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Literature Review: Human Behaviour and Evacuation Fire System

Endang Suparto[1]*, Dadan Erwandi[2]
[1,2]Universitas Indonesia, Depok, DKI Jakarta, Indonesia
Email: ndangsuparto@gmail.com[1*], dadan@ui.ac.id[2]

ABSTRACT
Human behavior during fire emergencies significantly influences evacuation processes and overall safety outcomes. This literature review synthesizes findings from various research journals to explore the complexities of human behavior and evacuation dynamics in fire incidents. Key factors such as decision-making, evacuation timelines, and the impact of environmental factors on evacuation efficiency are examined. The study underscores the critical role of understanding human behavior in formulating effective fire safety strategies, particularly in residential settings where behavioral responses differ from those in public, commercial, or industrial spaces. Insights from this review emphasize the need for further research into the interplay between spatial planning, demographic factors, and infrastructure in optimizing evacuation procedures for enhanced fire safety in urban environments.
Keywords: Human Behavior, Fire, Fire Evacuation.

INTRODUCTION

During a building fire, prompt decision-making and swift evacuation are paramount for ensuring safety (Ortiz et al., 2023). Consequences arising from the propagation of fire dangers, including radiation, heat levels, harmful fumes, and indoor visibility (Feng et al., 2023)

The behavior of people during fires in public, commercial, and industrial spaces is a common concern, but residential fires receive only limited attention. The behavior and motivation of experiencing a fire in a residence directly by the fire service will be better at increasing survival rates and reducing the number and severity of injuries resulting from accidental residential fires. They will be quick to respond and investigate fire clues (but without needing to realize that the clues indicate a fire), enter the room or area where the fire is located, try to contain the fire, be forced out of the area where the fire originated, and then choose to call 999 when they realize that their own efforts are not working and further assistance is needed (Wales, David. Frank, 2013).

Fire regulations and standards generally do not clearly outline presumptions regarding human conduct, leaving the fundamental conceptual frameworks ambiguous. Nevertheless, these guidelines allude to typical fire-related human behaviors that warrant consideration and imply potential evacuation responses (Daniel J. O'Connor et al., 2019). Fire regulations and guidelines offer a set of fundamental criteria to attain a specific standard of fire protection across various structures and residences (Daniel J. O'Connor et al., 2019). Fire poses a danger within residential settings due to its intricate mechanisms involving heat, smoke, and chemical reactions. Understanding these elements aids in assessing and enhancing fire safety measures, as depicted by the familiar fire triangle, which emphasizes the necessity of oxygen, fuel, and heat for fires to ignite (Gales et al., 2017).

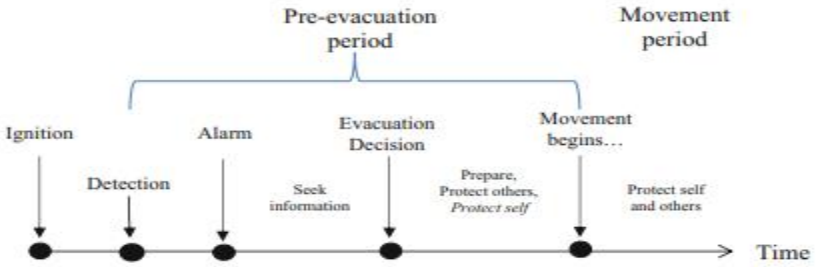

Figure 1. Building fire emergency timeline that displays an example of a building (Daniel J. O'Connor et al., 2019)

The timeline model forms the foundation for how people respond to fire evacuation systems in buildings. Typically, these timelines outline the steps individuals take when they become aware of a fire emergency, including the cognitive and social processes they undergo as they make their way to safety (Daniel J. O'Connor et al., 2019). A behavioral timeline can be used to describe actions taken during an evacuation (Ronchi, 2021). The development of the timeline is to determine whether the individual can or cannot arrive at a safe place (Daniel J. O'Connor et al., 2019). When a fire occurs, to ensure safety, the RSET (required safe exit time) must be less than the ASSET (safe exit time available)(Mu et al., 2013).

The study aims to investigate how individuals respond to fire emergencies in residential environments, exploring their decision-making processes and evacuation behaviors. By developing a behavioral timeline specific to residential fires, the study seeks to improve understanding of evacuation dynamics and potentially enhance fire safety protocols in homes.

RESEARCH METHODS

This type of research is a literature review, where the information used in this study comes for several research journals published through Science Direct, Pubmed, and Garuda. The material analyzed is human behavior in fire and evacuation at the time of fire.

RESULTS AND DISCUSSION

Table 1. Results

NO	Name of researcher and year	Heading	Research Design	Research Respondents	Research Results
1	Balboa., et al, 2023	online experiment and regression analysis of evacuation decisions in response to fire alarms	Regression logistics	1,807 respondents	Based on the results of research by investigating environmental and sociodemographic factors on evacuation decisions in 1807, respondents with the result that 79% decided to stay if they heard a fire alarm.
2	Bernardini. , et al, 2023	Can active and passive wayfinding systems support fire evacuation in building? Insight from a virtual reality-based experiment	Experiments	70 respondents	Demonstrating the dangers of passive EWS received higher ratings and support in direction selection, whereas active EWS was more effective. Employees are impressive at the pursuit of a capabilities-based approach and VR, which will enhance future work and real-world experimentation as well as VR in emergency tasks and directional systems
3	David A. Purser, 2023	Assessment of pre-warning, pre-travel and travel behavior interactions with smoke and toxic gases during fire incidents	Chi square	460 respondents	for 293 residents simultaneously entering the stairs with an evacuation of approximately 7 minutes, for stairs of 1-meter-wide stairs approximately 460 people (20 people per level as at Grenfell
4	Karemaker , 2022	Social cognitive determinants of fire safe behaviour in older adullts	questionnair e consisting of 42 questions	5766 respondents	The results indicated that the majority of participants demonstrated cautious actions regarding fire safety within their residences. Nonetheless, older individuals exhibit a lesser sense of susceptibility towards the threat of housing fires, as evidenced by their lower perception of risk and vulnerability scores.

5	Kinateder, 2014	Social influence in a virtual tunnel fire - influence of conflicting information on evacuation behavior	Experiments	40 respondents	Results show that in active conflict conditions, virtual agents move in the opposite direction to emergency exits, whereas in passive conflict conditions, virtual agents remain passive. Participants were less likely to move to emergency exits
6	Samuelsson, 2023	For the sake of safety: A time lagged study investigating the relationships betwee perceived leadership behaviors and employee safety behaviors	Cross sectional	123 respondents	The results supported a positive association between all perceived categories measured by leadership behavior and employee safety behavior.
7	Sujatmiko, 2014	Performance-based fire safety evacuation in high-rise buildings flats in Indonesia-a case study in Bandung	Case studies	33 respondents	Indicates that in order to meet life safety, the building requires an appropriate additional fire protection system
8	Tawfik, 2023	The correlation between leadership actions and various aspects of safety culture, involvement, and the overall welfare of healthcare workers.	Cross sectional	16,797 respondents	Local leadership behaviors can be measured using a 5-item scale and are strongly associated with pre-existing behaviors i.e. health care worker well-being, safety culture and engagement.
9	Elnaz Bakhshian and Beatriz Martinez-Pastor in the year 2023.	Evaluating human behaviour during a disaster evacuation process	A literature review	177 references, analysis and discussion in the research area	Meto

10	A. Camillo, E. Guillaume, T. Rogaume, A. Allard, F. Didieux, 2013	Risk analysis of fire and evacuation events in the European railway transport network	Engineering methodology (scenario design)	Fire scenarios include the initial steps of a fire to the completion of an evacuation by developing a fire risk analysis using various tools such as event trees and probability distributions	• Describe the rail transport network, sources of fire and events that may affect the spread of fire. • Estimating input parameters: relative probability and severity scale. For each event, the probability of the event and the severity are assumed to be independent of each other. • Build a matrix of relative event/severity probabilities for each train type.
11	Mu H L, Wang J H, Mao Z L, Sun J H, Lo S M, Wang Q S, 2013	Pre-evacuation human reactions in fire: An Attribution analysis considering psychological process	Literature review and investigation of representative fire cases	24 literature analyzed	During a building fire, human actions revolve around five key behaviors: staying put, attempting to put out the fire, alerting others, gathering information, and evacuating. The examination of human psychology during fires encompasses elements such as the factors shaping behavior during fires, perceptions of risk, decision-making processes, psychological variations, and cultural influences.
12	Enrico Ronchi, 2021	Developing and validating evacuation models for fire safety engineering	Developing a technique for illustrating the evacuation procedure during a fire situation.	- The evacuation model development process - Modeling human behavior using a time line	In the evacuation simulation, how people respond to evacuations repeatedly affects their decisions, which could influence future evacuation choices. The level of detail in representing human behavior in evacuation models depends on their specific use cases.
13	Margrethe Kobes, Ira Helsloot, Bauke de Vries, Jos	Building Safety and Human Behaviour in fire	A literature review	Individuals behave in case of fire and fire evacuation	Human behavior when facing fires is very important for the provision of appropriate policy measures for safe evacuation. Factors that determine fire response performance include

	G. Post, 2010				perpormance response performance, hazard factors: fire, human factors and environmental factors: buildings and understanding of psychonomics related to fire safety,
14	David Wales and Owain Frank Thompson	Human behaviour in fire: Should the fire service stop telling and start listening	Qualitative pilot studies	10 interviews	Shows a strong desire among respondents to deal with fires. The paper highlights a number of risk factors and also finds that the decision to call the fire service is often secondary to other goals and concerns, including issues related to shame and guilt.
15	Michael Gerges Mohamma d mayouf Peter Rumley David Moore, 2017	Human-behaviour under fire situations in high-rise residential building	Quantitative and qualitative methods	57% of respondents were men and 43% women	Regarding respondents' knowledge and experience of fire, it was found that 42% had previous experience (1-2 years ago) in fire situations and 7% had similar but much longer experience (5 years or more). It should be noted that 34% of respondents had no direct knowledge or experience related to fire incidents. that 91% of respondents were permanent residents of buildings, either living in apartments as part of a family or living alone. Most respondents stated that they had lived in the building for more than a year. The remaining 9% stated that they were visiting family or friends, indicating that 84% had never received fire training before
16	Hristos Karahalios, 2017	Effect of human behaviour in shipboard firefighting decisions: The case of fire in engine rooms	Conduct a risk analysis based on accident reports	Behavioral analysis for a ship captain	The enhancement of risk evaluation methods could lead to a more thorough examination of fire risks aboard ships. The initial phase of the research involved an analysis of 77 reported fire incidents documented by the IMO, aiming

					to gauge the probability of such occurrences within a ship's engine room. The examination of fire occurrences categorized by vessel age and size revealed that the risk of fire is prevalent across various vessel types. Notably, RO-RO cargo ships, containers, and passenger vessels are particularly susceptible to fire hazards. Additionally, ships aged 15 years or older demonstrate heightened vulnerability to such risks.
17	Erica Kuligowski, 2016	Integrating new perspectives from the social sciences into human behaviour in fire research	Qualitative research	Integrate social science concepts into research design by collaborating with social scientists on research projects relevant to the research design	In relevant social science disciplines it can provide additional insight into specific projects such as the field of human behavior in fire benefiting each time new theories are introduced. HBiF involves the range and depth of knowledge provided by a social science perspective.
18	Milad Haghani, Ruggiero Lovreglio, Mary Langridge Button, Enrico Ronchi, dan Erica Kuligowski pada tahun 2023.	Human behaviour in fire: Knowledge foundation and temporal evolution	Study literature: Examined 1900 papers and identified 6600 references	Identified 20 clusters, each reflecting a significant aspect of human behavior in fires	Contribute to a holistic understanding of HBiF. Identify items based on metrics where frequency, local explosion and centrality.
19	Yi Wang, Miltos Kyriakidis, Vinh N. Dang, 2021	Incorporating human factors in emergency evacuation-An overview of behavioural	Research conducted on pedestrian evacuation and vehicle evacuation	Offer a summary of empirical understanding and modeling in the realm of evacuation research	A timeline for evacuations that considers the viewpoints of both those being evacuated and the coordinators, backed by real-world data from different evacuation scenarios. Insights into agreement on how people

		factors and models	through empirical methods		behave, as depicted in studies on evacuations.
20	Rui Feng Cao, Eric Wai Ming Lee, Wei Xie, Dong Li Gao, Qian Chen, Anthony Chun Yin Yuen, Guan Heng Yeoh, Richard-Kwok-Kit Yuen, 2023	Development of an agent-based indoor evacuation model for local fire risks analysis	A quantitative approach to evaluate local fire risk and refugee stress levels according to evacuation pathways	The integrated evacuation model of fire was developed through the dynamics of evacuees in indoor fire scenarios on a microscopic scale	Evacuation performance varies significantly depending on the severity of fire hazard conditions faced by evacuees, emphasizing the importance of minimizing pre-evacuation time in a fire evacuation emergency
21	Axel Mossberg, Daniel Nilsson, Håkan Frantzich, 2022	Assessing the effectiveness of novel evacuation systems in underground settings through a situational awareness perspective: Investigating the integration of evacuation elevators.	Case study on underground metro with evacuation elevator	Identify several important measures that accommodate information needs such as audible alerts containing information under the elevator can be used for evacuation and systems in the elevator lobby that indicate that the elevator is operating	Developing evacuation design, behavioral analysis in the first step of the proposed strategy can be used to identify what information should be conveyed inside a building, and how. However, analysis can also be used to assess where key behavioral uncertainties may occur in evacuation design, and thus used to identify important aspects that should be included in sensitivity analysis
22	Qi Lu Tan, Mingyuan Hu, Hui Lin, 2014	Creating a simulation of building evacuation that merges human actions with anticipated spatial access during a fire crisis.	Simulation model with three fire scenarios	Agent-based building evacuation model in which evacuees' knowledge, including spatial knowledge of the environment	Using the proposed model, a series of evacuation simulations have been conducted for refugee groups with different levels of knowledge during three specific fire scenarios. The simulation results suggest that the proposed model can evaluate the potential effect of spatial changes on evacuation

	remains during normal situations and event knowledge of predictable spatial changes for firefighting purposes	efficiency, which depends on the knowledge level of evacuees and the location of fire safety facilities. Although it is a prototype at this stage, the model will facilitate more realistic evacuation simulations in fire emergency scenarios and will support building evacuation management.

Discussion

Human behavior at the time of fire

In the event of a fire, human actions typically encompass five key elements: remaining still, putting out the flames, alerting others, gathering additional details, and evacuating the area (Mu et al., 2013). Analysis of human behavior preceding evacuation during a fire involves understanding psychological aspects such as risk perception and decision-making, alongside factors like psychological deviation and cultural context (Mu et al., 2013).

According to (Gerges, Michael. Mayouf, Mohammad. Rumley, Peter. Moore, 2017), Regarding respondents' knowledge and experience of fire, it was found that 42% had previous experience (1-2 years ago) in fire situations and 7% had similar but much longer experience (5 years or more) while 34% of respondents had no direct knowledge or experience related to fire

By (Daniel J. O'Connor et al., 2019) Gender serves as a significant factor in determining responses to fire, with women demonstrating a higher tendency to issue warnings, alert others, and evacuate. Cultural influences are presumed to shape social connections, roles, and duties, potentially impacting behaviors during emergencies. Age-related disparities in evacuation capabilities are foreseeable and necessitate consideration, particularly given the aging demographic trend and its implications for evacuation planning. It is crucial to categorize anticipated performance variations into sensory, decision-making, and physical action domains, encompassing factors like mobility and reaction time. These aspects are likely to impact all stages of evacuation, from initial awareness to movement within the structure and decision-making en route. Furthermore, age is likely to affect walking speed and resilience to fire-related hazards, with the very young and elderly individuals in poor health being particularly vulnerable to smoke and heat-induced impairments (Daniel J. O'Connor et al., 2019)

Based on research conducted (Karemaker et al., 2022), The first shows that the average respondent reported safe behavior towards fires while at home. The action specifically does not connect the extension sockets to each other and cleans the filter dryer fibers. Secondly, the research indicated a robust affirmative relationship between the perception of controlling

behavior, attitude, and efficacy of response. Additional determinants within social cognition, like norms, obstacles, and perceptions of risk, demonstrated moderate associations with intent, while severity and vulnerability displayed weaker correlations. Linear regression analysis highlighted that perceived control over behavior, attitudes, and normative efficacy significantly aid in forecasting general intentions toward fire safety.

Based on research conducted (Ortiz et al., 2023), Of the 1,807 respondents between the ages of 18 and 76 who participated in the experiment, a mean of 47.88 and a standard deviation of 16.13 were obtained. The target population consisted of individuals representing Spanish residents according to gender and age who noted that they were not yet familiar with building alarm signals. Safety in the occurrence of fires depends on the effectiveness of choosing the right evacuation route (Bernardini et al., 2023). Therefore, a study that aimed to compare the efficiency of early warning systems involving more than 70 respondents showed the dangers of passive EWS received higher ratings and support in direction selection, while active EWS was more effective.

Based on research conducted (Kinateder et al., 2014), vacating the smoke-filled tunnel requires quick decision-making and action from the tunnel occupants. Technical systems like emergency signs in tunnels are designed to direct people to the closest emergency exit. However, when other tunnel occupants behave differently, it can lead to conflicting information. In a study involving forty participants exposed to smoke-filled virtual reality tunnels, various forms of social influence were observed. In the control scenario, participants were alone in the tunnel, while in experimental scenarios, another individual was present. In scenarios without conflict, the accompanying individuals moved towards the emergency exit. However, in situations with active conflict, they moved away from it, and in passive conflict situations, they remained inactive. Participants were less inclined to head towards emergency exits in conflict situations compared to non-conflict ones. Notably, in passive conflict scenarios, participants exhibited delayed movement timings compared to other conditions and covered the longest distance.

According to (Samuelsson et al., 2023) Perceptions of planning behavior, safety commitment, safety-specific positive feedback, and leadership active listening behavior will be positively associated with employee compliance, participation, and safety voice behaviors. Positive relationships were found for all cross-sectional hypotheses: the degree to which employees feel that their managers engage in planning behavior, safety commitments, safety-specific positive feedback, and active listening behaviors. Positively related to the extent to which employees engage in safety compliance behaviors, participation, and sound behavior.

Based on research (Tawfik et al., 2023) It was discovered that favorable evaluations of leadership conduct correlated significantly with reduced emotional exhaustion, improved safety and cooperative environments, decreased perception of workload, and decreased inclination to quit employment.

By (Karahalios, 2017), Risk assessment is to improve firefighting plans, mathematically risk resulting from likelihood and severity. Therefore, steps are needed to conduct a risk analysis of existing accident reports to determine the likelihood of a fire, assess the severity of each incident based on behavioral analysis, calculate the total risk

According to (Yasemin et al., 2009) Social psychology (i.e. environmental and social) and sociology (i.e. environmental) can improve human behavior in fires which provides human behavioral benefits throughout the timeline of fire events. Currently, human behavior in fires primarily focuses on the disaster phase or response to building fires, but that focus misses significant periods of time occurring both before and after a fire event

Based on analysis (Haghani et al., 2023) Human behavior in Wildfire requires further exploration, namely with rapid urbanization, the complexity of fire evacuation which must investigate the influence of spatial planning, knowledge and experience of the community and elements of transportation infrastructure on evacuation efficiency; deeper exploration of cultural, socioeconomic norms and the needs of vulnerable populations influencing evacuation behavior; harnessing the potential of emerging technologies and approaches such as machines, monitoring systems (sensors); decision-makers during fire emergencies.

Fire evacuation system

The structure's surroundings and how people respond during evacuations significantly impact how smoothly evacuations proceed. The effectiveness of evacuations can be affected by alterations in the building layout, contingent upon the evacuees' familiarity with the surroundings and the accessibility of fire safety resources. (Tan et al., 2014)

The effectiveness of evacuations differs greatly based on the level of danger posed by a fire, highlighting the crucial need to reduce the time taken for pre-evacuation in fire emergencies (Feng et al., 2023).

An understanding of how individuals behave in the case of fire and fire evacuation is essential if we align fire safety measures with the needs of occupants during the incident (Kobes et al., 2010). The most crucial aspect of a building's safety in the face of fire is the possibility of safe evacuation (Kobes et al., 2010). Evacuation models in fire safety engineering operate on a performance basis, just as pedestrian movement models are crafted to explore crowd dynamics, and traffic models are tailored for optimizing traffic flow (Ronchi, 2021).

Fire safety measures in skyscrapers necessitate unobstructed staircases for safe evacuation, corridors outfitted with fire extinguishers, and elevators tailored to facilitate evacuation. Regular inspections of fire safety apparatus within buildings are imperative (smoke detectors and sprinklers) (Gerges, Michael. Mayouf, Mohammad. Rumley, Peter. Moore, 2017)

Based on research conducted (Sujatmiko et al., 2014) at 33 respondents and compared them with results from computer simulation models comparing ASET (available safe evacuation time) and RSET (required safe evacuation time) showing that to meet life safety, buildings need

appropriate fire protection systems. The evacuation speed during the experiment is in accordance with the simulation prediction. If the occupants are walking normally, the evacuation time can be considered because it includes the health condition of the occupants. Additional fire protection, such as sprinklers, detection and alarm systems, and fire load regulation, must be installed.

According to (Camillo et al., 2013) Every occurrence is shaped by circumstances that existed prior and by preceding events. The sequence of events impacting the progression of the fire unfolds as follows:

1. Source of combustion: This represents many sources of fire inside the vehicle.
2. Fire detection/Alarm: An automatic or manual alarm is activated when a fire occurs.
3. Ventilation system: The ventilation system can be stopped when detection is activated
4. Fire containment and suppression: methods to reduce the spread of fires or control fires.
5. Strategy for halting transportation: Upon activation of detection, the driver or control center is tasked with determining the location for halting transport to ensure the safe evacuation of passengers. In the event of an outdoor fire, transport may cease immediately, whereas within a tunnel, it may be necessary to continue transport to guide passengers to the designated evacuation point.
6. Evacuation plan: Once the detection system is triggered and fires are contained, passengers, aided by staff, will determine life-saving actions tailored to the layout of the transport. Certain transports offer designated safe areas, like neighboring vehicles, providing a temporary refuge from fire until reaching the ultimate safety destination.

Alternative approaches can include building lifetime simulations that put fire evacuation safety in the bigger picture, making it possible to consider the implications of real fire threats and false alarms on evacuation decision-making (Ronchi, 2021).

Evacuation time is affected mainly by walking time and to a lesser extent by pre-movement time. The average total evacuation time was found to be 539 seconds in the case of unobtrusive smoke and 695 seconds in the presence of disturbing smoke, compared to a value of 524 seconds found in the absence of smoke. The presence of smoke affects the evacuation process by reducing walking speed, especially with annoying fumes. Average walking speed is estimated to be reduced from 1.1 m/s smokeless to 1.0 m/s with unobtrusive smoke, to 0.7 m/s in the presence of disturbing smoke. The presence of an emergency ventilation system is able to control the development of smoke during a fire partially. (Caliendo et al., 2012)

Factors that determine fire response performance are fire, human, and building characteristics. Knowledge of human behavior in the face of fires is essential for providing appropriate policy measures for safe evacuation. The performance of an emergency response depends on the environment in which a person is located, the starting point for fire prevention

measures requires the interaction between human behavior and building characteristics (Kobes et al., 2010)

Enhanced attention to human factors is necessary to guarantee sufficient infrastructure, decision-making procedures, and safety protocols for evacuation. An analysis of pedestrian and vehicle evacuations was conducted to assess how different factors influence evacuees' actions across various stages of a fire incident. (Wang et al., 2021)

The design strategy for developing an evacuation system design for subway stations with elevators can be a cost-efficient evacuation strategy in many buildings or facilities. However, there needs to be several steps that meet the needs of evacuees, for example, 1) sound alerts containing information that elevators can be used for evacuation in elevator lobbies, 2) systems in elevator lobbies that indicate that elevators are operating and moving. Along with this, knowledge in the field of human behavior and elevator evacuation is identified. Specific areas to consider are 1) Exit options, 2) waiting times, 3) elevator loads, and 4) social influences influence behavior (Mossberg et al., 2022)

CONCLUSION

Human behavior during fires encompasses various responses: from staying put to extinguishing flames, notifying others, seeking information, and evacuating. This behavior is influenced by factors such as knowledge, experience, gender, age, and cultural background. Social psychology and sociology contribute significantly to understanding and improving these responses. As urbanization accelerates, there is a growing need to explore the complexities of fire evacuation, including how spatial planning, individual knowledge, transportation infrastructure, and evacuation routes impact efficiency. Evacuation behavior plays a critical role in evacuation performance, influenced by factors like evacuees' knowledge levels and the accessibility of fire safety facilities. Understanding pre-evacuation behavior provides insights into how individuals react during fire emergencies. Ensuring fire safety in tall buildings involves maintaining clear evacuation routes, equipping corridors with extinguishers, and designing elevators suitable for evacuation purposes, with regular checks on safety equipment like smoke detectors and sprinklers essential for ensuring preparedness.

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