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Fire Risk and Structural Safety: A Study of High-Rise Buildings

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Fire Risk and Structural Safety: A Study of High-Rise Buildings

Tahmid Tamjid Turag, Md Adib Rahman, Md Sami, Md.Salman Rizvy

Abstract— **This study investigates the integration of AI-based fire safety systems, sensor technologies, and mobile notification platforms to enhance fire safety management in residential buildings. The research employs a mixed-methods approach, combining surveys to assess user awareness and willingness to adopt smart fire safety solutions, with a review of current technological implementations and challenges. Findings indicate a high level of occupant awareness and a strong willingness to adopt these technologies, suggesting a positive outlook for their implementation. However, challenges such as high initial costs, technical reliability, and integration with existing infrastructure were identified as significant barriers. The study concludes that while the adoption of smart fire safety technologies is promising, addressing these challenges through policy support, technological advancements, and public awareness campaigns is crucial for widespread implementation.**

Keyword— Fire Safety, Smart Fire Detection, AI-based Fire Systems, Mobile Evacuation Apps, Sensor Technology, Real-time Fire Monitoring, Residential Buildings, Emergency Response, Fire Safety Management, IoT in Fire Safety.

I. INTRODUCTION

Due to certain critical social and economic necessities, the number of high-rise structures has steadily expanded in all areas of the world, owing to technical advancement and scientific advances [3]. As urbanization accelerates and the demand for high-density living increases, the construction of high-rise buildings has become more prevalent. These structures, while providing necessary housing and commercial space, pose unique challenges in terms of fire safety due to their height, complexity, and the potential for rapid fire spread. Effective fire protection measures are crucial to safeguard occupants and minimize property damage.

Historically, many high-rise buildings were constructed with insufficient fire protection systems, leading to tragic outcomes during fire emergencies. The evolution of building codes and fire safety regulations has prompted the integration of advanced structural fire protection measures in newer constructions. Despite the existence of building codes such as the Bangladesh National Building Code (BNBC 2020), which outlines fire protection requirements for high-rise buildings, not all buildings meet modern safety standards [2]. However, there remains a gap in understanding the effectiveness and implementation of these systems across different generations of high-rise buildings. This study aims to address this gap by investigating the types of structural fire protection systems commonly used in high-rise buildings and comparing them between newly constructed and older buildings [5].

The research problem focuses on identifying the specific structural fire protection systems employed in high-rise buildings and assessing their effectiveness in preventing fire incidents. The objective of this study is to evaluate whether newly constructed high-rise buildings incorporate more advanced fire protection measures than their older counterparts. This leads to the hypothesis that newly constructed high-rise buildings have more advanced structural fire protection systems than older buildings.

II. METHODOLOGY

Fire safety remains a major concern in buildings across Bangladesh due to outdated infrastructure, lack of awareness, and poor enforcement of regulations. Recent major incidents have highlighted the urgency of this issue, including the fire in a Dhanmondi residential building in August 2024 that caused multiple injuries [7] and the Mohammadpur residential building fire in June 2023 which resulted in fatality [4]. These incidents demonstrate the critical need to implement smart fire safety systems, such as real-time fire detection sensors, automated alerts, and mobile evacuation apps. When combined with regular inspections and public awareness programs, these technologies can significantly enhance fire prevention and emergency response, ultimately saving lives and reducing property damage.

To understand fire safety conditions in residential buildings and explore the potential of smart fire safety technologies, especially mobile apps for real-time exit guidance and sensor-based fire detection systems, a questionnaire-based survey was conducted. A Google Form with 15 targeted questions was created and shared through social media platforms such as Facebook, WhatsApp, and Messenger. The questions aimed to gather information about current fire safety infrastructure, awareness levels, and opinions on using modern technologies like real-time fire detection sensors and mobile evacuation apps. Responses were collected from building owners, tenants, caretakers, and watchmen. Their feedback was used to generate visual data, such as charts, to help analyze the feasibility and acceptance of implementing smart fire safety solutions.

A mixed group of people took part in the survey, including building owners, tenants, caretakers, and watchmen. These participants were selected because they are directly involved with residential buildings and play important roles in managing or living in them. Each group provided different but important views—owners focus on safety setups, caretakers and watchmen handle daily maintenance and emergencies, and tenants shared their awareness and experience of fire safety. This variety helped give a complete picture of current fire safety conditions and how people feel about using smart fire safety systems. In total, 39 responses were collected, and the data was presented in the chart form to clearly show trends and insights from the survey.

III. RESULT AND DISCUSSION

A. *Analytical Result:*

This pie chart shows the key findings from a structured survey conducted among 42 respondents involved in building management or occupancy. The purpose was to assess the current state of fire safety measures and to evaluate awareness and attitudes toward modern technologies for fire prevention and response.

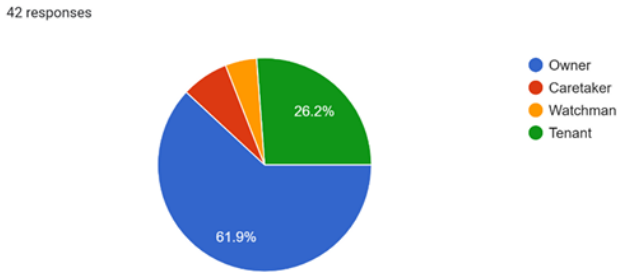

Fig 1. Respondent's relationship with the building

In here figure 1. It shows us individual people's relation with building

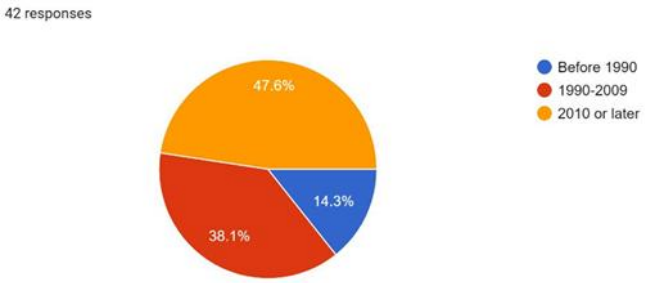

Fig 2. Year of Construction of the Building

In fig 2. It shows the time period of construction of the buildings mainly in which year the buildings have been made

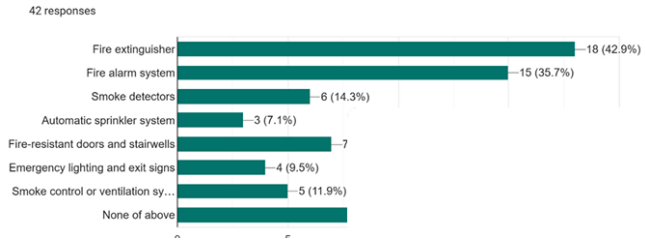

Fig 3. How many fire protection systems are installed.

In fig 3 The survey also shows how much a building is equipped with fire safety systems.

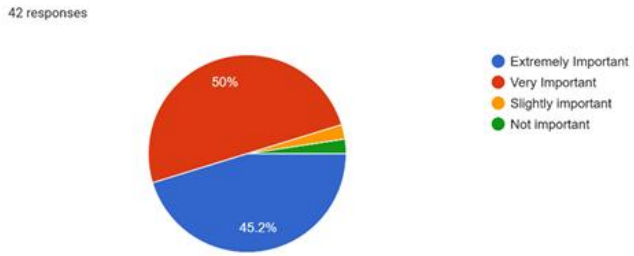

Fig 4. How important it is to use smart technologies

In fig 4 The survey shows that nowadays everyone wants a smart technology for fire safety in high rise buildings

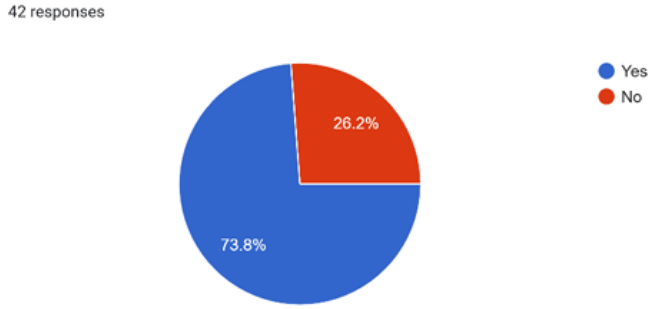

Fig 5. Evacuation plans

Fig 5 shows us that almost every person is unknown from a evacuation plan during fire emergency

B. *Discussion:*

From the data in the result section, it is clear that the implementation of smart fire safety technologies, such as mobile evacuation apps and fire detection systems using sensors, is widely supported by residents. One of the key findings is that 78.6% of respondents are in favor of a mobile app that shows real-time fire locations and exit routes, which shows strong public interest in technology-based emergency tools. In addition, over 95% of participants consider the use of smart technology in fire safety as either very or extremely important. This suggests a strong awareness of the limitations of traditional fire safety measures. A majority of respondents have also shown familiarity with evacuation plans and smart fire detection systems, which further supports the potential for adoption. If implemented, these technologies could significantly improve emergency response times and reduce casualties in high-rise or complex residential buildings.

IV. CONCLUSION

This research highlights the strong support and potential benefits of implementing smart fire safety technologies, such as mobile evacuation apps and sensor-based fire detection systems, in residential buildings. The survey results indicate high awareness and willingness among occupants to adopt these modern solutions, which can significantly improve emergency response and reduce fire-related risks. Real-world implementations of cloud-integrated AI-based fire detection

systems have already begun to show promise in enhancing building safety [1]. While these technologies are promising, challenges such as implementation costs and integration with existing infrastructure remain important considerations.

A. *Limitations:*

The implementation of smart fire safety technologies faces challenges such as high initial costs and potential technical issues. These include risks of system failure due to battery backup limitations, power outages, or users turning off Wi-Fi or mobile data, which may prevent timely notifications and reduce the system's effectiveness. Additionally, this study focused exclusively on residential buildings and did not include data from malls, factories, or industrial sites. As a result, the findings may not fully represent fire safety challenges and technological needs in commercial or industrial settings. Future research should consider these environments to develop more comprehensive fire safety solutions.

B. *Sugestions:*

To address cost-related challenges, future research and development should explore low-cost sensor alternatives, local manufacturing, and government subsidies or incentives to encourage adoption. Improving the accuracy and reliability of sensors through AI integration and machine learning can enhance fire detection while minimizing false alarms. To ensure uninterrupted functionality during power outages, integrating solar-powered backup systems can provide sustainable, off-grid energy solutions. Additionally, optimizing mobile app performance to work even under low-connectivity conditions (such as offline alerts or SMS fallback) will improve reliability during critical emergencies. Future developments in AI-driven fire safety technologies show promising potential for more cost-effective and scalable implementations. Research efforts and innovations, such as AI-based fire detection using Wi-Fi signals and particle analysis, are already underway to create affordable, efficient systems for widespread use [6].

ACKNOWLEDGEMENT

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APPENDIX

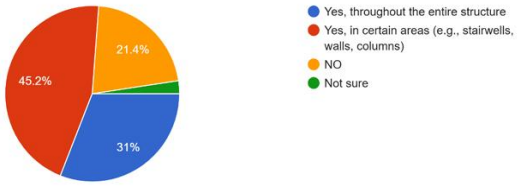

Figure 3. number of fire resistance materials use in buildings structure

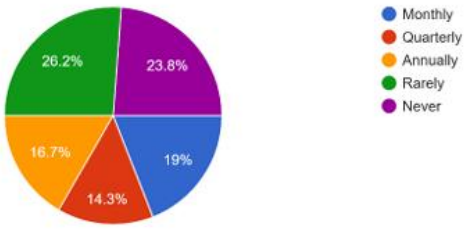

Fig 5. How many times buildings fire safety system tested

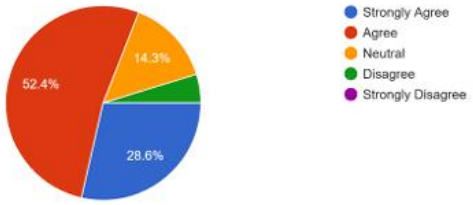

Fig 6. High rish buildings has better fire protection system

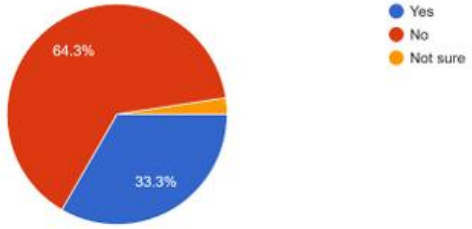

Fig 7. Conducting fir drills in buildings

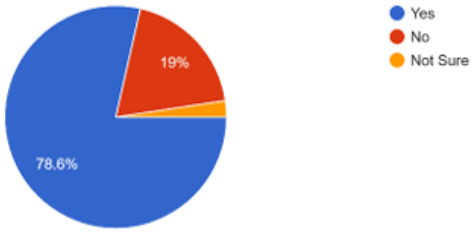

Fig 8. Implementing mobile aaps for fire emergency

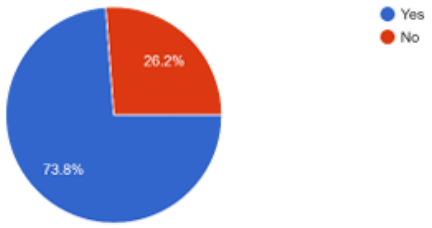

Fig 10. Evacuation plans

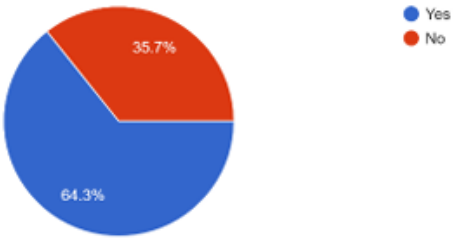

Fig 11. Upgradation of fire protection system

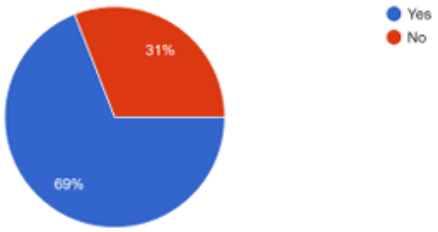

Fig 12 smart fire detection system

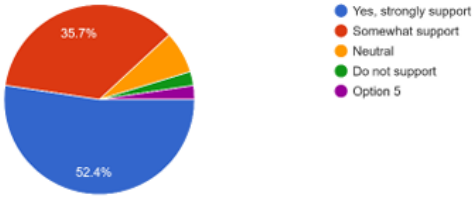

Fig 13 implementation of smart fire safety system