Contemporary Landscape of Fire Safety Monitoring and Control Practices in Buildings

1st Mubarak Aldossary [1,2]
[1] School of Engineering
Cardiff University
Cardiff, United Kingdom
Aldossarym1@cardiff.ac.uk
[2] College of Architecture and Planning
Imam Abdulrahman Bin Faisal University
Dammam, Saudi Arabia
Mssaldossary@iau.edu.sa

2nd Yacine Rezgui [1]
[1] School of Engineering
Cardiff University
Cardiff, United Kingdom
rezguiy@cardiff.ac.uk

3rd Ioan Petri [1]
[1] School of Engineering
Cardiff University
Cardiff, United Kingdom
petrii@cardiff.ac.uk

***Abstract*— This study explores the existing gaps, limitations, and key drivers in building fire safety, with a particular focus on identifying the underlying causes of fire incidents. Employing a qualitative research design, in-depth interviews were conducted with industry experts from diverse backgrounds, including mechanical engineering, architecture, building engineering, and fire protection, to capture a comprehensive range of perspectives. A carefully developed interview guide, informed by a rigorous literature review and expert feedback, ensured consistent yet flexible data collection. Purposive sampling was used to target professionals with specialized backgrounds in construction and fire safety; the subsequent analysis employed both deductive and inductive coding methods. The findings reveal persistent problems across three dimensions: (1) Human factors (negligence and error), (2) Technical failures (electrical systems), and (3) Organizational deficiencies (maintenance practices). Economic considerations, such as asset protection and investment, also emerged as influential drivers alongside safety imperatives. Inconsistencies in stakeholder awareness and uneven technology adoption further complicate the fire safety landscape.**

Keywords*— *Fire safety, Fire incidents, Interviews

I. Introduction

Fire safety in buildings remains a critical global concern, with building fires accounting for over one-third of all fire incidents worldwide [1]. These incidents are affected by a complex interplay of factors, including management practices, human behaviour, and technical systems, all of which shape fire risk outcomes [2]. To mitigate these risks, a combination of passive measures such as fire-resistant materials and compartmentalization, and active systems, including smoke detectors and sprinklers, are typically employed [1]. However, compliance with fire safety standards remains inconsistent across various countries and building types. For instance, a case study in Saudi Arabia revealed gaps in critical safety measures, such as inadequate means of egress and non-functional fire suppression systems, despite partial adherence to codes [3]. Similarly, in the UAE, high-rise buildings face challenges related to lack in enforcement of fire regulations, insufficient accident investigations, and occupants' unsafe behaviours, highlighting systemic vulnerabilities in fire safety frameworks [2].

The enforcement of fire safety standards is further complicated by aging infrastructure and evolving hazards. Many existing buildings struggle to meet modern safety requirements due to accountability gaps, particularly when inspections are outsourced to third parties. The Grenfell Tower tragedy in the UK, for example, stressed a devastating consequence of flawed oversight and prioritization of cost over safety [4]. While updated regulations have reduced global fire-related deaths by 65% over three decades, contemporary risks such as flammable cladding materials and overcrowded egress routes, demand more holistic strategies that integrate prevention, management, and stricter oversight [5]. These issues are competing objectives among stakeholders, limited public awareness, and insufficient regulatory coordination, which increase fire risks over a building's lifecycle [6].

Fire safety compliance remains a pressing issue, as demonstrated by fire and rescue audits from 2023–2024, which found 59,034 cases of non-compliance across various building premises in England [7]. Research on student housing facilities highlights the necessity of standardized checklists to systematically address code violations, indicating persistent procedural gaps even within regulated environments [8]. Furthermore, traditional prescriptive codes may fail to address unique vulnerabilities, requiring performance-based frameworks that balance safety with architectural preservation [9]. Technological innovations, such as ontology-driven systems for automated compliance checking, offer promising solutions by synthesizing regulatory knowledge and expert insightsto streamline safety assessment [10]. These advancements underline the potential for technology to bridge gaps in enforcement and adaptability.

Effective fire safety management (FSM) is equally vital, especially in high-rise buildings where risks are magnified. Recent studies have developed frameworks to strengthen FSM, such as structural equation models that optimize fire safety reliability by integrating variables like evacuation protocols and maintenance practices [11]. Pilot assessments in Malaysian universities further validated stakeholder-centric tools for assessing FSM effectiveness, emphasizing the role of training and accountability [12]. Emerging technologies, including digital twins which combine building information modelling (BIM), IoT sensors, and AI are revolutionizing

FSM by enabling real-time risk monitoring and predictive analytics [13]. Despite their potential, barriers such as high implementation costs and knowledge gaps hinder widespread adoption [13]. Similarly, fire risk assessment models tailored to specific contexts, like office buildings in Nigeria, demonstrate the importance of localized strategies that account for cultural and infrastructural realities [14].These studies highlight the need for adaptable, multidisciplinary approaches to fire safety in diverse building environments.

Fire safety in buildings requires urgent attention as urbanization and aging infrastructure amplify risks globally. While advancements in regulations and technology have reduced fatalities, persistent gaps in enforcement, compliance, and stakeholder coordination continue to endanger lives. Case studies from Saudi Arabia, and the UAE illustrate disparities in fire safety adherence, emphasizing the need for context-specific strategies. Innovations such as digital twins and ontology-based compliance systems offer transformative potential but require addressing financial, technical, and educational barriers. By adopting a holistic approach that integrates robust regulation, technological integration, and public awareness, stakeholders can mitigate fire risks more effectively. Future efforts must prioritize lifecycle-oriented frameworks, performance-based standards, and stronger accountability mechanisms to ensure that fire safety evolves in tandem with emerging challenges.

Therefore, this study aims to investigate the existing gaps, limitations, and primary causes of fire incidents in buildings by leveraging expert insights from diverse disciplines in the fire safety industry. It builds upon previous efforts that examined secondary sources of evidence (literature) [15]. Through a qualitative research approach, the study seeks to identify the critical drivers that influence fire safety practices, assess the impact of regulatory enforcement, and explore potential improvements in fire prevention and mitigation strategies. The findings will contribute to a more comprehensive framework for fire safety, emphasizing the integration of regulatory oversight, technological advancements, and enhanced educational initiatives to foster safer built environments. This paper is structured as follows: Section I presents the background and related literature; Section II outlines the research methodology; Section III details the key findings; Section IV discusses the results and implications.

II. Methodology

This study has utilized qualitative research approach as shown in Fig.1, to identify existing gaps, limitations, key drivers, and causes of fire incidents in buildings.

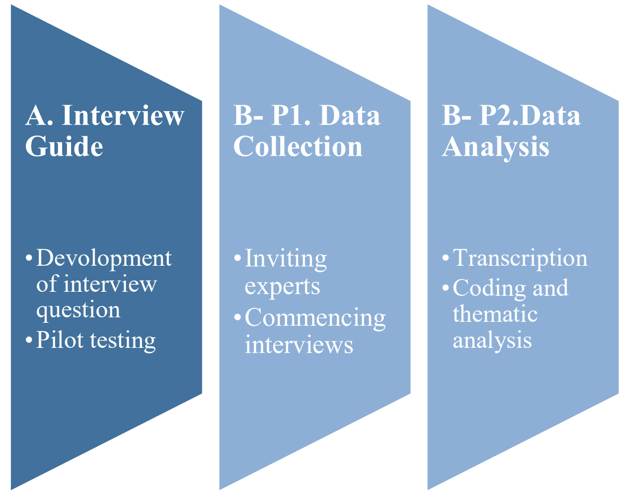

Fig. 1. *The Study Methodology*

A. Development of Interview Guide

To establish a clear picture of industry landscape, in-depth interviews with industry experts were conducted, utilizing qualitative interviews to capture their perspectives and insights on the topic [16], [17].

Interview guides are crucial tools for conducting effective qualitative research interviews. They serve as memory aids, ensuring comprehensive topic coverage and consistent questioning across various participants [18]. A well-structured guide provides rigor on the interview process while allowing flexibility [19]. The development of an effective interview guide is crucial for qualitative research, involving several key steps. These include identifying prerequisites, utilizing previous knowledge, formulating preliminary questions, pilot testing, and finalizing the guide [20]. The interview guide was formulated as an integral part of the authors' literature investigation [15]. Therefore, the guide was developed to investigate existing gaps, limitations, key drivers, and causes of fire incidents in buildings key gaps. The interview guide was initially developed from literature, then refined through several rounds of pilot testing which involved the research team and research group, and finally pilot-tested with three experts. This comprehensive process reduced the guide from 10 to 7 questions, shortened response time, and eliminated ambiguities. This also helps in improving the qualitative research quality, developing the interview questions, develop researcher skills, and identify potential issues before conducting the interview [21].

B. Data Collection and Analysis

The study targeted industry experts whom are directly involved in the building fire safety industry. The sampling process in interview-based research involves four key steps: defining the sample universe, determining sample size, selecting a sampling strategy, and sourcing participants [22]. Given the exploratory nature of the investigation and its focus on a specific group of experts, The data collection has adopted a purposive sampling which involves smaller sample sizes than quantitative research and continues until data saturation is reached [23]. A further benchmark was drawn from similar qualitative studies, which indicate that a sample size of 20 experts considered falls toward the upper end of the commonly reported range of 8 to 30 experts [24]. In order to have a comprehensive outlook over the investigation and assure competence, the following criteria were considered in the selection of participants:

- Professional background in the field of construction in particular buildings fire safety, this includes and is not limited to design, material, fabrication, installation, testing, codes, and regulations.
- Educational Background in relevant building disciplines, this includes and is not limited to Fire Protection Engineering, Civil Engineering, Architectural/Building Engineering, Mechanical Engineering, and Electrical Engineering.

Interviews were conducted using two methods: in person (face-to-face) and online via Microsoft Teams. To ensure the validity and reliability of the data, consistent procedures were followed, and well-structured, clearly formulated questions were used across both formats. Careful planning and compliance to ethical guidelines assured the collection of accurate and trustworthy data [25]. The data analysis was carried out through two major phases: transcribing the interviews and the coding. Interview transcription involves converting oral speech into written text for analysis [26]. The study has adopted both deductive and inductive approaches in analysing qualitative data, with each method offering unique insights [27].

III. Findings

A total of 20 experts have been interviewed based on the available time frame and the availability of the interviewee. Given the interdisciplinary nature of the study expertise from various engineering and architectural disciplines, was reflected in the structure of experts in this study. As depicted in Fig.2, the majority were mechanical engineers (7) forming the largest group, followed by architects (4), building engineers (3), electrical engineers (3), a civil engineer (1), a fire protection engineer (1), and a fire specialist (1).

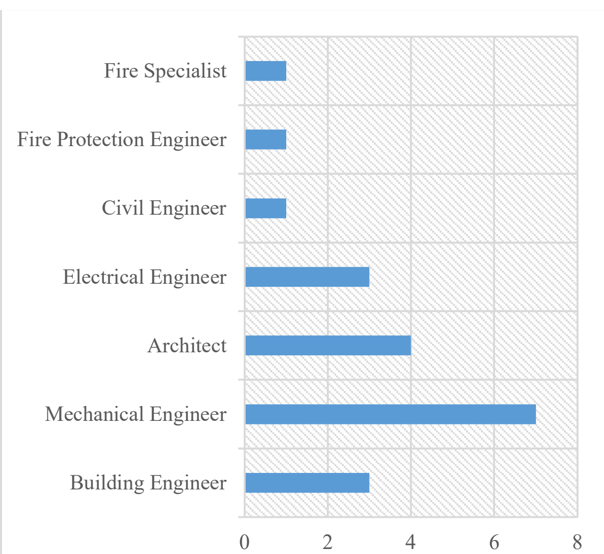

Fig. 2. *Interviewees educational background*

A In terms of professional fields shown in Fig.3, the largest group consisted of experts in technical and engineering design (5), who focus on fire safety measures in architectural and structural domains. They were followed by fire protection and prevention specialists (4), responsible for fire risks and compliance with safety regulations. Additionally, technical fire safety engineers (2) contributed expertise in designing fire suppression systems, while facility management experts (2) focused on maintaining fire safety standards within buildings. Other interviewees included one representative each from a technical committee, loss prevention, fire safety officer, fire specialist, cost and tender, project management, and electro-mechanical fields, each bringing valuable perspectives on fire risk assessment, enforcement, budgeting, and the integration of safety systems into building infrastructure.

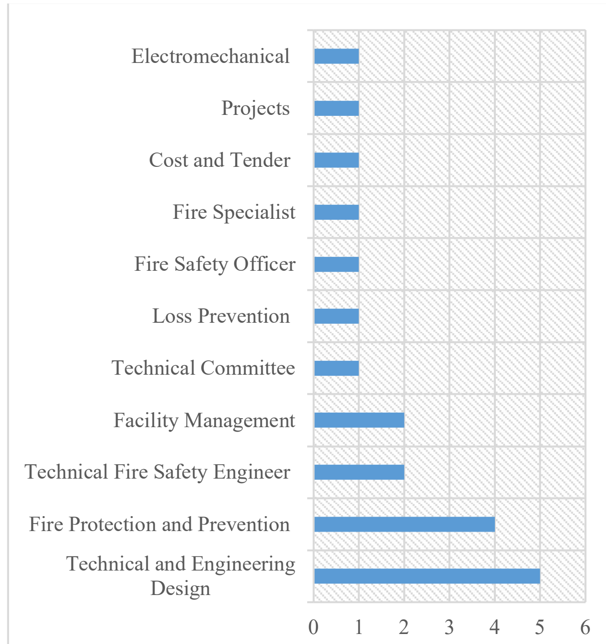

Fig. 3. *Interviewees* Professional Field of Experience

Interviewees professional years of experience, the analysis revealed that 8 experts had 6 to 11 years of experience, making this the highest group. In contrast, only 2 experts were found in both the 0 to 5 years and 17 to 21 years categories, while 5 experts possessed 12 to 16 years of experience and 3 experts had more than 21 years of experience. Fig. 4 demonstrates the distribution of the interviewee’s professional years of experience.

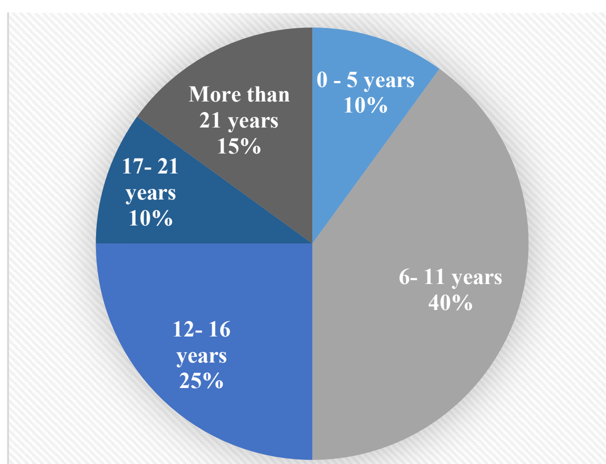

Fig. 4. Interviewees professional years of experience

The distribution of certifications among experts, as shown in Fig. 5, indicates a strong focus on fire safety, building regulations, and occupational health. National Fire Protection Association (NFPA) certification is the most common (7), emphasizing expertise in fire protection, followed by International Building Code (IBC) (3) and Occupational Safety and Health Administration (OSHA) (2) certifications, reflecting knowledge of building codes and workplace safety, respectively. Project Management Professional (PMP) certification (3) indicates project management expertise in fire safety implementation, while American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) certification (1) represents specialization in HVAC systems, particularly in smoke control.

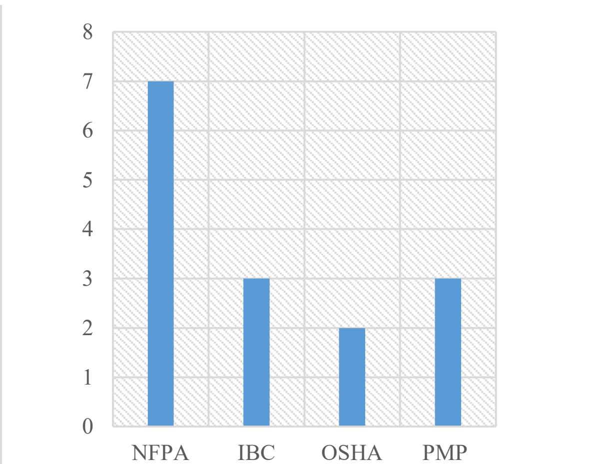

Fig. 5. *Interviewees professional certifications*

The classification of stakeholders in this study, as demonstrated in Fig. 6, shows a balanced representation of key roles in building fire safety. Owners established the largest group (5), emphasizing their critical role in decision-making and fire safety implementation. Suppliers and designers (4 each) highlight the importance of material selection and fire-safe design strategies. Consultants (3) provide specialized expertise in fire risk assessment and regulatory compliance, while general contractors and authorities (2 each) ensure the practical execution and enforcement of fire safety measures.

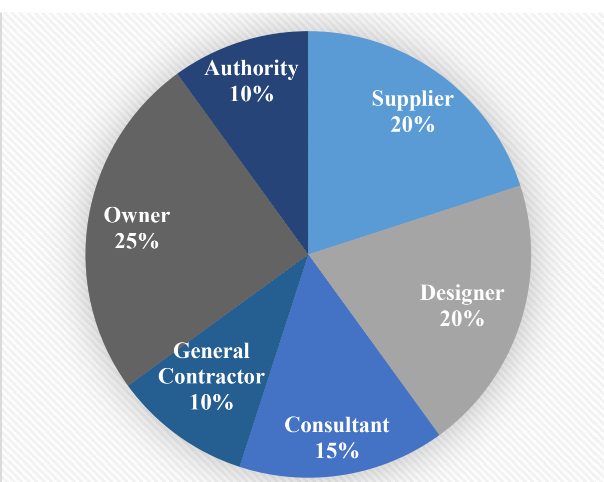

Fig. 6. *Interviewees professional classification*

A. *Fire Safety Level*

The analysis of expert interviews reveals that a significant improvements in building fire safety have been achieved due to stricter regulations and enforcement by authorities, through the mandatory compliance with standards such as the Saudi Building Code (SBC) and NFPA guidelines before construction can commence (3). This supports recent research asserting that sustained regulatory enforcement is critical for enhancing fire safety performance across all stages of a building's life cycle [28]. Government bodies, particularly the Civil Defense, play a crucial role in the approval, monitoring, and commissioning processes, ensuring that safety measures are both implemented and maintained (2). However, there is a marked inconsistency in the application of these fire safety measures; while high-priority facilities like industrial or government buildings exhibit robust compliance, residential and commercial buildings often fall short due to cost constraints and limited stakeholder awareness (2). Additionally, the effectiveness of fire safety systems frequently depends on building ownership, as some owners focus solely on meeting minimal requirements, thereby neglecting ongoing maintenance and compromising overall safety standards (2).

Challenges continue post-construction, with the deterioration of fire safety systems stemming from inadequate maintenance practices and modifications that overlook safety considerations (2). Technological advancements, such as centralized monitoring integrated with Building Management Systems (BMS), have enhanced remote and continuous oversight of fire safety measures; however, the adoption of such systems is inconsistent across different facilities (3). A recurring theme among stakeholders is the low level of fire safety awareness, which underlines the necessity for more robust educational and training initiatives to promote a deeper understanding of fire risks and the importance of sustained system maintenance (3). Despite these challenges, there are exemplary cases in high-stakes environments and signs of improvements like hospitals that demonstrated the potential for achieving high safety standards when best practices are rigorously applied (4). Table I. provides a summary of recurring themes.

TABLE I. SUMMARY OF RECURRING THEMES

No.	**Theme**	**Freq.**
1	Indicators of Excellence and Improvement	4
2	Stricter regulations and enforcement	3
3	Technological Advancements	3
4	Fire Safety Awareness	3
5	Role of Government Bodies	2
6	Inconsistency in Compliance	2
7	Ownership and Maintenance Issues	2
8	Post-Construction Challenges	2

Freq.: Frequency

B. *Key Drivers for The Continuous Monitoring and Control of Fire Safety*

The results indicate that among the various drivers examined, see Table II, Human Safety and Life Protection emerged as the most critical factor, with a frequency of 9, supporting the view that life safety is the fundamental priority in fire safety management [29]. Closely following, Asset Protection and Investment (8) and Financial Repercussions (7), highlighting the significant role that economic considerations play alongside safety imperatives.

Other drivers such as Awareness and Knowledge Dissemination, Government Oversight, and Regulatory Compliance each registered a frequency of 6, indicating a moderate yet consistent emphasis on these factors in the overall context. In contrast, Penalties and Reputation and Insurance Coverage were mentioned the least, with frequency of 3, which may imply that while these elements are relevant, they are not as compelling as the direct impacts on human safety and financial stability. Overall, the data demonstrates a hierarchy of drivers where immediate safety concerns and asset protection take precedence, supported by a balanced consideration of regulatory and oversight mechanisms, while reputational and insurance factors, though present, appear to exert a relatively lower influence.

TABLE II. KEY DRIVERS FOR THE CONTINUOUS MONITORING AND CONTROL OF FIRE SAFETY

No.	Driver	Freq.
1	Human safety and life protection	9
2	Asset protection and investment	8
3	Financial repercussions	7
4	Awareness and knowledge dissemination	6
5	Government oversight	6
6	Regulatory compliance	6
7	Penalties and reputation	3
8	Insurance coverage	3

Freq.: Frequency

C. Critical Factors Influencing Fire Incident Occurrence

The analysis of expert interviews identified multiple factors to fire incidents across various building types. These factors can be broadly categorized into three dimensions: human, technical, and organizational. This structured categorization provides a clear understanding of the interdependencies between different elements influencing fire safety outcomes.

Table III presents the critical factors, organized according to these dimensions. Within the human dimension, human error and negligence recorded the highest frequency (13), reaffirming its role as the predominant contributor to fire incidents. This finding aligns with prior research, which has identified human factors such as unsafe behaviors, as leading causes of fire outbreaks in buildings [5]. Other human-related concerns in the study included cooking activities (4), insufficient management support (2), and lack of periodic fire inspections (4). The technical dimension was led by electrical failures (11), followed by combustible and flammable materials (6), machine malfunctions (3), and inadequate installation practices (2). The organizational dimension comprised lack of maintenance (7) and non-compliance with codes and standards (3). Extreme weather conditions were identified separately as an external contributing factor (1). These findings align with previous research by Ouache et al. [30], which indicated that approximately 55% of residential fire incidents are due to human error. Overall, the results highlight the complex nature of fire causation and underline the need for comprehensive strategies that address human, technical and organizational vulnerabilities.

TABLE III. CRITICAL FACTORS INFLUENCING FIRE INCIDENT OCCURRENCE.

Dimension	Factors	Freq.
Human	Human error and negligence	13
	Cooking activities	4
	Insufficient management support	2
	Lack of periodic fire inspections	4
Technical	Electrical failures	11
	Combustible and flammable materials	6
	Machine malfunctions	3
	Inadequate installation practices	2
Organizational	Lack of maintenance	7
	Non-compliance with codes and standards	3
Other	Extreme weather conditions	1

Freq.: Frequency

IV. DISCUSSION

The study involved 20 experts, demonstrating an interdisciplinary approach that drew upon a diverse range of engineering and architectural disciplines. The majority of the experts were mechanical engineers (7), followed by architects (4), building engineers (3), and electrical engineers (3). Additional representation came from a civil engineer, a fire protection engineer, and a fire specialist. The diversity of expertise evident in this study reflects current best practices, where interdisciplinary collaboration is regarded as essential for the development of robust fire safety strategies [31]. This varied expertise underlines the study's comprehensive scope, drawing on perspectives from both design and safety-critical fields.

In terms of professional fields, the largest subgroup was those involved in technical and engineering design (5), followed by fire protection and prevention specialists (4), with additional input from technical fire safety engineers (2) and facility management experts (2). Furthermore, single representatives contributed from sectors such as technical committees, loss prevention, fire safety operations, cost and tender management, projects, and electromechanical fields. The analysis of professional experience revealed that the highest number of experts (8) had between 6 and 11 years of experience, while only 2 experts fell into both the 0–5 and 17–21 years categories. The remaining experts had 12–16 years (5) and more than 21 years (3) of experience. Certification profiles further reinforced the focus on fire safety and regulatory compliance, with NFPA certification being the most prevailing (7), followed by IBC (3), OSHA (2), PMP (3), and ASHRAE (1).

The investigation of fire safety levels reveals that significant improvements have been achieved in building fire safety through stricter regulatory and enhanced enforcement practices. Mandatory compliance with standards such as the Saudi Building Code (SBC) and NFPA guidelines has been instrumental in this progress, with government bodies playing an essential role in approval, monitoring, and commissioning processes. These findings are supported by recent studies showing that stringent code enforcement substantially improves fire safety outcomes [32]. However, the analysis also identified persistent inconsistencies, particularly in residential and commercial sectors where cost constraints and stakeholder awareness gaps contribute to weaker compliance compared to high-priority facilities such as industrial and governmental structures. However, the analysis also identified persistent inconsistencies, particularly in residential and commercial sectors where cost constraints and stakeholder awareness gaps contribute to weaker compliance compared to high-priority facilities such as industrial and governmental structures. These findings reinforce those of Medved [1], who demonstrated that budget constraints and limited recognition of long-term fire protection benefits often result in underinvestment, especially in buildings perceived as lower risk, such as standard residential and commercial properties.

Further Key drivers for maintaining effective fire safety measures were also identified. Human Safety and Life Protection received the highest frequency of 9, emphasizing its central role in fire safety decision-making. Asset Protection and Investment (8) and Financial Repercussions (7) further demonstrated the economic dimensions influencing fire risk management. Awareness and Knowledge Dissemination, Government Oversight, and Regulatory Compliance, each with a frequency of 6, highlighted the need for balanced integration of regulatory rigor and stakeholder engagement. In contrast, factors such as Penalties and Reputation and Insurance Coverage, with a frequency of 3, were perceived to have less immediate influence. This pattern is consistent with recent research emphasizing the importance of risk monitoring and prioritization of human safety in effective fire safety frameworks [33].

The study also identified critical factors contributing to fire incident occurrences, which were categorized into three dimensions: Human, Technical, and Organizational. Within the human dimension, Human Error and Negligence recorded the highest frequency (13), emphasizing the central role of behavioural factors in fire risk. In the technical dimension, Electrical Failures (11) and Combustible and Flammable Materials (6) emerged as significant contributors, alongside issues such as Machine Malfunction (3) and Inadequate Installation Practices (2). Organizational deficiencies were highlighted by the Lack of Maintenance (7) and Non-compliance with Codes and Standards (3), with additional concerns related to Insufficient Management Support (2) and Lack of Periodic Fire Inspection (4). Although Cooking Areas (4) and Extreme Weather Conditions (1) were identified as contributing factors, their lower frequencies indicate a more localized influence. These findings align with broader research that recognizes human operational deficiencies, technical system failures, and organizational weaknesses as principal drivers of fire risk [34]. They underline the complex interplay across multiple dimensions of fire safety management and highlight the necessity for integrated, multi-disciplinary strategies to address these diverse vulnerabilities effectively.

V. Conclusion and Future Work

This study has provided critical insights into the challenges, limitations, and key drivers of fire safety in buildings by leveraging expert perspectives from diverse background. The findings highlight that despite the implementation of stringent regulations and compliance with building codes, fire incidents continue to be a significant concern due to challenges across human, technical, and organizational dimensions. Human factors, such as operational error and limited stakeholder awareness, persist as major contributors. Technical failures, particularly electrical malfunctions, and organizational deficiencies, including inconsistent maintenance practices, further compound fire risks.

While regulatory frameworks such as the Saudi Building Code (SBC) and NFPA guidelines have contributed to improvements in fire safety, inconsistencies in their application remain prevalent, particularly in residential and commercial buildings. High-priority facilities, such as industrial and government buildings, demonstrate higher compliance levels, whereas cost constraints and limited stakeholder awareness hinder effective implementation in other building types.

The study further reveals that economic considerations, such as asset protection, financial repercussions, and investment, play a substantial role in shaping fire safety decisions. Owners and stakeholders often weigh fire safety expenditures against financial constraints, which can result in minimum compliance with safety standards rather than proactive investment in long-term fire prevention strategies. Additionally, inconsistencies in regulatory enforcement, coupled with inadequate fire safety awareness, contribute to lapses in fire prevention and risk mitigation. Government oversight and regulatory compliance were found to be key drivers for maintaining fire safety, but their effectiveness is limited when enforcement mechanisms lack uniformity across different sectors.

Another major finding of this study is the role of technological advancements in enhancing fire safety. While innovations such as Building Management Systems (BMS), centralized fire monitoring, and real-time safety assessment tools have demonstrated potential in improving fire prevention and mitigation efforts, their adoption remains inconsistent. Financial barriers, knowledge gaps, and a lack of technical expertise among industry stakeholders have restricted the widespread implementation of such technologies. Additionally, ongoing maintenance of fire safety systems presents a significant challenge, as many buildings fail to allocate adequate resources for sustaining fire protection measures beyond initial installation.

Addressing these challenges requires a multidisciplinary approach that strengthens regulatory oversight while promoting technological integration and public education. A comprehensive fire safety framework should not only enforce compliance across all building types but also emphasize proactive measures such as continuous monitoring, stakeholder training, and the adoption of modern fire prevention technologies. Policymakers, industry professionals, and building owners must collaborate to establish clear accountability mechanisms, ensuring that fire safety measures are effectively implemented and maintained throughout a building's lifecycle.

Future research will focus on evaluating the long-term effectiveness of fire safety interventions, identifying various methods for implementing fire prevention technologies, and exploring ways to enhance public awareness and stakeholder engagement. Additionally, studies on fire risk assessment tailored to different building environments could provide further insights into localized fire safety strategies. By adopting a holistic framework that balances regulation, technological advancement, and proactive risk management that can be significantly reduced, leading to safer built environments and improved overall fire safety.

LIMITATION

This study provides important insights into fire safety monitoring and control practices within the built environment; however, several limitations should be noted. The sample size, although sufficient for qualitative research, primarily included experts from engineering and architectural backgrounds relevant to fire safety. The geographical focus on Saudi Arabia may limit the generalizability of findings to regions with different regulatory frameworks and cultural contexts. Additionally, while the study relied on expert interviews, measures such as a structured interview guide, ethical compliance, and systematic thematic analysis were employed to enhance the credibility and trustworthiness of the findings.

MATCH & CONTRIBUTION

The study aligns with the theme of the ICE/IEEE ITMC 2025 conference by contributing to the advancement of safety and resilience practices within the built environment. By investigating fire safety practices through expert insights from engineering and architectural fields, the research supports the conference's focus on integrating technological innovation, regulatory strategies, and real-world applications. It emphasizes a strong linkage to industry by addressing practical challenges faced in implementing fire safety measures across various building sectors. The study also reflects ICE 2025's broader mission of combining engineering, technology, and innovation to drive societal progress and create sustainable, impactful solutions.

ACKNOWLEDGMENT

The authors would like to thank all participants who contributed their time, expertise, and insights into this study. Their voluntary contributions were invaluable to the development of the findings and the overall depth of the research.

APPENDEX A. INTERVIEW GUIDE

A. *Introduction and background about the participants*

- What is your educational and professional background?
- How many years of professional experience do you have?
- What group of stakeholders do you belong to? (i.e., supplier, consultant, designer, or tester … etc.) What is your current role in the field? i.e., specifier, designer, installation/contractor etc.

B. *Interview Questions*

- In your view, what is the current level of fire safety monitoring and control measures in buildings?
- What are the key drivers that motivate the continuous monitoring and controlling of building fire safety measures?
- Based on your experience, what do you believe are the major contributing factors behind fire incidents at different building type?

APPENDEX B. INTERVIEWEES REFERENCES

A. *Safety Level*

TABLE IV. SUMMARY OF RECURRING THEMES AND ASSOCIATED INTERVIEWEES' PERCEPTIONS

No.	Theme	Freq.	Interviewee
1	Stricter regulations and enforcement	3	1,12,15.
2	Role of Government Bodies	2	9, 12.
3	Inconsistency in Compliance	2	14, 13.
4	Ownership and Maintenance Issues	2	2, 19.
5	Post-Construction Challenges	2	4, 6.
6	Technological Advancements	3	3, 13, 18.
7	Fire Safety Awareness	3	2, 13, 14.
8	Indicators of Excellence and Improvement	4	10, 15, 18, 20.

Freq.: Frequency

B. *Key Drivers for The Continuous Monitoring and Control of Fire Safety*

TABLE V. KEY DRIVERS FOR THE CONTINUOUS MONITORING AND CONTROL OF FIRE SAFETY AND ASSOCIATED INTERVIEWEES' PERCEPTIONS

No.	Driver	Freq.	Interviewee
1	Awareness and knowledge dissemination	6	5, 8, 13, 17, 19, 20.
2	Penalties and reputation	3	1, 10, 11.
3	Financial repercussions	7	1, 6, 12, 13, 17, 18, 19
4	Government oversight	6	6, 8, 9, 10, 14, 15.
5	Regulatory compliance	6	3, 4, 8, 9, 14, 20.
6	Human safety and life protection	9	1, 3, 6, 7, 10, 11, 12, 18, 19.
7	Insurance coverage	3	9, 14, 20.
8	Asset protection and investment	8	3, 5, 6, 9, 12, 13, 18, 19.

Freq.: Frequency

C. Critical Factors Influencing Fire Incident Occurrence

TABLE VI. CRITICAL FACTORS INFLUENCING FIRE INCIDENT OCCURRENCE AND ASSOCIATED INTERVIEWEES' PERCEPTIONS

No.	Driver	Freq.	Interviewee
1	Combustible and Flammable Material	6	1, 4, 6, 8, 13, 18.
2	Extreme Weather Conditions	1	9
3	Human Error and Negligence	13	4, 6, 7, 9, 10, 11, 12, 13, 14, 17, 18, 19, 20.
4	Cooking Area	4	6, 9, 18, 20
5	Lack of Maintenance	7	3, 4, 12, 14, 15, 17, 20.
6	Inadequate Installation Practices	2	10, 14.
7	Lack of Periodic Fire Inspection	4	4, 5, 12, 17.
8	Insufficient Management Support	2	8, 19.
9	Machine Malfunction	3	7, 11, 14
10	Non-compliance with Code and Standards	3	5, 8, 12
11	Electrical Failure	11	1, 4, 8, 9, 10, 11, 13, 15, 17, 18, 20.

Freq.: Frequency

REFERENCES

[1] S. Medved, *Building Physics: Heat, Ventilation, Moisture, Light, Sound, Fire, and Urban Microclimate*. 2021. [Online]. Available: http://www.springer.com/series/15088

[2] M. Omar, A. Mahmoud, and S. Bin Abdul Aziz, "Critical Factors Affecting Fire Safety in High-Rise Buildings in the Emirate of Sharjah, UAE," *Fire*, vol. 6, no. 2, Feb. 2023, doi: 10.3390/fire6020068.

[3] M. B. Hamida and Mohammad A. Hassanain, "Fire safety in the built-environment: a case study in a residential facility," *Architecture, Civil Engineering, Environment,* vol. 12.2, pp. 27–34, 2019.

[4] N. Naderpajouh, Rita Peihua Zhang, and Jan Hayes, *Outsourced Enforcement: Improving the Public Accountability of Building Inspectors*. in SpringerBriefs in Applied Sciences and Technology. Cham: Springer International Publishing, 2022. doi: 10.1007/978-3-030-89792-5.

[5] *Kodur, P. Kumar, and M. M. Rafi, "Fire hazard in buildings: review, assessment and strategies for improving fire safety," PSU Research Review, vol. 4, no. 1, pp. 1–23, Apr. 2020, doi: 10.1108/PRR-12-2018-0033.*

[6] *B. J. Meacham, "Fire safety of existing residential buildings: Building regulatory* system gaps and needs," *Fire Saf J*, vol. 140, Oct. 2023, doi: 10.1016/j.firesaf.2023.103902.

[7] Fire and Rescue Services, "Fire Statistics: Fire Prevention and Protection Statistics." Accessed: Apr. 24, 2025. [Online]. Available: https://www.gov.uk/government/collections/fire-statistics

[8] M. A. Hassanain, J. A. Garkuwa, and M. O. Sanni-Anibire, "A code-compliance framework for fire safety in student housing facilities," *Facilities*, vol. 36, no. 7–8, pp. 423–436, 2018, doi: 10.1108/F-12-2016-0099.

[9] J. L. Torero, "Understanding Fire Safety of Historical Buildings," in *RILEM Bookseries*, vol. 18, Springer Netherlands, 2019, pp. 33–43. doi: 10.1007/978-3-319-99441-3_3.

I. Fitkau and T. Hartmann, "An ontology-based approach of automatic compliance checking for structural fire safety requirements," *Advanced Engineering Informatics*, vol. 59, Jan. 2024, doi: 10.1016/j.aei.2023.102314.

[10] P. S. Nugroho, Y. Latief, and W. Wibowo, "Structural Equation Modelling For Improving Fire Safety Reliability through Enhancing Fire Safety Management on High-Rise Building," *International Journal of Technology*, vol. 13, no. 4, pp. 740–750, 2022, doi: 10.14716/ijtech.v13i4.5517.

[11] Y. Ebenehi, S. Mohamed, N. Sarpin, A. Ahmodu Adaji, R. Omar, and S. Ta Wee, "Assessing the Effectiveness of Fire Safety Management from the FSM Stakeholders' Perspective: A Pilot Study," *Journal of Technology Management and Business*, vol. 6, no. 1, May 2019, doi: 10.30880/jtmb.2019.06.01.005.

[12] M. Almatared, H. Liu, O. Abudayyeh, O. Hakim, and M. Sulaiman, "Digital-Twin-Based Fire Safety Management Framework for Smart Buildings," *Buildings*, vol. 14, no. 1, Jan. 2024, doi: 10.3390/buildings14010004.

[13] M. K. Alao, Y. M. Yatim, and W. Y. W. Mahmood, "Model of Fire Safety Management for the Assessment of an Office Building in FCT Abuja Nigeria," *International Journal of Academic Research in Business and Social Sciences*, vol. 10, no. 8, Aug. 2020, doi: 10.6007/ijarbss/v10-i8/7542.

[14] M. Aldossary, Y. Rezgui, and I. Petri, "A Critical Review of Fire Safety Monitoring and Control Measures in Buildings," in *2023 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)*, IEEE, Jun. 2023, pp. 1–8. doi: 10.1109/ICE/ITMC58018.2023.10332330.

[15] G. R. Webber and S. E. Byrd, "Sloan Network Encyclopedia Entry Basic Concepts and Definitions," 2010.

[16] P. B. Rutledge and J. L. C. Hogg, "In-depth interviews," *The International Encyclopedia of Media Psychology*, pp. 1–7, 2020.

[17] E. Magnusson and J. Marecek, "Designing the interview guide," in *Doing Interview-based Qualitative Research*, Cambridge University Press, 2015, pp. 46–57.

[18] K. Gerson and S. Damaske, *The science and art of interviewing*. Oxford University Press, 2020.

[19] H. Kallio, A. M. Pietilä, M. Johnson, and M. Kangasniemi, "Systematic methodological review: developing a framework for a qualitative semi-structured interview guide," Dec. 01, 2016, *Blackwell Publishing Ltd*.

[20] M. A. A. Majid, M. Othman, S. F. Mohamad, S. A. H. Lim, and A. Yusof, "Piloting for Interviews in Qualitative Research: Operationalization and Lessons Learnt," *International Journal of Academic Research in Business and Social Sciences*, vol. 7, no. 4, May 2017.

[21] O. C. Robinson, "Sampling in Interview-Based Qualitative Research: A Theoretical and Practical Guide," *Qual Res Psychol*, vol. 11, no. 1, pp. 25–41, Jan. 2014.

[22] J. Ploeg, "Identifying the best research design to fit the question. Part 2: Qualitative designs," 1999.

[23] M. Sohail, A. O'Donovan, and P. D. O'Sullivan, "Design frameworks for ventilative cooling: Perceptions from building design practitioners in Ireland and the United Kingdom," *Build Environ*, vol. 263, Sep. 2024, doi: 10.1016/j.buildenv.2024.111860.

[24] T. Peasgood, M. Bourke, N. Devlin, D. Rowen, Y. Yang, and K. Dalziel, "Randomised comparison of online interviews versus face-to-face interviews to value health states," *Soc Sci Med*, vol. 323, Apr. 2023, doi: 10.1016/j.socscimed.2023.115818.

[25] V. Azevedo *et al.*, "Interview transcription: conceptual issues, practical guidelines, and challenges," *Revista de Enfermagem Referencia*, vol. 4, no. 14, pp. 159–168, Sep. 2017.

[26] T. Azungah, "Qualitative research: deductive and inductive approaches to data analysis," *Qualitative Research Journal*, vol. 18, no. 4, pp. 383–400, Nov. 2018.

[27] B. J. Meacham, "Fire safety of existing residential buildings: Building regulatory system gaps and needs," *Fire Saf J*, vol. 140, Oct. 2023, doi: 10.1016/j.firesaf.2023.103902.

[28] R. Van Coile, G. Jomaas, and L. Bisby, "Defining ALARP for fire safety engineering design via the Life Quality Index," *Fire Saf J*, vol. 107, pp. 1–14, Jul. 2019, doi: 10.1016/j.firesaf.2019.04.015.

[29] R. Ouache, E. Bakhtavar, G. Hu, K. Hewage, and R. Sadiq, "Evidential reasoning and machine learning-based framework for assessment and prediction of human error factors-induced fire incidents," *Journal of Building Engineering*, vol. 49, May 2022, doi: 10.1016/j.jobe.2022.104000.

[30] D. Brzezińska, P. Bryant, and A. S. Markowski, "An alternative evaluation and indicating methodology for sustainable fire safety in the process industry," *Sustainability (Switzerland)*, vol. 11, no. 17, Sep. 2019, doi: 10.3390/su11174693.

[31] B. Maiworm, M. Göldner, K. Mannl, and C. Hammann, "Evaluating 900 Potentially Harming Fires in Germany: Is the Prescriptive Building Code Effective? German Fire Departments Assessed Fire

Safety Measures in Buildings Through On-Site Inspections," *Fire Technol*, vol. 60, no. 3, pp. 2041–2065, May 2024, doi: 10.1007/s10694-024-01560-6.
[32] E. Danzi, L. Fiorentini, and L. Marmo, "FLAME: A Parametric Fire Risk Assessment Method Supporting Performance Based Approaches," *Fire Technol*, vol. 57, no. 2, pp. 721–765, Mar. 2021, doi: 10.1007/s10694-020-01014-9.
[33] Supporting Performance Based Approaches," Fire Technol, vol. 57, no. 2, pp. 721–765, Mar. 2021, doi: 10.1007/s10694-020-01014-9.
[34] S. Tan, D. Weinert, P. Joseph, and K. Moinuddin, "Sensitivity and uncertainty analyses of human and organizational risks in fire safety systems for high-rise residential buildings with probabilistic t-h-o-risk methodology," Applied Sciences (Switzerland), vol. 11, no. 6, Mar. 2021, doi: 10.3390/app11062590.