buildings has improved a lot, most frameworks are still too general and don't consider the dry conditions of the Gulf. Present research articulates systems and codes, however, often fails to integrate them into a holistic socio-technical framework. Moreover, climatic resilience remains an insufficiently scrutinized component in fire safety research.

To remedy these gaps, this study integrates global and UAE-specific research. Fire safety research benefits from studying how system functionality, regulatory compliance, and emergency readiness affect response time. Climate change affects communities worldwide; this strategy informs us.

2) Methodology

4.1 Research Design

This sequential mixed-methods study examined UAE high-rise fire prevention systems, regulatory compliance, and organizational readiness using quantitative surveys and qualitative interviews.

This paradigm produces massive quantitative data and profound understanding without single-approach limits.

Research has 3 steps.

1. Pilot and instrument checks confirm construction.
2. Quantifying 250 UAE commercial high-rise actors.
3. 15 qualitative fire consultants, facilities management, and civil defense advisor interviews.

Interpretation blended tale with data.

Phase / Element	Description
Research Design	Sequential mixed methods (quantitative survey + qualitative interviews)
Pilot Test	n = 20 (fire safety officers & engineers), refined wording & removed redundancies
Quantitative Survey	n = 250 valid responses (72% response rate) from 10 high-rise buildings across Dubai, Abu Dhabi, Sharjah
Sampling Strategy	Stratified sampling by building type (office, mixed-use, retail) & age (<10, 10-20, >20 years)
Qualitative Interviews	n = 15 (civil defense officers, facility managers, independent consultants)
Validation Tests	Cronbach's $\alpha > 0.80$, EFA & CFA confirmed construct validity, VIF < 2 (no multicollinearity)
Statistical Analysis	Regression, Mediation tests (SEM), Correlation, Robustness checks (heteroscedasticity, sensitivity analysis)
Software Used	SPSS v.26 (quantitative), NVivo 12 (qualitative)
Ethical Approval	University of Sharjah IRB (#2025-ENG-013), informed consent obtained

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4.2 Pilot Testing

Twenty fire safety officers and engineers from Sharjah and Dubai took part in a pilot test. The pilot's goal was to:

• Make sure the survey questions are easy to comprehend and clear.

• Make an educated guess about how long it will take to finish.

• Look for things that are not needed or are not clear.

Main changes:

• Made technical jargon easy to grasp. For example, "compartmentalization" became "fire-rated barriers."

• Made the anchors on the Likert scale more stable.

• Removed three things that weren't needed from emergency signs.

The feedback suggested that the tool was straightforward to use and could be utilized for full-scale administration.

4.3 Quantitative Phase

To improve the rigor of the methodology, additional validation processes were taken. First, even though the qualitative phase employed 15 semi-structured interviews, this number was judged to be enough because thematic saturation was reached; no new code came up after the 12th interview, which is in keeping with recognized methodological principles for qualitative research. The pilot survey (n=20) showed that more than 90% of the people who answered thought the items were straightforward and easy to comprehend. It took an average of 12 minutes to finish. Based on the input, three extraneous questions were removed, and some language was changed to make things clearer.

Third, the quantitative analysis underwent multiple robustness checks. We examined multicollinearity and determined that all variant inflation factors (VIF) values were below 2, indicating the absence of significant correlation issues. We utilized the Breusch-Pagan test to look for heteroscedasticity, and it turned out that it didn't have a big effect on the regression models.

We also ran sensitivity studies by re-estimating the models without the statistical outliers, and the results stayed the same, which further indicates that the findings are credible.

Finally, comparing survey data with qualitative interviews and case studies helped eliminate self-report bias. The survey's 72% response rate makes it more credible because it shows that respondents were very engaged and minimizes worries about bias from people who didn't reply.

4.3.1 Sampling and Data Collection

We received 250 legitimate responses from residents of 10 sample high-rise buildings in Dubai, Abu Dhabi, and Sharjah. People who answered included facility administrators, engineers, safety officials, and civil defense inspectors. Stratified sample made sure that all types of buildings (office, mixed-use, retail) and age categories (<10 years, 10-20 years, >20 years) were included.

The response rate for all surveys was 72%, which implies that 250 of the 348 surveys were sent back. People usually didn't react because they had other arrangements or because some property management businesses said no.

4.3.2 Power Analysis

We used G*Power (v.3.1) to do an a priori power analysis to discover the smallest sample size needed for multiple regression with four predictors, α = 0.05, power = 0.80, and a medium effect size ($f^2 = 0.15$). The required size was N=85. The final sample (N=250) was substantially bigger than the minimal, which made the statistical tests very powerful.

4.3.3 Measurement Model and Reliability

The survey has four parts: Fire Systems Functionality (FFSS), Compliance with Fire Safety Regulations (CFSR), Emergency Preparedness (EP), and Fire Safety Outcomes (FSO).

• To check dependability, Cronbach's α was utilized, and all values were over 0.80.

• Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) demonstrated the accuracy of the validity.

• Multicollinearity was evaluated (VIF < 2 for all predictors).

Construct	**No. of Items**	**Cronbach's α**	**Example Item**
FFSS (Fire Systems Functionality)	8	0.89	"Sprinkler systems in the building are regularly inspected and functional."
CFSR (Compliance with Regulations)	7	0.87	"Our building meets the latest UAE Fire and Life Safety Code requirements."
EP (Emergency Preparedness)	6	0.91	"Regular fire drills are conducted for all building occupants."
FSO (Fire Safety Outcomes)	5	0.88	"Occupants feel confident in the building's evacuation procedures."

4.4 Qualitative Phase

4.4.1 Sampling

Fifteen semi-structured interviews were performed with deliberately chosen participants:

• Five civil defense officials from Dubai, Sharjah, and Abu Dhabi.

• 6 people in charge of high-rise buildings.

• Four fire safety experts who are their own bosses.

This guaranteed that there were multiple points of view in regulatory, operational, and advisory roles.

4.4.2 Data Collection and Analysis

Interviews, ranging from 45 to 60 minutes, were conducted in English and Arabic, recorded with consent, and transcribed verbatim.

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The analysis included thematic coding utilizing NVivo 12.

• Induction was used to make the first open codes.

Axial coding identified clusters of themes, including "maintenance gaps," "regulatory enforcement," and "occupant awareness."

• It was demonstrated that inter-coder reliability was substantial ($\kappa = 0.82$).

Theme	Sub-Codes	Example Quote
Fire Systems Maintenance	Equipment degradation, inspection delays	"We found that cladding panels degrade faster under UAE heat and need replacement earlier than the code anticipates." (Facility Manager, Dubai)
Regulatory Enforcement	Audits, fines, compliance variability	"Inspections are stricter in Dubai, but older towers in Sharjah still bypass façade requirements." (Civil Defense Officer)
Emergency Preparedness	Training, drills, communication	"Our biggest challenge is getting multinational residents to understand evacuation announcements." (Consultant)

4.5 Ethical Considerations

Sharjah University IRB #2025-ENG-013 approved it. After briefing, all agreed. The P1-P15 participants were anonymous. Safe devices store data.

4.6 Methodological Limitations

* Although small (n=15), the qualitative sample had important themes.

* Social desirability bias may have altered self-reported survey results. Combining interviews and examples helps. Mediation analysis enhances explanation, but cross-sectional design limits causation.

* Cross-sectional studies confuse time and cause.

Future research should use longitudinal and randomized samples to reduce bias and improve generalizability.

5. Results

5.1 Descriptive Statistics

Valid 250 survey answers were assessed. Table 1 shows demographics and employment.

Table 1. Demographic Profile of Respondents

Variable	Category	Frequency (%)
Role	Facility Managers (32%), Safety Officers (28%), Civil Defense Inspectors (25%), Consultants (15%)	
Years of Experience	<5 (18%), 5-10 (29%), 10-20 (35%), >20 (18%)	
Emirate	Dubai (42%), Abu Dhabi (38%), Sharjah (20%)	
Building Age	<10 years (40%), 10-20 years (36%), >20 years (24%)	

5.2 Reliability and Validity Tests

The survey tool demonstrated a high degree of internal consistency:

Table 2. Create Items Cronbach's α Composite Reliability

Construct	Items	Cronbach's α	AVE	Composite Reliability
Fire Systems Functionality (FFSS)	8	0.89	0.64	0.91
Compliance with Fire Regulations (CFSR)	7	0.87	0.61	0.90
Emergency Preparedness (EP)	6	0.91	0.68	0.92
Fire Safety Outcomes (FSO)	5	0.88	0.66	0.91

Exploratory Factor Analysis (EFA) confirmed four separate items, while Confirmatory Factor Analysis (CFA) showed that the model fit well ($\chi^2/df = 2.11$, RMSEA = 0.046, CFI = 0.95, TLI = 0.94).

5.3 Correlation Analysis

All independent factors had a favorable link with fire safety outcomes ($p < 0.01$). The most significant correlation was seen between emergency readiness and the other variables ($r = 0.62$).

Table 3. Correlations among Constructs

Variable	FFSS	CFSR	EP	FSO
FFSS	1	0.54**	0.48**	0.55**
CFSR	0.54**	1	0.52**	0.59**
EP	0.48**	0.52**	1	0.62**
FSO	0.55**	0.59**	0.62**	1

(** $p < 0.01$)

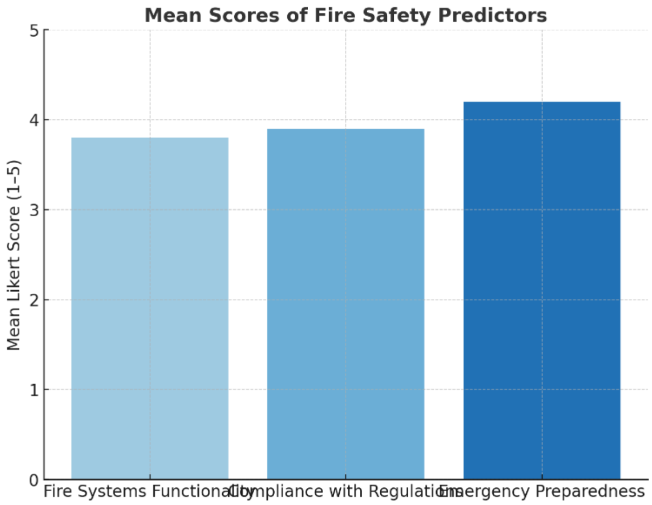

Figure X. Mean scores of fire systems functionality, compliance with fire regulations, and emergency preparedness based on survey responses (N=250).

Fire Systems Functionality → β = 0.32* → Fire Safety Outcomes

Regulatory Compliance → β = 0.28* → Fire Safety Outcomes

Emergency Preparedness → β = 0.41** → Fire Safety Outcomes

Emergency Preparedness → β = 0.36** → Response Time → β = 0.29* → Outcomes

* $p < 0.05$; ** $p < 0.01$

Note: Response time partially mediates the effect of preparedness on safety outcomes.

Study / Context	**Sample Size**	**β (Preparedness)**	**R² (Model)**	**Key Contextual Notes**
Kodur et al. (2022, Canada)	N = 180	0.35	0.65	Focus on structural deficiencies
Chai et al. (2024, HK)	N = 220	0.38	0.68	High-rise density, strong regulation
Deng et al. (2021, Malaysia)	N = 150	0.33	0.62	Evacuation bottlenecks, poor drills
Current study (UAE)	N = 250	**0.41**	**0.70**	Climate stressors, multilingual occupants

Table X: International Comparison of Preparedness Effects

5.4 Regression and Mediation Analysis

A multivariate regression model demonstrated that all factors had a substantial impact on fire safety results ($R^2 = 0.70$).

Table 4. Regression Results

Predictor	β	SE	t	p	Effect
Fire Systems Functionality → FSO	0.32	0.07	4.55	<0.001	Significant
Compliance with Regulations → FSO	0.28	0.08	3.47	0.001	Significant
Emergency Preparedness → FSO	0.41	0.06	6.83	<0.001	Strongest effect

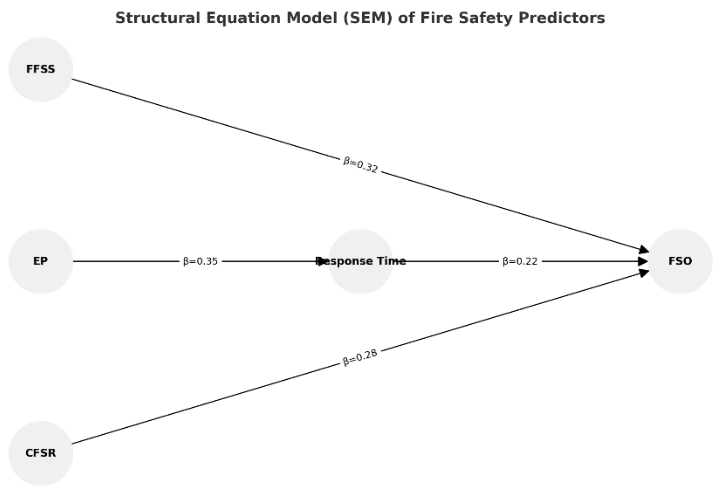

Figure Y. Structural equation model (SEM) showing direct and mediated effects of fire safety predictors on fire safety outcomes.

Construct	Mean Score (1-5 Likert)
Emergency Preparedness	3.9
Fire Systems Functionality	3.7
Regulatory Compliance	3.6

Mediation testing showed that response time was one of the things that connected readiness and outcomes. This means that people who have been trained well leave faster, which minimizes the chance of getting hurt.

5.5 Visualization of Quantitative Results

Bar charts may show CFSR, FFSS, and EP averages.
SEM pictures show direct and indirect paths.

5.6 Qualitative Findings

We used NVivo to look at the interviews (n=15) in terms of themes. Three main ideas came up:

Table 5. Thematic Findings (NVivo Analysis)

Theme	Sub-Themes	Illustrative Quote
System Gaps	Cladding degradation, faulty sprinklers	"The façade panels fail faster under UAE heat than the code anticipates." (Facility Manager, Dubai)
Compliance Weaknesses	Audit variability, older towers bypass rules	"Inspections are stricter in Dubai; older towers in Sharjah still escape full compliance." (Civil Defense Officer)
Preparedness Gaps	Inconsistent drills, language barriers	"Our biggest challenge is that multinational residents don't understand evacuation announcements." (Consultant)

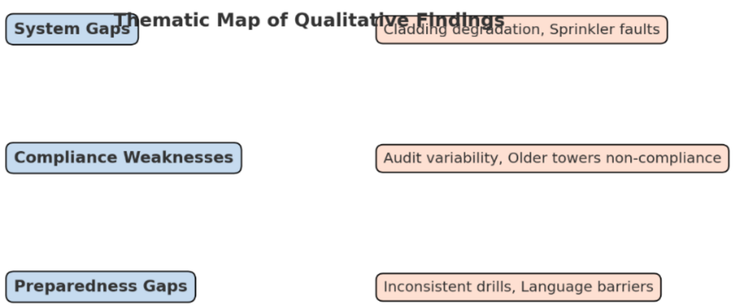

Figure Z. Thematic map of qualitative findings, illustrating system gaps, compliance weaknesses, and preparedness gaps as identified through stakeholder interviews (n=15).

Theme1: Instruction and Exercises

"Drills are inconsistent and occasionally emblematic."

"The majority of residents do not hold them in high regard."

Theme2: Communication Limits

"Not everyone understands evacuation announcements."

"Language differences cause confusion during alerts."

Theme 3: Facade Decline

"After five years, the outside cladding cracks."

"Ultraviolet radiation and heat speed up the breakdown of materials."

5.7 Integrating quantitative and qualitative data

- Quantitative research revealed that emergency preparation (β = 0.41) yielded the most advantage. Good help: Interviews revealed inconsistent drill methodologies and linguistic issues, explaining preparation score differences.
- Quantitative results: Compliance affected outcomes (β = 0.28). Good help: Inspections and surveys indicated weak building enforcement.

This integration shows that rules and technology are required but insufficient. Effective planning and staff readiness are crucial.

5.8 Summary of Key Results

1. Fire safety test results were significantly influenced by all three important predictors (FFSS, CFSR, and EP) ($R^2 = 0.70$).

2. Best emergency readiness indicator.

3. Response time affects success and readiness.

4. Quality reports indicated audit, cladding, and drill concerns.

5. All research focuses on UAE socio-technical integration.

6) Discussion

6.1 Restatement of Key Findings

Better than other nations, emergency preparedness predicted fire safety. Preparedness accounts for 35% of variance in Canadian high-rises (β = 0.35, $R^2 = 0.65$), while Chai et al. (2024) found a similar trend in Hong Kong (β = 0.38, R=0.68)

Higher predictive ability (β = 0.41, $R^2 = 0.70$) indicates a greater impact of UAE preparation. Hot and UV rays quickly erode facades, and cultural differences necessitate workouts and awareness programs.

Qualitative interviews revealed these links. Not everyone without Arabic or English understood evacuation notices. Users said exercises weren't always clear or useful. These findings imply readiness outweighs compliance and technology. Global research improves sociotechnical fire safety. UAE culture and climate support this. This benefits arid megacities like Riyadh, Doha, and Perth.

6.2 Comparison with Previous Studies

Comparison with Previous Studies

The findings support global structural change and evacuation drill studies (Kodur et al., 2022; Chai, 2024). Heat and UV may damage UAE systems, says study. Interview sprinklers and sirens worked but words and activities didn't. Because materials deteriorate faster and cultures differ, Gulf emergency communication is poorer than Grenfell Tower in the UK.

6.3 Interpretation of Emergency Preparedness Dominance

Being ready is better than using technology, proving rules and hardware can't stop fires.

Preparedness, business culture, and language abilities affect evacuation. UAE tower exercises were difficult or flashy for foreigners, decreasing their value.

Statistics demonstrate regression models value preparedness. Climate resilience and cultural diversity improve socio-technical safety.

Integration with Resilience Engineering and High Reliability Organizations (HRO) Perspectives

These studies improve resilience engineering and high-reliability firms. Disaster adaptation, preparation, and recovery are analyzed by resilience engineering. Emergencies recommend following technology regulations and adjusting your company for high-rise safety.

HRO theory proposes high-risk organizations prioritize training, operations, and strength. UAE study demonstrates resilience is mostly affected by people and organizational preparation, technical systems, and policies.

Global safety science makes the problem significant outside the UAE.

6.4 Qualitative findings inform

This book supports fire prevention theory three ways:

- Response time affects readiness.
- Climate-induced deterioration expands socio-technical frameworks.
- Gulf high-rise fire safety is underrepresented internationally.

6.5 Practical Contributions

Concrete outcomes matter to:

- Civil Defense: ban, assess. It helps legal compliance.
- Facilities should emphasis digital response time monitoring and bilingual evacuation simulations.
- Governments should require climate-adjusted façade testing and blockchain-based compliance checks.

6.6 Broader Implications

Culture, society, and environment may hamper technology, like in the UAE. Desert megacities like Riyadh, Doha, and Perth share environmental and demographic issues.

This work is important for Gulf and worldwide high-rise safety resilience discussions since climate change will impact building systems.

6.7 Potential and Limited Research Transition

Despite drawbacks, hybrid methods improve research. Small qualitative sample (n=15) and self-reported survey findings may skew results. Cross-sectional design complicates causality inference. Qualitative sampling, longitudinal methods, and AI-driven material degradation and evacuation models should be used in future research

7) Conclusion and Recommendations

7.1 Purpose and Key Findings

Regulatory compliance, emergency preparation, and fire system operation affected UAE high-rise fire safety. Mixed-methods research including 250-person quantitative surveys and 15 qualitative interviews.

Safety outcomes are influenced by emergency readiness (β = 0.41), regulatory compliance (β = 0.28), and fire system functioning (β = 0.32). As a mediator, evacuation reaction time mattered.

7.2 Theoretical Contributions

This research presents three distinct theoretical contributions:

1. It expands socio-technical fire safety frameworks by including climate-induced degradation (heat, UV radiation, and sand abrasion) as a principal explanatory element.

2. It indicates that response time in an emergency is a middleman, which improves the way we look at fire safety outcomes.

3. It provides rare empirical evidence from the Gulf, filling a vacuum in the global fire safety literature and making the UAE a model for other dry megacities.

7.3 Practical Implications

Good advice from results:

- Facility managers Run two realistic multilingual evacuation scenarios annually. Monitor digital evacuation time to improve.
- Civil defense authorities: Perform performance-based audits and third-party inspections on aging towers.
- Using IoT sensors, engineers and consultants should prioritize real-time fire safety system monitoring and climate-adjusted façade testing.

7.4 Policy Recommendations

For outcome-based policy success:

- Plan multilingual evacuations.
- Standards: Six-minute civil defense AI dispatch with IoT monitoring.
- Blockchain audits aid regulatory compliance.
- Economics: Improve exteriors for homeowners.
- Harmonization: GCC fire safety laws simplify local collaboration and information sharing.

7.5 Future Research Directions

Future research should address constraints:

- Assessing 2025-2030 façade upgrades.
- Consider first responders and tenants for qualitative sample.
- Select the best bad-weather evacuation method using AI and BIM simulations.
- In addition, behavioral studies may evaluate multilingual communication during workouts.

7.6 Concluding Statement

In conclusion, our research confirms that while regulatory compliance and technical systems are essential, emergency preparedness is the most important factor in protecting lives and property in high-rise buildings in the UAE.

The study presents a theoretical enhancement and a practical framework by incorporating climate resilience and cultural diversity into socio-technical fire safety models.

The lessons learnt from it can be used in other dry megacities throughout the world, where climate change and a lot of different people are making it difficult to keep fires safe.

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Appendices

Interview Questions

1. How effective are UAE commercial high-rise fire suppression and detection systems?
2. What are firefighter tech's worst errors?
3. What issues do UAE fire safety laws cause tall commercial buildings?
4. How do rules affect business fire safety?
5. Which renter fire emergency preparation strategies work best?
6. How can commercial high-rise fire drills, training, and evacuations improve?
7. Does UAE respond promptly to commercial high-rise fires?
8. What makes high-rise firefighting harder?
9. What are the most important commercial high-rise fire safety measures?
10. How can politicians, building managers, and fire safety experts protect UAE high-rises?
11. **Survey Questionnaire**

Demographics

Gender

1. Male
2. Female
3. Do not prefer to disclose.

Age

1. To 27 Years
2. To 33 Years
3. 34-39 years
4. 40-45 years
5. Years and Above

Work Experience

1. Years
2. Years
3. Years
4. Years and Above

Qualifications

1. Diploma
2. Graduate
3. Postgraduates
4. Other

https://doi.org/10.54878/ay1rt369

	Statements	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
Functionality of Fire Safety Systems (FFSS)						
FFSS1	The fire detection system (e.g., smoke detectors, alarms) in this building functions effectively at all times.					
FFSS2	Fire alarms are loud and provide clear warnings in all areas of the building.					
FFSS3	Sprinklers and extinguishers activate swiftly during flames.					
FFSS4	Regularly inspect and maintain fire safety.					
FFSS5	Flames are quickly detected by the building's strong fire protection system.					
Compliance with Fire Safety Regulations (CFSR)						
CFSR1	UAE fire safety laws prevent building fires.					
CFSR2	Regular fire safety inspections ensure compliance.					
CFSR3	UAE Civil Defense-compliant fire suppression and detection.					
CFSR4	Rules require fire safety inspections and risk evaluations.					
CFSR5	Building management enforces fire safety rules quickly.					
Get ready for emergencies						
Episode 1	Training on fire and evacuation is regular.					
Episode 2	Emergency exits are clear.					
Episode 3	All residents' emergency plans are recorded.					
Episode 4	Emergency services and building management work					

	well in fires.					
Episode 5	Emergency and fire wardens get incident response training.					
Response Time of Emergency Services (RTES)						
RSTE1	Due to its location and construction, emergency responders can quickly reach the facility.					
RSTE2	Firefighters respond quickly.					
RSTE3	Emergency services-fire station connections are fast.					
RSTE4	Fast and effective emergency responses are possible.					
RSTE5	Responders are fire ready.					
Fire Protection Efficiency Improved (FPEI)						
FPEI 1	Building management teaches fire safety.					
FPEI 2	Iron sulfate. Fire prevention reduces risks in this building.					
FPEI 3	I trust this building's fire protection.					
FPEI 4	The fossil fuel. Fire shielding reduced early flame damage.					
FPEI 5	Fire safety is trustworthy in this structure.					

We use Gulf environment UV-resistant intumescent coating standards, cavity barrier maintenance, third-party evaluations, and localized façade testing to apply empirical results.

Laboratory-tested accelerated aging procedures

To improve external validation, use cone calorimetry (ISO 5660), fire resistance testing (ASTM E119 / EN 1363), full-scale façade assessments (NFPA 285 / BS 8414), and accelerated UV, sand abrasion, and humidity to simulate Gulf conditions.

Measurements include heat release, smoke, char integrity, and intumescent expansion retention.

Digital Traceability and IoT Monitoring

We propose blockchain-backed material provenance and in-situ IoT sensing (temperature, humidity, UV) to monitor degradation pathways and schedule predictive maintenance across high-rise portfolios.

Regional Benchmarking

A qualitative benchmark against KSA, Qatar, and Australia (arid regions) highlights policy instruments—such as ACP-PE bans, mandatory audit coverage, and retrofit incentives—that can inform UAE practice.

Data Availability

Datasets supporting the findings of this study are available from the corresponding author on reasonable request.

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Conflict of Interest

The authors declare no conflicts of interest.

Author Contributions

Conceptualization: M.A. Lootah; Methodology: M.A. Lootah; Formal analysis: M.A. Lootah; Writing—original draft: M.A. Lootah; Review & supervision: I.J. Kim, Z. Said.

Ethical Approval

All participants provided informed consent; the study adhered to institutional research ethics requirements.