

Addressing Fire Risks in High-Rise Buildings in Dhaka, Bangladesh: Strategies for Safety and Prevention

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ABSTRACT: High-rise buildings, while equipped with modern amenities, face significant fire safety challenges due to their height, complex designs, uses and diverse materials. Fire incidents, whether accidental or intentional, can lead to devastating consequences, including loss of life, extensive property damage, and environmental impact. This study examined various fire incidents in high-rise structures and utilized Failure Mode and Effects Analysis (FMEA) to pinpoint the underlying causes. Key factors identified include electrical malfunctions, improper cooking or hot work, hazardous household chemicals, and combustible materials. The analysis also highlights systemic issues such as inadequate emergency preparedness, design flaws, and administrative shortcomings like insufficient training and poor maintenance. To reduce fire risks in high-rise buildings, it is essential to enforce the Fire Prevention and Extinguishing Act, 2003 of Bangladesh and adhere to the Bangladesh National Building Code (BNBC), 2000.

Keywords: Fire Hazard; Fire Safety and Prevention; High-rise Building; Failure Mode and Effects Analysis; Key Factors of Fire Incident

INTRODUCTION

Bangladesh has a long history of tragic fire-related accidents that have caused significant damage nationwide. As the urban economy continues to grow, these fire incidents are becoming increasingly severe. In recent years, multiple fire incidents have occurred, including the Sejan Juice Factory fire in 2021, the FR Tower fire in Banani, the Khaja Tower fire in Gulshan and Syed Grand Centre in 2023 (Fig. 1(a), 1(c) and 1(d)) and the most recently, the Green Cozy Cottage fire on Baily Road in 2024 (Fig. 1(b)) resulted in serious respiratory and burn injuries, along with significant loss of life, property damage, and environmental harm (Rita, 2024; Star Online, 2019; TBS, 2023a, 2023b, 2021). Not only commercial buildings but also residential high-rise buildings have experienced devastating fire incidents. According to data from the Fire Service and Civil Defense, there were 27,624 fire incidents reported in 2023 (FSCD, 2023). These fire disasters resulted in an estimated loss of approximately US\$66.5 million,

with 102 fatalities and 281 injuries. Statistics from the Fire Service and Civil Defense reveal that 548 fires occurred in high-rise buildings between 2020 and 2023, averaging 137 incidents annually. These fires resulted in property losses amounting to approximately US\$0.7 million, with 78 injuries and 16 fatalities reported (Fig. 2) (BBC News বাংলা, 2019; FSCD, 2023; RAJUK, 2023). These incidents demonstrate that the risk of fire in high-rise buildings is becoming increasingly dangerous and deadly over time.

According to the Fire Prevention and Extinguishing Act, 2003 of Bangladesh, a building with at least seven stories or a height exceeding 20 meters is classified as a high-rise. The Bangladesh National Building Code (BNBC) 2020 defines a high-rise as any building over 18 meters in height. Similarly, the National Fire Protection Association (NFPA) defines a high-rise building as any structure with a height of 22.86 meters or more. Dhaka City has 4,804 buildings with 4 to 6 floors and 443 buildings that exceed seven floors.

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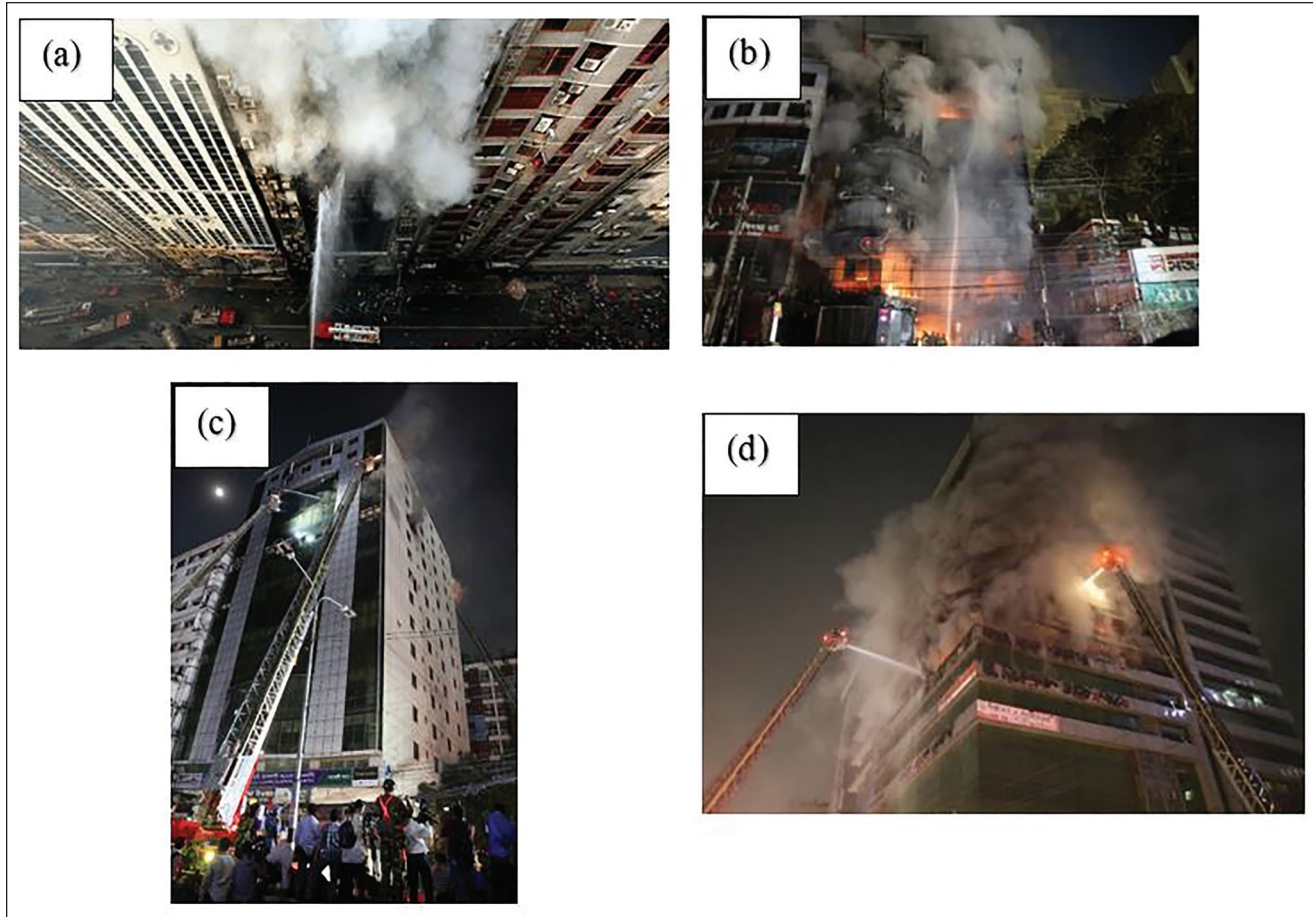


Figure 1: (a) FR Tower, (b) Green Cozy Cottage, (c) Khaja Tower, (d) Syed Grand Centre

In total, the city is home to around 4,000 high-rise buildings (Islam and Hossain, 2018; JICA, 2015). Rajdhani Unnayan Kartipakkha (RAJUK) plans to construct 20- to 30-story high-rise buildings as part of the Purbachal New Town Project, where 60,000 apartments will be developed. Such density creates an chance for fire incidents (Bispo et al., 2023) physical damage and life losses. However, despite the impact that fires may have in urban areas, research in urban fire prediction remains limited. In this study, we modelled urban fire occurrences while making a comparative analysis of different strategies to account for spatial autocorrelation. Considering space dependence in addition to a range of social-economic explanatory variables has proven to strengthen the validity of the fitted models. The spatial Durbin error model, including population density, degraded buildings density and buying power, was selected as having the best fit. This model allowed to map the estimated probability of fire occurrence across Portugal, revealing a spatial pattern with clusters centred on the two main Portuguese city districts (Lisboa and Porto. Failure to properly

implement the fire safety plan in these high-rise buildings can pose a serious risk to both life and property (Omar et al., 2023) and the Emirate is now third in the UAE in terms of the number of high-rise buildings and is home to 19% of the population. As a consequence, an increase in the rate of fire accidents has also been observed. As such, there is a need to conduct research on enhancing fire safety in high-rise buildings by conducting a literature review, in which nineteen factors affecting fire globally were identified. Because the fire characteristic is unique in every country, to identify the nature of fire in the Emirate of Sharjah, we consulted sixteen subject matter experts in the field of fire in the Emirate of Sharjah to identify the factors applicable to the Emirate. We used the failure mode, effect, and criticality analysis methodology to accomplish this goal. The outcome of the consultations resulted in the three main factor categories, which are management factors, human factors, and technical factors, and the critical factors affecting the high-rise buildings in the Emirate of Sharjah were identified, which are: fire regulations, fire enforcement regulations, accident

investigation, rescue speed, human behavior, lack of proper maintenance, fire training, building design, fire knowledge, combustible materials, fire culture of society, and urbanization. Using the Analytical

Hierarchy Process (AHP. Additionally, non-compliance with the Fire Prevention and Extinguishing Act, 2003 of Bangladesh, will complicate rescue operations and increase the danger during emergencies.

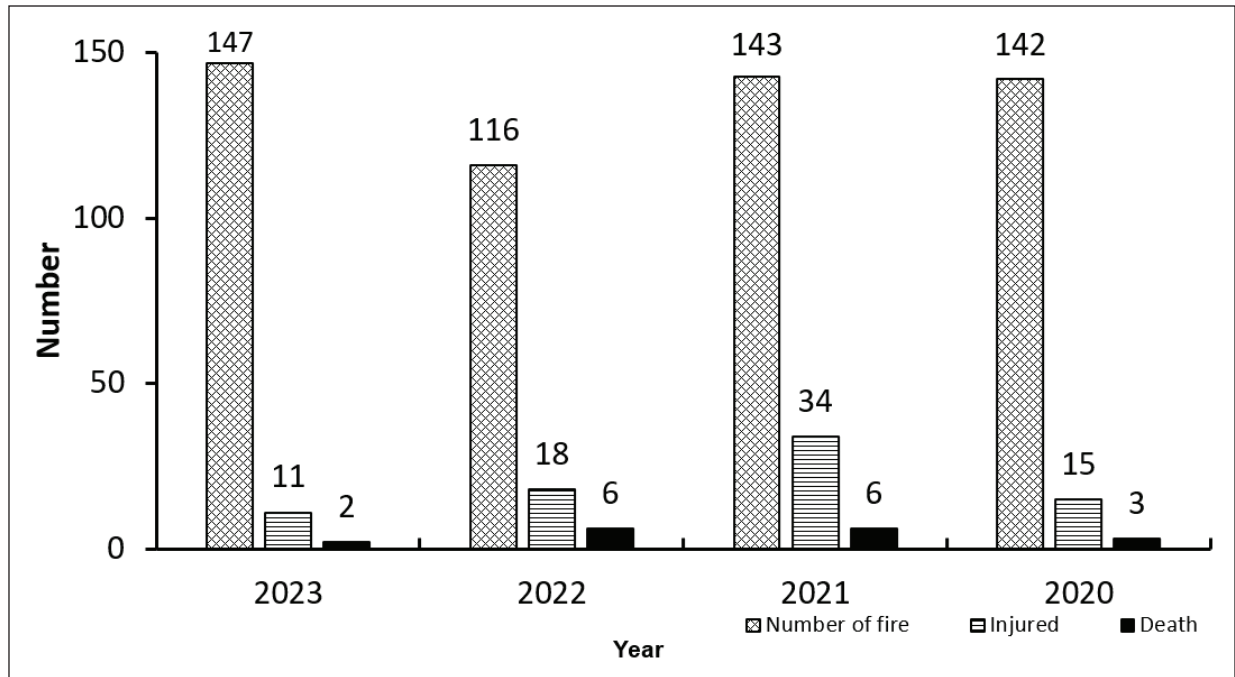


Figure 2: Images of Casualties Including Fire in a Multi-story Building (*FSCD, 2023*)

However, there is limited research on the specific causes of fire hazards in these structures, particularly within the context of Bangladesh. This is not the case outside of Bangladesh. Liao et al. (2024) studied the fire safety and fire incident reasons in single-room occupancy housing (SRO) which is targeted towards the poor and needy in Canada. Deficiencies in the structure of SRO buildings and systems, poor waste management and storage practices, unfair methods for addressing hoarding, disparities in access to information and the interplay between interpersonal and structural stigmas were found to be the main causes. There are works on the characteristics of fire in high-rise buildings as well. Fires in high-rise buildings are easy to spread and difficult to put out and the evacuation is very difficult due to the structure (Liu et al., 2012). Omar et al., 2023 applied failure mode analysis to understand the factors behind fire incidents in high-rise buildings. This study found effective fire management in urban areas involves several critical factors, including building design, fire regulations, rescue speed, fire knowledge, human behaviour, firefighting maintenance, the fire culture of society, fire training, combustible materials, fire enforcement regulations, accident investigation, and urbanization. Moreover, the education level, gender,

and living floor can also affect fire awareness and preparedness for a fire event (Vu and Lin, 2024). Bispo et al. (2023) found building density and population density are major factors for fire events in two cities in Portugal. They also concluded that the fire stations are not adequate for the region. Access to resources during a fire event can also be a source of vulnerability (Mandalapu et al., 2024). Furthermore, fire safety issues can also stem from the design itself. Cowlard et al. (2013) summarized that the outdated fire engineering of the World Trade Center (WTC) Tower, New York played a major role in its failure.

While studies on fire hazards in high-rise buildings and their underlying reasons have been conducted in other countries, as seen in the previous section, a significant knowledge gap remains in this area locally. This study addresses this gap by investigating fire prevention and safety programs, protection systems, and the human factors contributing to fire incidents in high-rise buildings. Additionally, it aims to provide a theoretical understanding of critical fire safety elements and control measures, offering practical insights and assessment steps for improving fire safety and establishing effective emergency preparedness programs.

METHODOLOGY

The authors utilized several methods to approach the problem. To begin with, the authors resorted to reviewing incident reports and newspaper articles to identify the initial problems and understand current practices. The authors have reviewed all the major national newspapers and focused on major fire events post 2020 in and around Dhaka.

With the knowledge of current practices, the authors needed more specialized information on this topic. Thus,

the authors performed a Key Informant Interview with several leading figures on fire safety issues in Bangladesh (Fig. 3). Similar approaches have been used to understand fire safety issues with satisfactory results in other studies (Owusu-Sekyere et al., 2017). The key informant analysis presents numerous benefits (Kibuacha, 2024). It grants access to expert knowledge, captures the subtleties and context of the subject, and can reveal hidden or sensitive issues that other methods might miss. The information gathered is comprehensive and detailed, providing a thorough understanding of the topic.



Figure 3: Key Informant Interview was Performed with the Fire Defense and Civil Services High Officials

The authors identified key information and then performed a failure mode analysis based on that information. The Failure Mode and Effects Analysis (FMEA) approach is widely used across various sectors to analyze and prevent the impacts of unexpected events or failures (Soltanali and Ramezani, 2023) advanced fault diagnosis and prognosis approaches are widely used for system safety and reliability assessments. As a proactive diagnosis approach, Failure Mode and Effects Analysis (FMEA). It is a systematic, proactive method used to identify potential failure modes within a system, process, design, or service and to analyze their causes and effects. The process identifies all possible failure modes in which a component or process might fail and assesses the potential impact of each failure on the system. These effects are then prioritized based on their severity, frequency, and detectability. FMEA is typically documented in a worksheet that includes columns for listing failure modes, their causes, effects, and the current controls in place. FMEA helps organizations implement corrective actions to mitigate risks, enhance product quality, and ensure safety by systematically addressing failure modes. The complexity of fire events and their required safety measures make identifying the cause challenging. Thus, FEMA is used to determine

the failure modes related to fire events. Eventually, the authors offered their recommendation for a safer city and building through rigorous brainstorming.

RESULTS AND DISCUSSION

Current Practices

Standards such as the Bangladesh National Building Code (BNBC), the Fire Act, the Fire Rule, the Energy and Utilities Act, and rules governing building construction are mandatory for compliance. Facility owners are required to follow these codes and regulations. However, incident reports reveal the reality of ill practice as many high-rise buildings fail to fully comply with these safety standards. Occupancy categories, approvals, and operational permits are often marginal or completely absent (Hassan, 2024). Most buildings do not meet the jurisdiction's fire safety requirements (Chowdhury, 2021). In 2019, 40,000 buildings were approved, but only 165 buildings had occupancy certificates (Shafiq, 2019). In addition to residential buildings, the Bangladesh Labor Act (BLA) and Labor Rule outline specific safety directives for business centers, but compliance in these sectors is similarly inadequate (Alam, 2024).

Key Informant Interview

Key informants revealed several significant points. The risk of fire in high-rise buildings in Bangladesh is increasing day by day due to the lack of original design and type of construction by building owners, use of low-quality construction materials, non-obtaining NOC of the fire safety plan, non-installation of fire safety

equipment and non-implementation of a safety plan, changing occupancy type after building construction. The risk of fire accidents is increasing in these high-rise buildings due to the lack of firefighting training of the residents. As RAJUK's certificate of occupancy does not require Fire Service and Civil Defense to accept fire safety plans, building owners are indifferent to fire safety plan implementation.

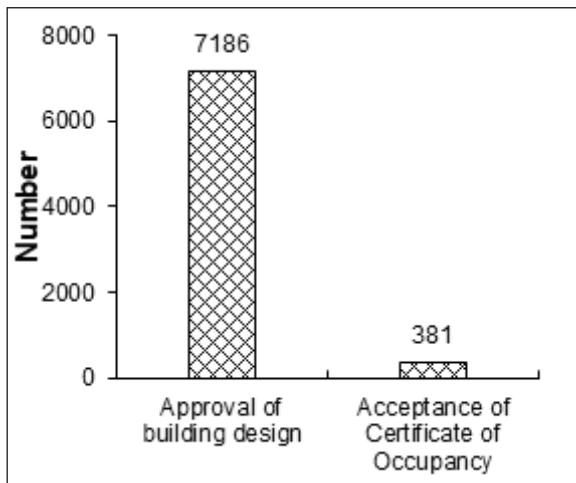


Figure 4: RAJUK Clearance and Occupancy Information for Year 2022-2023 (RAJUK, 2023)

After the fire at FR Tower in Banani in April 2019, RAJUK surveyed high-rise buildings in the area. According to the survey data, there are 1,818 high-rise buildings in the RAJUK area, 84 percent of which are constructed without design. According to RAJUK data, 7,186 building designs were approved in the financial year 2022-23, while only 381 took occupancy certificates (Fig. 4) (RAJUK, 2023). This means that even though the building has been constructed, many

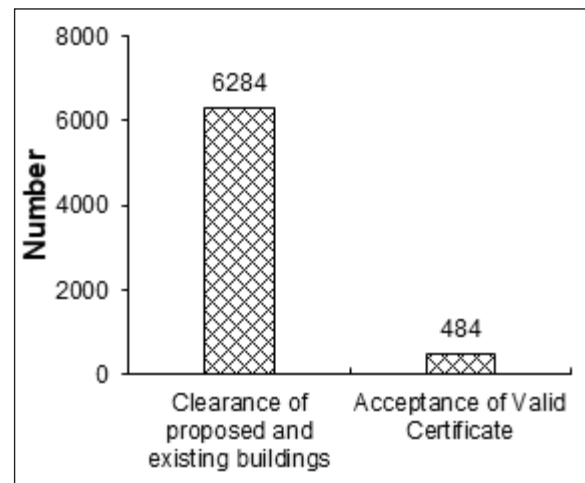


Figure 5: FSCD Clearance and Occupancy Information for Year 2022-2023 (FSCD, 2023)

people are not taking the occupancy certificate. On the other hand, according to Fire Service and Civil Defense information, 6,284 proposed and existing building permits have been issued till 2020-23, while only 484 have received valid certificates in these four years (Fig. 5) (FSCD, 2023). The increase in population (Fig. 6) is creating a demand for more residences; hence, it produces an opportunity for fast development with no regard for safety regulations.

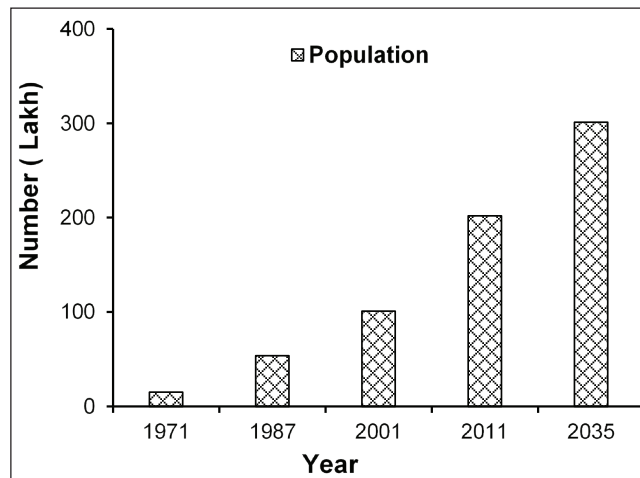


Figure 6: Population Living and the Growth of Population in Dhaka City (thousands) (World Population Review, 2025)

Failure Mode and Effects Analysis

Failure mode analysis of the fire incidents provides a multidimensional picture of these events. These events did not occur due to only one issue; instead, they

occurred due to the failure in multiple levels of safety and not adhering to safety regulations. Fig. 7 shows the failure mode diagram.

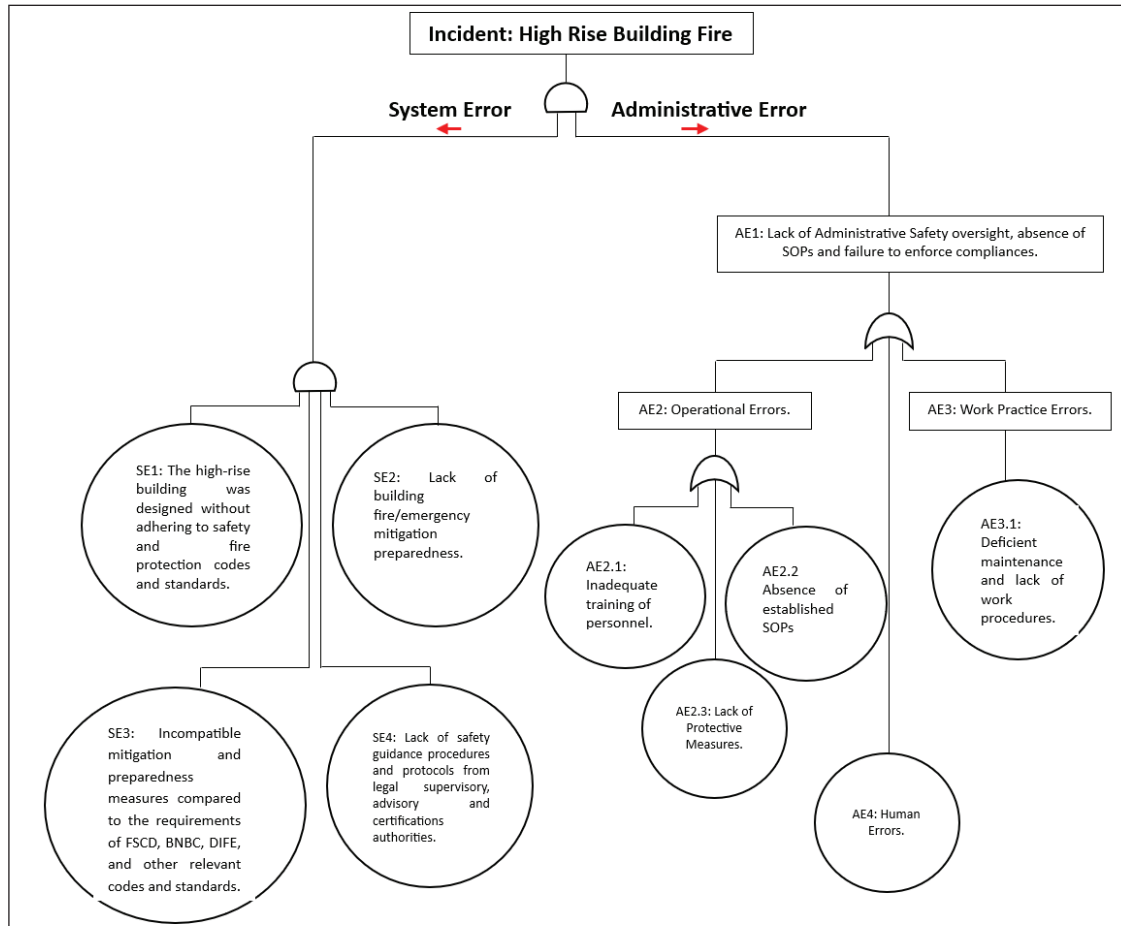


Figure 7: Failure Mode and Effects Analysis Diagram

Incident outcome: High Rise Building Fire caused decomposition of interior and exteriors, including loss of life and environmental degradation.

System Error

SE1: The High-Rise Building was designed without following safety code and fire protection standard

SE2: Lack of building fire/emergency mitigation preparedness

SE3: Incompatible mitigation and preparedness per FSCD, BNBC, DIFE

SE4: Lack of safety guidance procedure and protocols from legal supervisory, advisory, and certifications authority

Administrative Error

AE1: Lack of Administrative Safety, SOP, and Enforcement of Compliances

AE2: Operational Error

AE2.1: Lack of Training

AE2.2: Lack of SOP/ Standard Operating Procedure

AE2.3: Lack of Protective Measures

AE3: Work Practice Error

AE3.1: Lack of Maintenance and Work Procedure

AE4: Human Error

The severity of the devastating fire incident can be attributed to multiple factors, including both interior and exterior design flaws such as narrow staircases, the absence of emergency exit stairs, and unauthorized storage of materials on general stairways. Critically, the lack of passive and active fire protection systems, such as fire detection and suppression mechanisms, further exacerbated the situation. A major underlying issue was the widespread non-compliance with existing regulations, including the Bangladesh National Building Code (BNBC), Fire Act, Fire Rules, and other relevant local laws.

The facility owner's failure to ensure accountability and adhere to fire safety plans while disregarding building safety codes highlights systemic negligence. Furthermore, the lack of clearly defined enforcement responsibilities has hindered law enforcement agencies from ensuring strict compliance with safety and fire prevention measures.

Modern interior materials have also played a dangerous role. Compared to traditional decor, these materials ignite more rapidly, and the use of silicon in modern glass fittings and decorative claddings poses a serious fire hazard. Once ignited, silicon produces dense black smoke and accelerates the spread of fire by acting as a vertical channel, allowing flames to rapidly reach higher floors.

Similar results can be seen in other researches where monitoring and maintenance has played a large role as a cause of failure (El Tawil et al., 2019) boilers are considered vital and an expensive assets. In addition to initial cost, they require high maintenance budget to be available in order to secure production in safe and acceptable working conditions. This kind of assets must be well operated under experienced well-trained supervision and subjected to strict maintenance programs executed by professional skilled personnel; otherwise dramatic consequences including loss of lives may result. The literature includes much research that studied maintainability & reliability for water tube boilers, in which FMEA (failure mode and effect analysis). Underlying causes of fire hazards in other parts of the world has also been the lack of training and maintaining standards which can be seen in our analysis (Melinda et al., 2023) many efforts can be made to prevent the occurrence of these potential causes, which are the cause of the failure of the firefighting process. This study aims to implement the Failure Mode and Effect Analysis (FMEA).

RECOMMENDATIONS

At The National Level

Implementing various laws, including BNBC and Fire Prevention and Extinguishing Act-2003 ("Fire Prevention and Extinguishing Act," 2003), is the most important issue at every level, as found in the FEMA under SE1. Furthermore, key informants reveal many high-rise buildings are there in Bangladesh that do not follow the rule and there could be more that is not counted. Determining the definition of a high-rise building should be an inter-ministerial decision as this is confusing. Thus, a country-wide survey needs to be done soon to define high-rise buildings and check safety rules according to the Fire Prevention and Extinguishing Act 2003. The fire prevention system and fire safety plan should be implemented in every industrial plant, government, and private building as per the Fire Prevention and Extinguishing Act and Rules. As we have seen, unplanned and haphazard development permits the rules and regulations to remain unimplemented. Prevention of unplanned urbanization and industrialization is thus a vital issue. The high-rise buildings are often used as offices for important public-private organizations. This is why, if necessary, the offices of important public-private organizations or the entire capital should be moved elsewhere. Before issuing the certificate of occupancy from RAJUK, the fire safety plan of the fire service must be implemented, as this was seen as a major issue in our findings as stated in SE1. Conditions may be imposed to ensure that the certificate of occupancy cannot be issued without the implementation of the fire safety plan, or it should not be changed without proper institutional permission. The road in front of the building should be kept wide, and the rooftop should be kept clear. Additionally, a refuge area in high-rise buildings should be provided as per the latest Bangladesh National Building Code.

Institutional and Building Level

Implementing a fire safety plan per the Fire Prevention and Extinguishing Act 2003 ("Fire Prevention and Extinguishing Act," 2003) is the foremost requirement. Coordinating residential area associations and high-rise building associations with Fire Services and Civil Defense needs to be arranged. The FEMA AE2.1 found the lack of training is a major vulnerability. Thus, conducting fire and evacuation drills at regular intervals or at least twice a year with the assistance of the Fire Service and Civil Defense or a competent party. Comprehensive fire safety training is also vital, as it educates

occupants, building staff, and emergency responders on fire prevention, detection, and response procedures. Coordination within RAJUK, Fire Service, and City Corporation for regulation and enforcing Government Acts and Rules should also be a priority. Buildings must be equipped with multiple fire exits, emergency fire lifts, fire-rated doors, adequate fire extinguishers, correct power lines (substation), water reservoirs and width roads and open spaces in front of buildings should be according to rules and regulations. Fire exit of the building, fire door of the building, fire extinguisher of the building should be checked regularly. Leaving the rooftop (unoccupied) bare, refuge area, basement, fire elevator, power lines/substations, emergency signages (exit signs), emergency lights, proper corridor within permissible travel distance, fire detection system, and fire protection system of the building are needed as these options are reported to be mostly absent in most high-rise buildings. In FEMA, AE2.3 mentioned the lack of proper protection measures. Thus, implementing enhanced fire detection and suppression systems, such as advanced smoke detectors, sprinklers, and fire alarms, is crucial. In several reports, the building material is reported to be flammable, so utilizing fire-resistant materials and incorporating design features that facilitate evacuation and limit fire spread is essential for improved building materials and design. Regular inspections and maintenance of fire safety equipment and systems ensure proper functioning. Additionally, developing and practicing emergency evacuation plans facilitate efficient and orderly exits in case of a fire. By implementing these measures, we can significantly reduce the risk of fire accidents in high-rise buildings and protect the lives and property of occupants.

CONCLUSIONS

In summary, the rising frequency and severity of fire incidents in high-rise buildings in Bangladesh underscore the urgent need for comprehensive fire safety measures and strict adherence to existing regulations. The research reveals that unplanned urbanization and poor compliance with fire safety protocols have created a dangerous environment that threatens lives and property. However, many building owners neglect essential safety measures, exploiting legal ambiguities and failing to secure necessary clearances. The analysis also suggests that effective fire prevention strategies must be integrated into buildings' design and construction phases. Key recommendations include the strict enforcement of the Fire Prevention

and Extinguishing Act 2003, rigorous application of the Bangladesh National Building Code, and the necessity for regular fire safety audits and drills.

Additionally, raising community awareness and providing training on fire safety practices are crucial in mitigating risks. We can cultivate a stronger fire safety culture that prioritizes human life and environmental protection by fostering collaboration among government agencies, building owners, and residents. Addressing these challenges can significantly reduce the incidence of fire disasters in high-rise buildings, protecting current and future generations.

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