Demographic Determinants of Fire-Safety Behavior in High-Rise Residential Buildings: A Survey-Based Behavioral Analysis from Bengaluru, India

Mamatha N.
Alliance School of Design, Bangalore, India | Christ Deemed to be University, Bangalore, India
mr.dsarch@gmail.com (corresponding author)

Ajai Chandran CK.
CHRIST (Deemed to be University), Bangalore, India
ajaichandran.ck@christuniversity.in

Received: 7 December 2025 | Revised: 29 December 2025, 17 January 2026, 29 January 2026, and 6 February 2026 | Accepted: 7 February 2026

 DOI: https://doi.org/10.48084/etasr.16775

ABSTRACT

This study explores the role of demographic and experience-based parameters for fire safety behavior among residents of high-rise residential apartment buildings in the city of Bengaluru, a metropolitan capital in India. Data were gathered through a questionnaire-based survey among 262 residents. Multiple regression analysis was used to assess the correlation among demographic parameters and behavioral responses during evacuation. The results show that age ($R^2 = 0.154$, $p = 0.004$), presence of vulnerable household members ($R^2 = 0.137$, $p = 0.022$), and prior fire experience ($R^2 = 0.157$, $p = 0.004$) are statistically significant predictors of fire-safety behavior. In contrast, gender ($R^2 = 0.117$, $p = 0.073$), educational qualifications ($R^2 = 0.109$, $p = 0.136$), and chronic health conditions ($R^2 = 0.121$, $p = 0.500$) do not exhibit significant associations. Cross-tabulation analysis further indicates that residents who have received fire-safety training prioritize immediate evacuation, whereas untrained residents display delay behaviors. By providing empirical behavioral evidence from an Indian metropolitan context, this study highlights the demographic heterogeneity in evacuation behavior and supports the integration of behavioral realism into performance-based fire safety design for high-rise residential buildings.

Keywords-fire safety in high-rise buildings; human behavior in fire; risk perception and evacuation response; demographic determinants; inclusive design; performance-based fire safety

I. INTRODUCTION

Fire safety technology has been improved, partly due to the sophisticated high-rise design and construction. As building technology and fire risks evolve, fire safety standards continue to change, but they will remain central to building design and safety [1, 2]. Fires can cause loss of housing and property, as well as serious or fatal injuries. Therefore, fire safety should be viewed as a significant public health concern, requiring proactive measures, such as education and communication within the community. Although safety codes, legislative guidance, and community-based programs exist, significant gaps remain concerning high-risk populations (e.g., elderly and people with limited mobility), untrained residents, and individuals with limited experience in handling fire-related emergencies [3, 4].

Examining human behavior during a fire has provided valuable insights into how people perceive, process, and react to the cues generated by a fire event. Authors in [5] developed a conceptual model of essential behavioral processes for understanding egress modeling and evacuation success/failure, as a basis for integrating behavioral realism into fire engineering. Authors in [6] identified 37 specific research gaps in cognitive, physiological, behavioral, and environmental domains of human behavior, emphasizing the need to focus on decision-making processes in dynamically changing fire scenarios. In India, mainstream building codes overlook age-related limitations during high-rise evacuation [7], while reduced mobility, sensory decline, and inadequate preparedness significantly increase the risk of elderly occupants [8]. This highlights the importance of including age as a factor in the fire safety design and evacuation plans. Developments in computational modeling further extend the knowledge of occupant behavior. An agent-based model, simulating the fire

incident in Grenfell Tower [9], indicated that self-rescue capabilities of individuals, as well as centralized alarm systems significantly contribute to life saving outcomes. The social element was emphasized in [10], demonstrating how interactions between individuals, agencies, and older adults may frequently uncover latent fire hazards in domestic settings.

This study explores how residents of high-rise buildings in Bangalore perceive fire safety, how concerned they are about it in everyday life, and how these views are related to their demographic profile. Drawing on global literature and considering the demographic differences in India, the behavioral patterns of people that fit the unique resident profiles (elderly, households with vulnerable family members, residents with previous experience of fire incidents) were examined. The results of this study can potentially assist in creating inclusive architectural design strategies and improved evacuation plans, therefore increasing fire safety in high-rise buildings in India.

The findings of this study are grounded within existing Human Behavior in Fires (HBiF) frameworks, mainly in cue interpretation, confirmation behavior, and decision-making processes under conditions of uncertainty. Age, susceptibility, and personal experience shape the pre-movement phase of evacuation, as supported by theoretical descriptions of confirmation delay and risk appraisal described within HBiF. Confirmation behaviors among uninformed citizens support existing behavioral sequences described within models of decision-making during evacuations. Although international studies acknowledge behavioral variations among occupant groups, these insights are not efficiently integrated into the routine fire safety practices [11, 12] and India's regulatory framework [13, 14], creating a disconnect between proposed procedures and residents' perception and reaction to fire cues. In addition, HBiF research has largely relied on studies within Western contexts or simulation-based assumptions, with limited empirical evidence from high-rise residential buildings in urban environments of developing countries. The current study addresses this gap by presenting field-based behavioral data from Indian high-rise residences. By integrating these behavioral insights with implications for performance-based fire safety engineering, the study advances both behavioral understanding and practical design relevance.

II. RESEARCH METHODOLOGY

A quantitative, cross-sectional, and descriptive–analytical design is applied to explain how the behavioral attributes of residents living in high-rise settings shape their perception and response during fire emergencies. The central construct, behavioral modeling of fire-safety response, is investigated through a structured regression framework where perception-concern variables play the role of predictors for significant demographic and experiential determinants.

This approach has been guided by international behavioral fire research frameworks that encourage heterogeneity in evacuation responses. Therefore, the present study also incorporates:

- Cognitive components (risk evaluation, alarm interpretation).
- Behavioral components (evacuation priority, protective intent).
- Demographic moderators (age, gender, education, household vulnerabilities), and experiential factors (prior fire exposure, training).

The goal is to derive statistically validated behavioral insights tailored to the Indian high-rise context.

A. Study Area

The study was conducted in Bengaluru, India, a rapidly growing metropolis where vertical living is becoming more prevalent. The high-rise residential buildings included in this research were those that complied with NBC 2016 Type-2 residential category, measuring from approximately 30 to 75 m in height. Among other life-safety systems, they have refuge floors and fire lifts.

These buildings were selected for three important reasons:

1. They represent the current building type in the expanding cities of today.
2. They house a combination of resident types, which affects the way people behave in emergencies.
3. There are well-documented gaps in how prepared the residents are, by Karnataka Fire and Emergency Services (KFES).

B. Sampling and Participants

Data were collected through a structured questionnaire survey with purposive sampling by zoning, which resulted in a non-probability convenience sample. This approach was chosen due to restricted access to residents in gated residential complexes and inadequate list of residents to sample. Although the results are not generalizable, this strategy helps to identify evacuation-specific behavioral traits among residents. A total of 30 high-rise residential buildings were selected using stratified zoning (North, South, East, West, Central Bengaluru). Within each building, participants were recruited on a voluntary, convenient basis.

- Total respondents: N = 262.
- Age range: from 18 to 70+ years.
- Gender distribution: nearly equal.
- Household profiles: varied, including children, elders, and people with disabilities.

The sample is considered robust for behavioral modeling using Statistical Package for the Social Sciences (SPSS), where regressions allow interpretation even with complex predictor sets.

C. Instrument and Variables

In the structured questionnaire administered, demographic and experiential attributes are treated as independent variables,

while perception–concern variables related to fire risk and evacuation behavior are considered dependent variables.

More specifically, the variables used for modeling are:

- Independent Variables (Demographic and Experiential Predictors): Age, Gender, Education, Chronic health conditions (Family), Presence of vulnerable members at home, Prior experience of a fire or smoke-related incident.
- Dependent Variables (Behavioral Variables): Alarm interpretation, Intention to leave immediately, Tendency to confirm the situation with neighbors, Likelihood of attempting initial firefighting, Priority assigned to evacuation actions, Awareness of escape routes, Likelihood of reporting incidents.

These represent behavioral heuristics that guide actions during fire cues.

D. Questionnaire Design and Measurement Scales

The structured research questions were designed to reflect anticipated behavioral responses of the residents during a fire emergency. Behavioral variables were determined using both categorical and ordinal scaling, typically consistent with fire behavioral research methodology and practices. Where applicable, Likert scales were employed to capture responses, for example, from low to high, whereas action priorities required selection of a probable first response to an emergency.

For analysis, perception-concern variables were numerically coded, enabling statistical testing. Similar behavioral variables with slight variations were analyzed both separately and collectively, depending on the behavioral dimension involved. This allowed behavioral tendencies to be examined in relation to demographic and experiential predictors without assuming uniform behavioral aspects among residents.

E. Data Analysis Procedures

All statistical analyses were conducted using IBM SPSS Statistics (Version 29.0). Multiple linear regression was applied separately for each behavioral response variable using the enter method. Statistical significance was assessed at a 95% confidence level.

1) Regression Modeling

For each model, behavioral response measures were regressed against a block of demographic and experiential predictors.

The general form of the regression model is expressed as:

$$Y = B_i = \beta_0 + \beta_1(\text{Age}) + \beta_2(\text{Gender}) + \beta_3(\text{Education}) + \beta_4(\text{HealthConditions}) + \beta_5(\text{Vulnerability}) + \beta_6(\text{FireExperience}) + \varepsilon \quad (1)$$

where: Y is the fire-safety behavioral response variable, B_i is the behavioral response outcome, β_0 is the intercept of the model, $\beta_1 - \beta_6$ are regression coefficients corresponding to age, gender, education, household health conditions, household vulnerability, and prior fire experience respectively, and ε denotes the random error term. Each coefficient reflects the relative contribution of the corresponding predictor to fire-safety behavioral outcomes.

Model significance was evaluated using F-statistic, with a significance threshold of $p \leq 0.05$.

2) Diagnostic Checks

Standard regression diagnostics were performed to ensure model validity, including:

- Assessment of multicollinearity using Variance Inflation Factor (VIF).
- Examination of residual normality.
- Verification of homoscedasticity.

All diagnostic indicators were found to be within acceptable thresholds for behavioral research.

3) Cross-Tabulation Analysis

Cross-tabulation was used to examine the relationship between fire-safety training exposure and evacuation action prioritization, allowing comparison of behavioral differences between trained and untrained residents.

III. RESULTS AND ANALYSIS

A. Fire Safety Training versus Evacuation Prioritisation

The responds of residents on the evacuation action prioritization, along with their previous training are shown in Table I and Figure 1.

TABLE I. CROSS TABULATION OF RESIDENT RESPONSES

Evacuation action prioritization	Number of residents		Total
	With training	Without training	
1. Leave immediately	89	75	164
2. Confirm with neighbors	8	23	31
3. Call emergency services	4	7	11
4. Attempt to extinguish fire	5	3	8
5. Wait for instructions	0	5	5
6. Gather family members	1	3	4
7. Protect valuables	1	0	1
8. Move to refuge floor	0	1	1
9. Check cause of fire	6	0	6
10. Stay in place	0	1	1
11. Other	20	10	30
Total	134	128	262

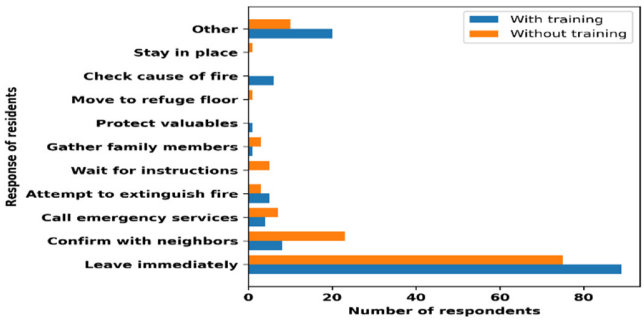

Fig. 1. Fire safety training versus evacuation action priority.

These results indicate that:

- Residents who received fire-safety training overwhelmingly prioritized immediate evacuation (89 responses versus 75 among untrained residents).
- Untrained residents displayed a wider spread across alternative actions such as confirming with neighbors (23), calling emergency services (7), or waiting for instructions (5).
- Trained residents showed more decisive and concentrated response behavior, while untrained residents were more uncertain and varied in their initial actions.

B. Summary of Regression Model Performance

The regression model results are illustrated in Table II. Figure 2 displays the coefficient of determination (R^2) values for each demographic group and Figure 3 depicts the age against the perception-concern index with a regression fit.

These results indicate that:

- Age, vulnerability, and prior fire experience show statistically meaningful behavioral associations.
- Gender, education, and general health do not significantly alter behavioral decisions in response to alarms.

TABLE II. MODEL SUMMARY FOR ALL DEMOGRAPHIC PREDICTORS

Predictor	R	R^2	F	p-value	Significance
Age	0.392	0.154	2.097	0.004	Significant
Gender	0.343	0.117	1.514	0.073	Not significant
Education	0.331	0.109	1.367	0.136	Not significant
Chronic health	0.347	0.121	0.973	0.500	Not significant
Vulnerable household members	0.371	0.137	1.774	0.022	Significant
Prior fire experience	0.396	0.157	2.121	0.004	Significant

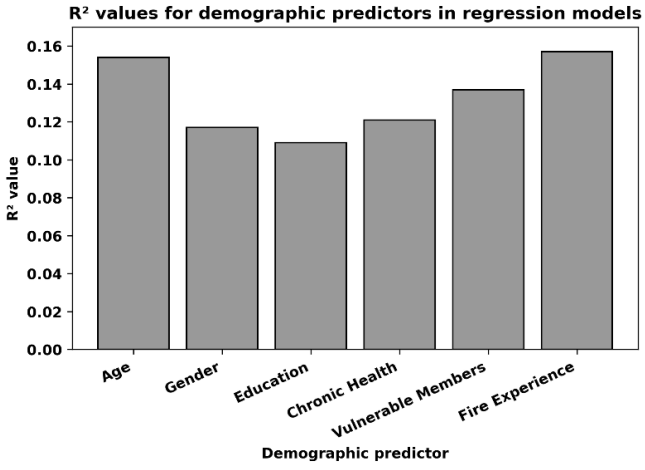

Fig. 2. Coefficient of determination (R^2) by demographic predictor.

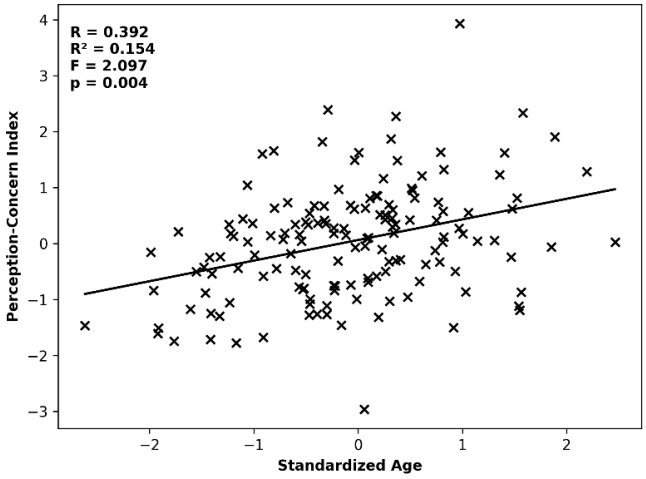

Fig. 3. Age versus perception-concern index with regression fit.

IV. DISCUSSION

A. Strength of Association

Age and reaction to fire safety scenarios are statistically significantly correlated according to the regression study. The R^2 of 0.154 and the p-value of 0.004, indicate that, based on age alone, about 15.4% of residents' responses to fire emergencies are explained. In behavioral and social research, this would already be a respectable effect size, given that the R^2 is often less than 10%. This relationship underlines age as a clear and influential factor shaping how individuals perceive fire cues, deciding what actions to take, and choosing whether to evacuate immediately or engage in confirmatory behaviors. Therefore, age should be an important element in understanding evacuation dynamics in high-rise residential settings.

The corresponding effect sizes (R^2 values of approximately 0.13 to 0.16) are discussed in terms of what is considered acceptable in behavioral or social scientific research, where small effect sizes are to be expected given the complex nature of human decision-making processes. While, statistical significance confirms that these systematic associations exist, their relevance is evaluated based on real-life fire response behavior, measured in terms of delay in evacuations, confirmation cues, or prioritization behavior.

B. Behavioral Patterns by Age

The behavioral analysis demonstrates significant differences between younger and older residents, where fire cues and alarms are involved. Older adults tend to respond with caution and immediacy: they evacuate without any delay, they put more trust in the alarm signals, and they are less likely to mistake the alarm for a false one. Their actions reflect a stronger awareness of danger, built from experience and deeper understanding of the risks tied to delaying evacuation. Younger adults might also take a more exploratory or confirmatory route, such as checking with neighbors, trying to pinpoint the source of the fire, or trying to suppress it before leaving. This adds additional time before they move, indicating a higher tolerance for risk and an attitude suggesting they can assess or

manage the situation themselves. Overall, these divergent patterns indicate that age affects not only risk perception but also decision-making speed and the effectiveness of evacuation during fire emergencies.

C. Gender and Fire-Safety Perception

The regression analysis results, focusing on gender and how people address fire safety, had a non-significant result p=0.073. Gender does not seem to influence how residents read the fire alarm, decide on when to evacuate and whether to report something, or judge the risk associated with an ongoing fire. This contradicts with the older theories of behavior, according to which men and women reacted differently in emergencies, in terms of risk tolerance or speed of decisions. Instead, it aligns with more modern evidence showing that contemporary homes and workplaces subject virtually everyone to similar information, drills, and communications about fire safety, which narrows any behavioral gap. Since there are no meaningful gender differences, fire-safety campaigns, training, and evacuation plans do not need to be tailored by gender.

D. Educational Qualification and Behavior

The regression analysis revealed no significant association between an individual's education level and their perceptions of fire safety or behavior during a fire incident, with p=0.136. This suggests that formal or higher education does not necessarily result in an increased likelihood of participants taking prompt and appropriate action in an emergency. One key point is that theoretical information cannot be assumed to directly correspond to practical behaviors. These results align with research on how individuals respond to fire emergencies, showing that the most successful way to ensure a positive response during a fire is through experiential learning, such as hands-on drills, live and fire safety focused training. Therefore, regardless of their education level, an individual's behavior during a fire cannot be predicted based solely on their academic background; thus, the focus of all fire-safety training programs should be on developing practical skills through continual drills, live training, and scenarios, to ensure that all residents, regardless of education, can perform a timely and effective evacuation of the building.

The lack of a statistically significant association between education and fire safety behavior is consistent with the HBiF literature. The evacuation process is dominated by the psychological factors of stress and uncertainty in the given situation and is less dependent on abstract knowledge and understanding [15]. Experience is more important in adopting positive behavior during evacuation in case of fire, compared to formal education and qualifications [10].

E. Prior Fire Experience as a Behavioral Determinant

Previous experience with fire emergency has the strongest correlation to fire safety behaviors, accounting for 15.7 % of variance explained (p=0.004). It gives people a heightened state of awareness related to potential risks, making them more vigilant, and an increased urgency to react, increasing the potential to quickly determine what needed to be done during an emergency. The experienced individuals tend to evacuate the premises more rapidly, pay close attention to any alarms sounding, and be aware of both the exit routes and the appropriate way to call for support. In addition, their reaction to fire emergencies positively influences the behavior of other residents, such as their family members, friends, or coworkers. On the contrary, for some individuals, a reaction of panic or anxiety resulting from a fire incident would cause an irrational reaction. Thus, if experiential learning was effectively implemented using realistic fire drills, simulations, and training techniques that replicate the cognitive impact of individual experience, safer behavioral patterns would be created among individuals.

F. Household Vulnerability

Households with vulnerable members (elderly, children, physically and/or mentally disabled), evacuate differently than other households. The statistical test of significance yielded a p-value of 0.022. These households tend to have longer evacuation times and rely more on external sources for assistance during evacuation, due to mobility limitations, additional caregiving responsibilities, or logistical issues. Parents of young children, while aware of the evacuation risks, need extra time to gather their dependents, significantly extending their effective evacuation time. Vulnerable households have a lower rate of participation in fire drill training programs, whether due to lack of access, social inhibition, or routine disruptions, increasing the risks during a real emergency. These behavioral barriers indicate that a more comprehensive fire safety plan should consider the existence of accessible escape routes, evacuation assistants, personalized evacuation plans, and community support networks. The findings of this study broaden the scope of vulnerability beyond demographic attributes and show its significant role in creating evacuations barriers.

This may not be significant on an individual scale since the behavioral decisions are aggregated at the household scale. The vulnerability factor, in its truest sense, is related to behavioral constraints which manifest through mobility dependence, caregiver coordination, and the need for assistance in evacuation [6]. This could be more suitably captured by a household vulnerability indicator rather than by an individual health status.

V. IMPLICATIONS AND CONCLUSION

The way people respond to fires is highly dependent on their age. Thus, training should support different age groups of residents. Younger residents typically check for cues or hesitate to leave the building; therefore, training should focus on how to act quickly when a fire alarm goes off and on the fact that delaying action can increase their risk of injury. Conversely, older adults may reply more quickly; however, they often come across limitations when evacuating due to poor mobility. This is a factor that should be considered while designing evacuation procedures. These behavioral variations between age groups have direct consequences for fire safety engineering, since the evacuation models should not assume a uniform behavior. By incorporating age-related behavior into the design, drills, and simulations, fire safety strategies will be improved, allowing for greater accuracy and inclusion of all occupants.

Age-sensitive evacuation strategies should account for variations in reaction time, mobility, and confirmation behavior, while households with vulnerable members require special training and support systems. Recognizing behavioral variability integrates pre-movement times, confirmation delays, and response times into performance-based fire safety engineering and evacuation modeling, enhancing the realism and effectiveness of fire safety strategies and preparedness.

The conclusions drawn are directed at influencing fire safety planning and behavioral understanding in the context of high-rise residential structures in an Indian metropolitan setting. Generalization beyond this context requires caution given the sampling method and the context-specific environmental, cultural, and regulatory conditions. While some significant behavioral processes, especially vulnerability, prior fire experience, and training, may be relevant in other settings, other factors, such as informal communication networks and limited institutional training exposure, reflect local conditions.

The main scientific contribution of this work lies in its empirical validation of demographic heterogeneity as a crucial input to fire-safety behavior analysis in high-rise residential buildings. Using field-based data from an Indian metropolitan context, the study demonstrates that evacuation-related behavior is systematically influenced by age, household vulnerability, and prior fire experience, which are often underrepresented factors in conventional fire-safety engineering and evacuation modeling. By strengthening the behavioral evidence base for developing-country high-rise environments, this research supports more realistic performance-based fire safety design and modeling approaches. Future studies should combine behavioral survey data with evacuation simulation models to assess the impact of the observed heterogeneity on the evacuation performance in dynamic fire conditions. The integration of building-specific variables related to alarm audibility, signage clarity, and management protocols would lead to further advancements in behavioral realism. Longitudinal studies and validation using evacuation drills or observations from actual events are also proposed as a means of determining the reliability of self-reported behavior and reinforcing the empirical basis for performance-based fire safety design.

There are certain limitations to this study, which need to be taken into consideration when understanding and interpreting these results. Initially, this study is based upon a self-reporting investigation confined to the specific context of a cross-sectional study that identifies perceived or intended behavior, but does not include actual behavior in the event of fire safety evacuations. Moreover, the sampling technique that was adopted was a stratification technique that was voluntary, and therefore leads to a non-probability sample, specifically a convenience sample. This is ideal since it will be able to reach people living in different high-rise buildings; however, the results may be subject to self-selection bias, and thus may not be generalizable.

Finally, this paper examines the demographic and experiential drivers of behavior rather than explicitly modeling building-specific factors related to evacuation, such as stairway widths or actual smoke conditions.

The current research did not explicitly model any contextual variables, such as building management practices and alarm audibility and visibility conditions. These are influenced by the local communication customs and can potentially condition demographic and experience-related behavioral factors. The omission of such variables can be seen as a limitation for the current study and a research direction for studies merging behavioral variables and building-related variables.

REFERENCES

[1] N. Ventikos, K. Louzis, P. Sotiralis, A. Koimtzoglou, and E. Annetis, "Integrating Human Factors in Risk-Based Design: A critical Review," presented at the *Ergoship 2021*, Busan, South Korea, Sep. 2-4, 2021.

[2] M. Gerges, P. Demian, and Z. Adamu, "Customising Evacuation Instructions for High-Rise Residential Occupants to Expedite Fire Egress: Results from Agent-Based Simulation," *Fire*, vol. 4, no. 2, 2021, Art. no. 21, https://doi.org/10.3390/fire4020021.

[3] J. Pauluhn, "Estimation of time to compromised tenability in fires: is it time to change paradigms?," *Regulatory Toxicology and Pharmacology*, vol. 111, Mar. 2020, Art. no. 104582, https://doi.org/10.1016/j.yrtph.2020.104582.

[4] T. J. Shields, B. Smyth, K. E. Boyce, and G. W. H. Silcock, "Towards the prediction of evacuation behaviours for people with learning difficulties," *Facilities*, vol. 17, no. 9–10, pp. 336–344, Sept. 1999, https://doi.org/10.1108/02632779910278746.

[5] S. M. V. Gwynne, E. D. Kuligowski, M. J. Kinsey, and L. M. Hulse, "Modelling and influencing human behaviour in fire," *Fire and Materials*, vol. 41, no. 5, pp. 412–430, 2017, https://doi.org/10.1002/fam.2391.

[6] E. Kinkel, C. N. van der Wal, E. Ronchi, and E. D. Kuligowski, "Gaps in Human Behaviour in Fires Research: A Scoping Review," *Fire Technology*, vol. 61, pp. 5963–6001, 2025, https://doi.org/10.1007/s10694-025-01781-3.

[7] A. Kumar, R. Khare, S. Sankat, and P. Madhavi, "Fire safety assessment for older adults in high-rise residential buildings in India: a comprehensive study," *International Journal of Building Pathology and Adaptation*, vol. 41, no. 3, pp. 625–646, 2023, https://doi.org/10.1108/IJBPA-02-2022-0030.

[8] A. Kumar, R. Khare, S. Sankat, and P. Madhavi, "Fire Evacuation of Elderly in High-Rise Residential Buildings in India," *Civil and Environmental Engineering*, vol. 18, no. 1, pp. 258–268, June 2022, https://doi.org/10.2478/cee-2022-0024.

[9] P. Lu, Z. Zhang, C. H. Onyebuchi, and L. Zheng, "Agent-based modeling of high-rise building fires reveals self-rescue behaviors and better fire protection designs," *Engineering Applications of Artificial Intelligence*, vol. 127, Jan. 2024, Art. no. 107401, https://doi.org/10.1016/j.engappai.2023.107401.

[10] P. Cassidy, N. C. McConnell, and K. E. Boyce, "The older adult: Associated fire risks and current challenges for the development of future fire safety intervention strategies," *Fire and Materials*, vol. 45, no. 4, pp. 553–563, Mar. 2020, https://doi.org/10.1002/fam.2823.

[11] *Life Safety Code*, NFPA 101, National Fire Protection Association, 2021.

[12] *Fire Safety Engineering - Assessment of Fire Risk*, ISO 16732-1, International Organization for Standardization (ISO), 2012.

[13] *National Building Code of India*, NBC 2016, Bureau of Indian Standards, 2016.

[14] *National Disaster Management Guidelines*, National Disaster Management Authority, 2021.

[15] E. Ronchi, "Developing and validating evacuation models for fire safety engineering," *Fire Safety Journal*, vol. 120, Mar. 2021, Art. no. 103020, https://doi.org/10.1016/j.firesaf.2020.103020.