Enhancing Safety and Inclusivity in High-Rise Building Evacuation Strategies: A Comparative Study of Building Safety Manager and Occupant Perspectives

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Abstract

Purpose

Understanding the egress considerations of fire evacuation strategies is fundamental to establishing the most effective methods for evacuation of people with and without vulnerabilities in High-Rise Residential Buildings (HRRB). The main aim of this study is to identify the main considerations to enable the assessment and improvement of operational procedures and processes from a Building Safety Manager (BSM) and occupant perspective.

Design/methodology/approach

Primary data was collected through group interviews and questionnaires with occupants and BSM of HRRB to achieve the aforementioned aim. Exploratory data from interviews from both groups was used to devise practical and effective operational strategies. The qualitative data was analysed using a systematic coding process with the use of QSR NVivo. Questionnaires data was collected via Qualtrics was analysed using SPSS.

Findings

Analysis reveals a substantial gap in evacuation strategy awareness between stakeholders, with occupants remaining significantly unaware of the current evacuation protocols in their buildings exacerbated by reluctance among private companies to invest in evacuation alert systems without mandatory legislation.

Originality/value

This research contributes to the disaster preparedness and response in urban settings literature, expanding the understanding of how HRRB evacuation strategies can be optimised for inclusivity and effectiveness.

Practically, the findings of this research have the potential to influence policy decisions and building management practices that directly affect the safety and well-being of HRRB occupants. Overall, this study provides actionable insights for policymakers, building managers, and emergency responders to enhance the preparedness and responsiveness of evacuation procedures in high-rise environments while considering the specific needs of vulnerable populations.

Keywords: egress considerations, evacuation strategies, high-rise residential buildings, response patterns, occupants, building safety managers

1. Introduction

As the world population grows and the demand for space increases, vertical living and the construction of high-rise residential buildings (HRRB) has become necessary. However, design of HRRB can be very challenging. Apart from the aesthetics, durability, and stability of the building, engineers must seriously consider fire safety issues.

Tragic fire emergencies highlighted critical deficiencies in HRRB evacuation strategies, particularly for disabled and vulnerable populations (Mytton et al, 2017). Despite enhancements in evacuation strategies in cladded buildings, a significant portion of building occupants remain unaware of current evacuation protocols (Safayet *et al.,* 2021). This lack of awareness diminishes the effectiveness of critical components in ensuring the safety of all residents, especially those with disabilities or vulnerabilities (Bryan and Mueller, 2019).

The existing literature on evacuation strategies and alert systems in HRRBs reveals a stark deficiency in comprehensively understanding their effectiveness from a multi-stakeholder perspective (Wang *et al.,* 2021). This gap is particularly pronounced when contrasting the insights and experiences of Building Safety Managers (BSMs) and occupants—two pivotal groups whose roles and interactions fundamentally shape the practical deployment and perceived efficacy of safety measures.

BSMs, tasked with the management and operational oversight of building safety, possess a technical understanding and regulatory knowledge that is crucial for the strategic planning and implementation of evacuation protocols and systems (British Standards Institution, 2015). Conversely, the occupants' experiential knowledge and firsthand insights into the practical aspects of these strategies during actual emergency scenarios provide invaluable feedback that is critical for assessing the real-world effectiveness of these measures (Mytton et al, 2017). The noted discrepancy between the awareness levels of BSMs and occupants, coupled with the inconsistent implementation of evacuation alert systems, not only underscores the pressing need for comprehensive research in

this area, but also highlights the necessity of integrating these diverse perspectives.

This study aims to bridge these gaps by examining the awareness and effectiveness of evacuation strategies and alert systems in HRRBs, with a focus on the inclusion and safety of disabled and vulnerable populations. By contrasting the viewpoints of both BSMs and occupants, this research contributes to the literature on disaster preparedness and response in urban settings, expanding the understanding of how HRRB evacuation strategies can be optimized for inclusivity and effectiveness.

While previous literature has concentrated largely on alert system enhancements, this study demonstrates that such technological solutions are insufficient without corresponding awareness and compliance among stakeholders. Findings reveal a striking disparity in evacuation strategy awareness between stakeholders demonstrating that evacuation effectiveness is compromised by a lack of occupant awareness and behavioral gaps in occupants.

2. Occupants' vulnerabilities impact on evacuation strategies

Fire evacuation in HRRB poses significant challenges due to the inherent complexities of their vertical structure, high occupant density, and the unique constraints of emergency situations. Evacuation procedures in HRRB can be broadly categorized into simultaneous evacuation, phased evacuation, and defend-in-place or stay-put strategies. Simultaneous evacuation involves the immediate descent of all occupants upon fire detection. While straightforward in design, it often results in severe congestion in stairwells, especially in densely populated buildings. Phased evacuation, by contrast, prioritizes the evacuation of occupants closest to the fire, allowing others to remain in place temporarily. This method requires robust communication and compartmentation systems to ensure safety during the delay. The defend-in-place or stay-put strategy advises occupants to remain in fire-resistant areas, such as their apartments or refuge floors, until the fire is contained, or rescue personnel arrive. Each of these methods has limitations, particularly in

situations where vertical descent is impeded by structural damage, congestion, or the psychological barriers occupants face during emergencies. For example, Chow et al. (2013) found that a top-to-bottom vertical evacuation in a 57-story building with 7,500 occupants was found to take over 45 minutes. The implications of such a long evacuation time highlights the importance of benchmarking evacuation times and congestion patterns, especially when considering people with mobility restrictions.

Previous studies also have demonstrated that strategies such as simultaneous evacuation, phased evacuation, and partial evacuation (including "defend-in-place" or "delayed evacuation") should be tailored to each building's design and occupant composition (Home Office, 2022). Experiments have shown that phased and partial evacuations, supported by compartmentation and communication, often outperform simultaneous evacuations in terms of safety and efficiency. Throughout the years, several policies promote the safety of people during the evacuation of HRRBs during fire emergencies and these affect the decision-making of the best evacuation practice for each building.

Stay-put policy has been advocated and incorporated since early 1960s in multiple countries, including the United Kingdom (UK) (British Standards Institution, 1962). This policy recommends that HRRB should be designed and constructed in a way that all occupants can remain in their place safely during a fire incident to avoid evacuating the building. However, safety regulations for people with disabilities and vulnerabilities was only integrated into building regulations in the late 1980s (Rubadiri, 1994). Later, in the late 2000s, emerging regulations in the UK incorporated the engagement of the “responsible person” in reducing fire risk and making sure that all building occupants (including people with disabilities, vulnerabilities and visitors) can safely escape (UK Parliament, 2005).

Effective and safe evacuations rely on factors such as the positioning of emergency exits and routes, regulations about the doors on the emergency routes leading directly in the direction of the escape, prohibition of sliding or revolving emergency doors, provision for a quick and safe evacuation, obvious

emergency signals and finally emergency lighting of adequate intensity (DHSSPS, 2011). Moreover, fire risk reduction or elimination measures and fire evacuation plans must consider people with vulnerabilities or disabilities including risk-based assessment tools for identifying and reporting potential hazards towards health and safety derived from potential failures in buildings (DCLG, 2006).

The significance of Personal Emergency Egress Plan or Personal Emergency Evacuation Plan (PEEPS) for people with vulnerabilities or disabilities has been increasingly strengthened over the last 20 years (UK Parliament, 2005; Home Office, 2021). PEEPs in HRRB are not as common as they are in the workplace, as HRRB are built under different circumstances, design, and structural standards (e.g., different evacuation times and techniques) (Home Office, 2021). Some HRRBs apply the "stay-put" strategy while others apply "simultaneous" evacuation, depending significantly on the presence of Aluminium Composite Materials (ACM) and the considerations when they were designed (MHCLG, 2017; Home Office, 2021).

The impact of vulnerabilities and disabilities on evacuation varies depending on their heterogeneous categories, namely, mobility impairment, cognitive and learning impairments, hearing impairment, and vision impairment (Koo *et al.,* 2013). Conversely, occupants' vulnerability is linked to (1) elderly and very young people, (2) heavily pregnant women, (3) obese/bariatric people, (4) people under medication, alcohol or drugs, (5) people recovering from injury or surgery and finally (6) people who do not understand the language or are illiterate (British Standards Institution, 2015).

Overall, the evacuation strategies and practices are impacted both by different housing policies and practices regarding occupants' vulnerabilities. First, the unawareness of designers about the flammable properties of materials such as ACM or cladding implied that several buildings had to change their evacuation strategy from stay-put to simultaneous evacuation, which means that vulnerable and disable persons must evacuate at the same time as the other occupants, even when the escape routes were not designed to accommodate

this. Second, the role of the "responsible person" (or equivalent) is key for the timely identification of residents with disabilities or vulnerabilities, establishing the PEEPs, monitoring, assessing, and preventing fire risk to make sure that vulnerable residents can safely escape during an emergency. Comparatively, Singapore enforces a similar role through a Fire Safety Manager, who ensures that emergency protocols are tailored to include vulnerable occupants, with frequent drills simulating diverse scenarios. In the United States, the National Fire Protection Association (NFPA) requires comprehensive emergency plans, emphasizing collaboration between building management and emergency responders to cater to vulnerable groups.

Evacuation alert systems are comprised of visual/audible alarms on every floor and in every flat, allowing the incident commander to activate the switches that will sequence the evacuation according to the corresponding evacuation plan (British Standards Institution, 2019). Evacuation alert systems focus on informing occupants of selected zones of the HRRB to evacuate after the arrival of the Fire and Rescue Service (FRS), rather than alerting occupants of the fire incident in advance of the arrival of the FRS, such as fire detection systems. Moreover, the evacuation alert systems can only be activated by the incident commander via the evacuation alert control and indicate equipment independently from likely coexisting systems such as alarm and fire detection (NFCC, 2021).

Though early smoke detection is a priority, increased use of smoke alarms (Mytton et al, 2017) and fire evacuation alarm systems being widely discussed (Bryan and Mueller, 2019), most of the research is focused on automated fire alert systems as opposed to alarms (Safayet, Rahman and Anam, 2021). The significant role of fire alarms in escaping a building with fire risk is paramount considering that the fire alarm system should be a hub of both alerting occupants and connecting with other BSM systems (Fire Protection Association, 2020).

3. Methods

This research employed a sequential mixed-methods approach, incorporating both quantitative (survey) and qualitative (interview) data collection techniques to explore the efficacy and awareness of evacuation strategies and alert systems in HRRBs, especially concerning the inclusion and safety of disabled or vulnerable groups. Data collection followed a structured sequence: first, self-reported awareness through a questionnaire survey, and subsequently, interviews were conducted to evaluate participants' actual understanding of evacuation hazards and procedures. This two-stage approach enabled a comprehensive analysis by identifying gaps between perceived and demonstrated awareness. Participants, including BSM and occupants selected from a range of stakeholders, including housing associations, cladding action groups, local housing authorities, and resident advocacy groups like the Residents Voice Group under the Ministry of Housing, Communities and Local Government in the UK.

3.1. Questionnaire Survey

The first phase of data collection involved a questionnaire survey, designed to capture self-reported awareness of evacuation strategies and hazards among participants. Data from the questionnaires were distributed through Qualtrics® and a unique URL was generated for each questionnaire to share. Two different questionnaires were sent to occupants and BSM consisted of 30 questions, respectively. Before sending the questionnaire, the research team piloted the survey. Each questionnaire composed of two parts. The first part focused on the demographics of the respondents. The second part, the questionnaires adopted a Likert scoring system where the respondents were asked to use a five-point Likert scale to assess specific topics. 127 occupants and 51 BSM participated in this study and were asked for demographic information such as age, physical condition, homeownership, and the number of people living together. Statistical analysis was done using Excel Microsoft® Office 365 (ver. 16.48) and the relevant correlation analysis between the tested variables using the IBM® SPSS® statistics 26 software.

Gender and age differences are associated with how individuals perceive risk. Younger people and men seem to perceive less risk compared to women and older people (Kinateder *et al.,* 2015). This is considered in the analysis of the data as 56% of occupants identified themselves as males aged between 36–45 (27.6%), 56–65 (21.3%), and 5.5% between 18–25 years of age.

Many occupants reported "good" (58.3%) and "excellent" (19.7%) physical condition while those reporting a form of physical disability, including those suffering from long-term illness, health problems, or disability that may limit their daily activities, were 14.2%, and 3.9% suffering from a chronic condition.

Among the BSM respondents, 71% of them were male, 27% were female, and 2% preferred not to say. Most BSM reported having less than 3 years of experience as a BSM (64.7%) followed by more than 10 years of experience (23.5%) and those with intermediate experience (between 4 and 9 years) (11.8%). In terms of the number of buildings that they currently managed, predominantly this was more than 5 buildings (66.7%), followed by 2 and 5 buildings (35.3%), and 3.9% only managed 1 building. Questionnaires were sent to a variety of homeowners and tenants of all age groups. Majority of occupants were tenants (64.6%) and only 13% had children under the age of 12, who are considered as people with vulnerabilities.

3.2. Group Interviews

After the survey phase, semi-structured interviews were conducted to further investigate participants' understanding of key evacuation hazards beyond their self-reported awareness. These interviews aim to provide an in-depth exploration of potential knowledge gaps. A total of 5 group interviews were conducted with HRRB occupants (11 interviewees) with and without vulnerabilities; and 1 group of BSM (7 interviewees) from a range of geographical areas in the UK. While the sample size of BSMs may appear small, their extensive expertise and representativeness make them highly suitable for this study. Each of these professionals has managed between 22,000 and 75,000 high-residential properties, offering a comprehensive and authoritative

perspective on evacuation policies, implementation challenges, and practical realities of ensuring resident safety. Furthermore, their geographical distribution enhances the generalizability of our findings, as they represent key urban and regional areas across the UK, two in London, two in Manchester, one in Cambridge, one in Scotland, and one in the West Midlands. A semi-structured methodology is useful for its flexibility in gathering further information and clarification during the interview. The interview protocols were made of open-ended questions allowing stakeholders to provide the deepest information possible about each one of the sections established. Occupants' questions were based on research related to the behaviour of people during fire evacuation occurrences, the features of the building they live in, the special categories of occupants, including people with disabilities or vulnerabilties and children, evacuation paths and signaling, and evacuation modelling and decision making during fire emergencies (Groner, 2016; Mytton *et al.* 2017). Group interviews lasted typically between one-half and two hours each via Microsoft Teams. Two members of the research team conducted all group interviews to ensure consistency and reliability in data collection. All interviews were recorded and later transcribed into text to ensure accuracy and strengthen the qualitative analysis.

The qualitative data was analyzed using content and contextual analysis with the use of QSR NVivo software version 14. The coding process involved in-depth exploration of the interview comments to filter the most meaningful contributions. A systematic coding procedure was conducted as follows. First, the reviewed transcriptions of the interview sessions were imported to NVivo version 14. Second, group interview sessions were analyzed based on individual interviewee comments to establish each interviewee as an individual case. This individualization enabled analysis in NVivo version 14, contrasting thoughts among interviewees within the same stakeholder group or across diverse stakeholder groups. Each of the cases had attributes related to their roles and demographics, among other factors. Cases facilitated the organisation of the transcriptions according to each of the respondents, so identifying the comments

relating to each of the questions. Third, a comprehensive line-by-line reading of the comments of each interview allowed the identification of patterns relating to each of the sections analyzed in the interviews. Nodes were created for storing the most significant comments of each of the interviews for further analysis in an iterative way. The objective was to code passages to provide enough context. This analysis enhances awareness of the contributions of each respondent and lessens biased analysis based on preconceptions.

The analysis moved beyond identifying patterns within individual interviews to a contextual and comparative examination of the data. This step involved comparing responses across cases to uncover consistencies and divergences in perspectives. For instance, responses from tenants and BSMs were contrasted to reveal differences in their understanding and preferences for evacuation strategies. Similarly, patterns in awareness gaps or preferred methods of evacuation were assessed across stakeholder groups to identify shared challenges or unique perspectives. The attributes assigned to each case, such as roles or demographic information, further enriched this analysis by revealing how factors like age, disability status, or professional responsibilities influenced respondents' views. This cross-case analysis was facilitated by NVivo's powerful querying tools, which allowed for detailed comparisons and the identification of trends that might otherwise remain hidden.

The contextual coding process aimed to preserve the richness of the data by coding at the level of passages rather than isolating single phrases. This ensured that the full context of each respondent's comments was considered, allowing for a deeper understanding of their meaning and intent. For example, a passage in which a tenant expressed concerns about evacuation strategies might be coded under multiple relevant nodes, such as "awareness gaps" and "vulnerable populations," to reflect its multidimensional relevance. This comprehensive approach to coding enhanced the interpretive value of the analysis, enabling the research to uncover nuanced insights. These insights were ultimately synthesized into overarching themes, highlighting key issues such as gaps in

awareness, the impact of vulnerabilities on evacuation preferences, and the role of policy and communication in addressing these challenges. Through this systematic and iterative process, the thematic coding provided a robust foundation for deriving actionable conclusions and recommendations from the qualitative data.

4. Results

4.1. Awareness of evacuation strategies

BSM demonstrated a significantly greater awareness of all evacuation strategies compared to occupants (Table I). However, their awareness was notably varied for immediate evacuation strategies, according to the higher mean values (2.11 and 2.14) and substantial standard deviations (σ>1.4) (Table I). Occupants demonstrated moderate awareness of defend-in-place according to their means (2.44), which can be explained considering that defend-in-place is significantly understood as a synonym of stay-put for occupants. An immediate evacuation was also the least familiar strategy with BSM. Occupants preferred to defend-in-place, stay-put, and phased evacuation as their preferred alternatives.

TABLE I HERE

The findings from the complementary qualitative interviews highlights significant gaps in awareness and understanding of evacuation strategies among occupants. Interestingly, 100% of BSM reported full awareness of stay-put strategies contrasts with only 38% of occupants showing awareness of stay-put strategies. Occupants demonstrated lower levels of awareness compared to BSM, with 55.7% of occupants declared not being aware of different evacuation strategies for HRRB in case of fires. This highlights a significant gap regarding the effective information that they are receiving on these strategies. Besides stay-put, defend-in-place was identified as the most familiar strategy among occupants. About 73% of the occupants interviewed demonstrated awareness of evacuation strategies, especially those who live in buildings with cladding, where the policy has changed from stay-put to full

evacuation since the 2017 Grenfell incident. However, it is a concern that the remaining occupants interviewed were not aware of the current evacuation strategy adopted within their building. None of the occupants interviewed had been involved in practice evacuations within their building, and only 18% of the occupants interviewed had evacuated because of a fire incident or emergency. Interestingly, 18% of the occupants highlighted that those occupants in rented apartments are more likely to have a reduced awareness about the current evacuation strategy because usually this information is sent as mailbox correspondence and is directed to the landlord. Moreover, 66% of occupants with no disability status demonstrated unawareness of the evacuation policy specific to their buildings while none of the occupants with vulnerabilities exhibited such unawareness. Occupants also demonstrated a preference for immediate evacuation when it concerns people with disabilities or vulnerabilities.

The analysis demonstrated two drivers of the occupants' limited and uneven awareness of evacuation strategies: information dissemination gaps and lack of direct engagement. Renters are less informed about evacuation strategies compared to homeowners because of the common practice of sending critical safety information, such as changes in evacuation policy, to landlords rather than directly to tenants. Moreover, none of the occupants reported participation in practice evacuations, and only a small fraction (18%) had experienced a real evacuation. This lack of hands-on engagement significantly diminishes their familiarity with evacuation protocols. The detrimental impact of these factors is exacerbated by the absence of visible incidents or practical drills, which may lead occupants to perceive evacuation strategies as low-priority information.

The differences in preferences for specific evacuation strategies are deeply rooted in the distinct roles, responsibilities, and perspectives of BSMs and occupants. While BSMs prioritize strategies that align with operational feasibility and risk management, occupants' preferences are shaped by their individual perceptions of safety, empathy for vulnerable groups, and limited exposure to comprehensive evacuation education. For BSMs, their role in

maintaining order and minimizing chaos during emergencies heavily influences their preference for strategies like stay-put and defend-in-place. These strategies align with the operational demands of managing large-scale evacuations, as they offer a structured and phased approach that reduces the risk of congestion in stairwells and corridors. From their vantage point, controlling the movement of occupants during an emergency is critical to ensuring overall safety. BSMs are also more familiar with the logistical challenges posed by immediate evacuation, such as bottlenecks, panic, and communication breakdowns, which further solidifies their preference for more contained and controlled strategies. However, their moderate awareness of immediate evacuation strategies could be due to limited exposure or training in scenarios where this approach is necessary, reflecting a potential gap in their preparedness for such situations. In contrast, occupants' preferences are shaped by their personal perceptions of risk and safety during emergencies. For many occupants, defend-in-place and stay-put strategies are more familiar because they are seen as intuitive responses to fire incidents—remaining in a secure location until further instructions are provided. This familiarity is often reinforced by a lack of direct engagement with evacuation procedures, as most occupants have never participated in evacuation drills or real emergencies. For those living in buildings where policies have shifted to full evacuation, the unfamiliarity with these changes can lead to confusion or adherence to previously understood strategies, even if they are no longer officially recommended. The divergence becomes more pronounced when considering vulnerable populations. Occupants are likely to perceive immediate evacuation as the most appropriate strategy for people with disabilities or vulnerabilities, driven by the belief that these groups are at heightened risk and require prioritized assistance. This perspective is rooted in empathy and a sense of urgency, emphasizing the need to address physical limitations or health concerns that may hinder their ability to remain safe in a stay-put scenario.

4.2. Evacuation alert systems

Although it is generally acknowledged that the increased use of domestic

smoke alarms has resulted in a reduction in the number of household fires [16], there is a lack of scientific research evidence to reveal the impact of alert systems on evacuation strategies in the UK. Overall, there is low awareness of dedicated, tamper-proof evacuation alert systems recommended to ensure clear, managed evacuation signals for emergency responders and prioritize accessibility for vulnerable populations. This is evidenced by the interviews. Only 2 out of the 11 occupants interviewed declared any awareness of alert systems. Conversely, all five BSM interviewed were aware of the evacuation alert system; however, 71% of these managers declared that none of the HRRB managed by them had implemented these evacuation alert systems yet, and some of their companies had expressly opposed financing these systems until its implementation become mandatory. This reluctance of private companies to finance evacuation alert systems is based on waiting for legislation to detail the requirements. As a manager (I.e., BSM3) commented: "*We are waiting on more advice because at the moment its recommendations and not legislation. If sprinklers become legislation, we've got to pay for the cost of fitting those. Then kind of make sure we're compliant with legislation before we start to go above and beyond*." A manager (BSM4) illustrated its implementation: "*We have them in 50% of our existing high-rise residential buildings and 100% of ours in development*".

However, 5 out of 7 BSMs declared that none of the high-rise residential buildings managed by them had implemented these systems yet, and some of their companies had expressly opposed financing these systems, as a manager commented: "*We haven't got any at all. I'm recommending them. I am pushing it but it's uphill*". From the interviews it was revealed that most of the buildings where the system has not been installed still have communal alert systems, which have significant issues with false alarms and there are plans for "repurposing" the current systems if it is possible, to reduce the investment required. As a manager commented (BSM3): "*We are waiting on more advice because at the moment its recommendations and not legislation. If sprinklers become legislation, we've got to pay for the cost of fitting those. Then kind of*

make sure we're compliant with legislation before we start to go above and beyond." This financial concern was depicted by a manager (BSM2): "*We've got 29 blocks that are within the scope, which is 18 metres above. But we're not gonna do the rest. So how do we say that we can do some but not the others? So how do you deal with that with the occupants? That's an issue that we're now gonna have to deal with because occupants talk*." As a result, the pace of the implementation of these systems is slow and varied among the high-rise residential buildings.

Once the interviewed occupants were notified about the evacuation alert systems, some of them raised concerns about their impact on the evacuation procedures. The first concern was that people's behaviour (such as panic) could lead to mass evacuation even if the alarm is activated on a different floor. This would impede the purpose of the system, and it was expressed by 27% of the occupants interviewed. There were also concerns about the behaviour of rental tenants because they are often less informed than owners. According to an occupant (Oc2): "*I think it all goes down to how much people understand about the system that's in place. We have lots of renters coming in and out, who's picking up the mail? Is it going directly to the occupant or leaseholder?*".

The second concern was the delay in activating the alarm until the FRS arrived at the building, which was claimed by 27% of occupants. An occupant described the trade-off of having these alert systems (Oc9) said: "*That could cause problems if people just won't evacuate until the fire service come, waiting for the alarm if they arrive delayed. Whereas with a traditional fire alarm there's probably going to be loads of false alarms, and then people won't evacuate because they think there are so many people burning toast. If it could be triggered by the concierge who is there 24 hours, that's better than waiting for the fire service, which could mean delays*". Across the board, all the interviewed BSM agreed that the main challenge, post-installation of alert systems, is to educate people to understand the system and how they should react once the alarm is activated.

From quantitative data, BSM declare that alarm systems are not adequately available for people with hearing disabilities and age-related difficulties (21% and 10% respectively). Similarly, occupants consider that alert systems are inadequate in the building they live in, including text messaging, visual alert systems, and vibrating pagers available to less than 2%.

4.3. Considerations regarding occupants' vulnerabilities

BSM demonstrated a significant agreement that stay-put was the best strategy for occupants with disabilities or vulnerabilities, having the highest frequency responses while occupants preferred to defend-in-place and stay-put as their preferred alternatives (Table II). Occupants also demonstrated to be in favour of immediate evacuation for occupants with disabilities or vulnerabilities. One noteworthy finding from the questionnaires is the variety in perception concerning the availability of housing policy information regarding occupants with vulnerabilities. While 82.9% of BSM consider they know the policies adequately, almost the same proportion of occupants (i.e., 78.8%) consider that they lack adequate information. This gap is even greater when the knowledge about the policies for occupants with disabilities or vulnerabilities for evacuation purposes is considered.

Majority of occupants, 73.7% and 17.1% of BSM considered that they do not have specific knowledge in this regard. This finding highlights the lack of effective communication regarding housing practices/policies concerning occupants with vulnerabilities between BSM and occupants.

TABLE II HERE

Majority of the occupants in the questionnaires, 54%, declare that they do not know which resources are available for people with disabilities or vulnerabilities generally and consider the escape stairs as the main resource they have available for their evacuation in case of fire.

Occupant interviews demonstrated that there is a general lack of awareness of housing policies concerning disabled or vulnerable occupants. Therefore, only 45% of the occupants interviewed were aware of any housing policies concerning occupants' vulnerabilities, especially when focusing on PEEPs.

Moreover, criticism against the implementation of PEEPs was expressed by 27% of the occupants interviewed. The occupants who highlighted this issue agreed on the BSM's negligence in conducting the PEEPs comprehensively by including all disabled or vulnerable residents. For example, another occupant (i.e., Oc6) revealed: "I wrote my own PEEP, I had to create it on my own with the support of an expert, this is unacceptable." This criticism also is related to the planning role of PEEPs, as one resident (i.e., Oc1) emphasized: "*There's not knowledge and understanding around the whole PEEPs process. The first three letters of PEEPs get done relatively well. It's the last letter, the planning that never gets implemented, from the managing agent's point of view and even hotels. You've seen the PEEPs forms, and they never fill that last page out, which is how you are going to evacuate from the building*."

There are two contradictory positions about the intended housing policy for disabled or vulnerable occupants. One perspective is a recommendation that disabled or vulnerable occupants should be required to live on lower floors in high-rise residential buildings, to facilitate their safe evacuation in case of an emergency. This policy is mainly supported by BSM. The second perspective is that occupants with vulnerabilities have the right to freely choose where they live, and anything obstructing that could be discriminatory. This point of view is mostly supported by occupants. 9% of the occupants interviewed declared that some could be prohibited from living on high floors. One occupant (i.e., Oc4) made a specific policy proposal such as: "If *I leave my house and I have a vulnerability, the government will not support me in anything to assist me in getting down from my house that might be on the 12th floor. What priority is? whether it's a nice car outside to get them around or let's think about it in pro rata that let's ensure that they can get a safer residence first*."

A significant proportion of occupants (i.e., 55%) said that they were not aware of any neighbours with disabilities or vulnerabilities. However, none of these occupants was aware of any help or support their disabled or vulnerable neighbours would need in the case of fire occurrence. Moreover, occupants stated less awareness of the different strategies regarding BSM and control

room operators. In addition, 55.7% of occupants declared not being aware of the different evacuation strategies for HRRB in case of fires. This highlights a significant gap regarding the effective information that they are receiving on these strategies. Interestingly, besides stay-put, they also considered defend-in-place as the most familiar strategy for them, reaching a higher consensus. Consequently, occupants demonstrated higher awareness of defend-in-place than control room operators according to their means (i.e., 2.44 and 3.03, respectively). Probably, the reason is that defend-in-place is significantly understood as a synonym of stay-put for occupants. An immediate evacuation was also the least familiar strategy with the control room operators and BSM.

100% of the BSMs interviewed agreed that stay-put was the best strategy for occupants with disabilities/vulnerabilities, having the highest frequency responses. BSM preferred defend-in-place to phase/delayed evacuation as the second most fit-for-purpose method. Occupants preferred to defend-in-place and stay-put and phased evacuation as their preferred alternatives. Occupants also demonstrated to be in favour of immediate evacuation for disabled or vulnerable occupants.

100% of the BSM and occupants agreed on considering limiting evacuation by prioritizing stay-put/defend-in-place, followed by phased/delayed evacuation. In general, there is significant room for improvement in the awareness of occupants regarding evacuation strategies. BSM agreed that all occupants with disabilities or vulnerabilities need a PEEP. Moreover, information for each disability or vulnerability in an appropriate format is required, such as braille for the visually impaired and vibrating pager for the hard of hearing, as additional resources for disabled or vulnerable people. However, BSM is not developing any training for disabled or vulnerable occupants for evacuation. Majority of the occupants declare that they do not know which resources are available for people with disabilities or vulnerabilities generally and consider the escape stairs as the main resource available for their evacuation in case of fire.

Only 36% of the occupants interviewed are aware of the dangers associated

with falling debris during evacuation. About 64% of occupants interviewed identified smoke as the main challenge to safe evacuation from a building, followed by bottlenecks of evacuating people in staircases and corridors (55% of occupants interviewed), and confusion if the fire alarm is activated (9% of occupants interviewed). In the case of smoke, occupants highlighted that the impact of it goes beyond the physical issues of breathing and visual difficulties, it also generates emotional issues such as panic, which increase the issues during the evacuation.

This study explored three interconnected hypotheses to examine the factors influencing preparedness and safety outcomes. The first hypothesis investigated whether demographic factors, particularly disability status, significantly influence awareness levels of evacuation strategies. Understanding this relationship is essential for designing tailored communication and training initiatives to improve safety outcomes. The second hypothesis examined whether disability status impacts awareness of specific hazards, such as falling debris, during evacuation. This focus on hazard-specific awareness highlights the importance of addressing unique vulnerabilities in emergency scenarios. The third hypothesis evaluated how enhanced awareness, integration of alert systems, and accommodations for vulnerable populations collectively improve preparedness and building safety management. Together, these hypotheses provide a comprehensive framework for understanding the interplay between individual, infrastructural, and procedural factors in shaping emergency preparedness in high-rise residential buildings.

Hypothesis 1 posited that demographic factors, particularly disability status, significantly influence individuals' actual understanding and self-perceived awareness of evacuation strategies. To assess this, our methodological design deliberately contrasted self-reported awareness (survey) with demonstrated understanding (interviews) across a diverse nationwide sample of building occupants. Results showed no statistically significant differences in self-reported awareness, with ANOVA's p-values exceeding 0.05 across all

categories. However, interview findings revealed a contrast as66% of occupants with no disability status demonstrated unawareness of the evacuation policy specific to their buildings while none of the occupants with vulnerabilities exhibited such unawareness. Moreover, renters exhibited lower awareness of occupants with no disability due to systemic communication barriers, as critical safety information is often directed to landlords rather than tenants. These findings suggest that while self-perceived awareness of evacuation strategies appears uniform, systemic gaps exist in actual understanding, particularly among non-vulnerable groups. The lack of hands-on participation in drills and real-life evacuation exercises exacerbates this issue, diminishing occupants' ability to act effectively in emergencies.

Hypothesis 2 investigated whether disability status significantly influences awareness of specific hazards, such as falling debris, during evacuation. A Chi-Square test was performed to analyze the relationship between disability status and awareness of falling debris dangers, yielding an X^2 of 2.019 with 4 degrees of freedom and a p-value of 0.732. These results support no statistically significant association between disability status and self-perceived awareness. However, a critical discrepancy emerged in the actual understanding assessed during the interviews: while 44% of non-disabled residents were aware of the risks posed by falling debris, none of the disabled residents demonstrated this awareness. Conversely, 100% of disabled residents identified smoke as the primary hazard during evacuation, compared to only 56% of non-disabled residents. This suggests that while disabled occupants may have a heightened awareness of immediate environmental threats, their understanding of secondary but equally dangerous hazards -such as falling debris- remains alarmingly low. This contrast highlights a crucial gap in safety education, particularly for those who may face greater challenges in reacting to such falling debris due to physical or sensory limitations.

Hypothesis 3 proposed that enhanced awareness of evacuation strategies, the integration of effective alert systems, and accommodations for vulnerable populations significantly improve emergency preparedness. Multiple linear

regression was used to assess the impact of these factors on preparedness levels. The model exhibited a strong fit, with an R-squared value of 0.9763, indicating that 97.63% of the variance in preparedness scores is explained by the predictors. The F-statistic of 54.96 ($p = 0.0010$) confirmed the overall significance of the model. Among the predictors, accommodations for vulnerable populations emerged as the only statistically significant factor, with a coefficient of 0.6012 ($p = 0.0149$). This finding indicates that accommodations such as PEEPs, accessible infrastructure, and tailored training, play a critical role in improving preparedness. In contrast, awareness of evacuation strategies ($p = 0.5688$) and integration of alert systems ($p = 0.5638$) did not show significant effects, suggesting that these factors may need to be better implemented or integrated into broader preparedness strategies to achieve meaningful impact. The significant role of accommodations underscores the necessity of inclusive measures to support disabled and vulnerable populations during emergencies.

5. Theoretical Contributions and Practical Implications

The theoretical contributions of this research provide vital insights into the often-overlooked complexities of evacuation strategies in HRRBs, especially those involving disabled and vulnerable populations. This study reveals significant gaps in both awareness of BSM and occupants regarding practical implementation of evacuation strategies and alert systems, challenging the adequacy of existing models and protocols.

The finding that BSMs have a markedly higher awareness of evacuation strategies compared to occupants, particularly in strategies like stay-put which are crucial during emergencies, provides an empirical foundation to revisit stakeholder communication strategies. The significant discrepancy in awareness levels between BSMs and occupants emphasizes the necessity of integrating these practices into management protocols to bridge the awareness gap. Similar trends are observed in Australia, where studies show occupants often lack awareness of evacuation protocols, despite detailed government guidelines. A benchmark to reduce this gap is the community-based disaster education

programs in Japan to address this awareness gap, focusing on drills and multimedia communication.

Findings complement previous studies exclusively focused on alert systems enhancements by demonstrating that those are not sufficient without corresponding increases in awareness and regulatory compliance (Safayet *et al.,* 2021). Moreover, the significant lag in the implementation of evacuation alert systems identified in this study contrasts sharply with the prevalent belief that such systems are widely implemented.

The reluctance of private companies to finance evacuation alert systems, pending legislation argues for policy reforms that incentivize the adoption of advanced alert systems through financial or regulatory support, ensuring better preparedness in HRRBs.

The differentiated evacuation preferences among occupants, particularly disabled or vulnerable groups preferring immediate evacuation contrary to the defend-in-place strategy often recommended by safety protocols, suggest that existing evacuation models may not adequately accommodate the diverse needs of all building residents. Similar heterogeneities have been found in Canada, where defend-in-place strategies are less favored by vulnerable groups who prioritize immediate evacuation. This advances the observations by Eismann (2016) on the complex dynamics of human behaviour in disaster responses, where individual decisions during evacuations can diverge significantly from prescribed behaviours due to varied perceptions of risk and safety. Similar patterns have been found in Germany, where psychological factors significantly impact compliance with evacuation protocols.

The preferences of occupants, particularly disabled or vulnerable groups, towards defend-in-place and stay-put strategies over immediate evacuation highlighted the discussion on designing evacuation strategies that are not only effective but also cognizant of the psychological and physical needs of vulnerable populations.

The preference for less familiar evacuation strategies among certain occupant groups, particularly when contrasted with BSMs' preferences, suggests

a misalignment between the design of evacuation protocols and occupant understanding or trust in these strategies. This calls for a reevaluation of how evacuation strategies are communicated and tailored, ensuring they are both comprehensible and practically applicable to the actual users, which is a gap not typically addressed in standard safety protocols or training.

These contributions highlight the critical need for a multidimensional approach to safety protocols that integrate technological, behavioural, and regulatory perspectives to enhance the overall safety and responsiveness of high-rise building evacuation processes.

The results of this study carry significant practical implications for building safety management, emergency preparedness, and policy development, in the context of HRRBs. These implications address critical gaps in evacuation strategy awareness, the integration of alert systems, and accommodations for disabled or vulnerable populations.

This study identified a notable gap in the awareness of evacuation strategies across HRRB occupants, which underscores the necessity for building managers and safety officials to enhance their educational outreach and training programs. Building managers should implement systems for informing all residents regardless of their housing arrangement about evacuation procedures through accessible channels such as digital platforms, printed materials, and verbal communication to ensure clarity.

The limited implementation of evacuation alert systems, with 71% of BSMs reporting no installation. In case no subsidies are feasible, a phased implementation plan for the installation of alert system may allow to start with most at-risk buildings.

Given the high consensus around defend-in-place strategies among disabled or vulnerable groups and the general preference for immediate evacuation in emergency scenarios, it is critical that PEEPs are reviewed annually and whenever significant changes occur in the building's occupancy. Building management must maintain an up-to-date repository of these plans, ensuring they are accessible to all relevant parties, including emergency responders.

The absence of practice evacuations among occupants further highlights the need for mandatory annual evacuation drills. These drills should include all residents, with special attention given to accommodating the needs of vulnerable groups. Such drills not only familiarize occupants with evacuation procedures but also provide opportunities to gather feedback and refine protocols. In tandem with drills, housing policies must mandate the availability of evacuation instructions in accessible formats, including braille, audio recordings, and translations into common languages spoken by residents. These measures ensure that every occupant has the tools to understand and execute the necessary actions during an emergency.

6. Conclusion

Current work aims to further extend current knowledge regarding egress considerations regarding fire evacuation strategies in HRRB with an emphasis on occupants with disabilities or vulnerabilities. Analysis of knowledge and understanding of evacuation strategies, evacuation alert systems and housing policy information was conducted by using a mixed qualitative (interviews) and quantitative (questionnaires) methodology to occupants living and BSM managing HRRB. Practically, the findings of this research have the potential to influence policy decisions and building management practices that directly affect the safety and wellbeing of HRRB occupants. Overall, this study provides actionable insights for policymakers, building managers, and emergency responders to enhance the preparedness and responsiveness of evacuation procedures in high-rise environments while considering the specific needs of disabled and vulnerable populations.

Regarding the knowledge and understanding of evacuation strategies, occupants are more familiar with the defend-in-place strategy and demonstrated a preference for immediate evacuation when it concerns people with disabilities or vulnerabilities. This finding is closely associated with the fact that there is a significant gap regarding the information that occupants are receiving on these strategies and lack of actively being involved in evacuation drills in their HRRB. A multi-agency approach would be required for keeping updated information in

the premises boxes including housing officers, concierges, and control rooms. BMS demonstrated a significant awareness of most evacuation strategies, except for immediate evacuation.

As evidenced by the interviews, a minority of occupants (18%), declared awareness of evacuation alert systems and only 38% of occupants expressed having awareness of stay-put strategies. This was not the case for BSM interviewed, as they all were aware of them. Still, an important finding was that the majority of the BSM declared that none of the HRRBs they managed had implemented such systems. Some of the managing companies had expressly opposed financing their installation. Quantitative data from occupants and BSM questionnaires highlight that installed systems in the majority of HRRB they live or manage are not adequate alert systems for occupants with disabilities or vulnerabilities.

From the analysis of quantitative and qualitative data a gap was identified concerning the housing policy information regarding occupants with disabilities or vulnerabilities, as the majority of BSM (74%) consider they know the relevant policies adequately whereas majority of occupants (82.9%) consider they do not have specific knowledge in this regard. Effective communication of housing policies could help to inform occupants.

Future research aims to further analyze primary data collected to better understand impact of occupants and BSM perceptions on their decisions and group dynamics.

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TABLES

Table I. Mean and Standard Deviation values from the responses of BSM and occupants regarding their awareness of evacuation strategies Data Set Summary

Evacuation Strategy	Mean* (BSMs)	SD (BSMs)	Mean* (Occupants)	SD (Occupants)	t-statistic	p-value
Defend-in-place	1.52	1.110	2.44	1.366	-4.26	<0.0001
Stay put	1.00	0.000	2.33	1.371	-9.70	<0.0001
Simultaneous evacuation	1.14	0.632	2.69	1.489	-8.77	<0.0001
Phased evacuation	1.20	0.594	2.95	1.459	-10.22	<0.0001
Delayed evacuation	1.34	0.776	3.11	1.530	-9.19	<0.0001
Partial evacuation	1.57	1.065	3.02	1.449	-6.70	<0.0001
High Rise Immediate Resident Evacuation (HIRE)	2.11	1.401	3.41	1.498	-5.02	<0.0001
Immediate Building Evacuation (IBE) commenced	2.14	1.488	3.40	1.537	-4.63	<0.0001

* Likert scale: 5–Not at all aware, 4-Slightly aware, 3-Somewhat aware, 2–Moderately aware, 1-Extremely aware

Table by authors

Table II. Occupants' and BSM' Considerations of best evacuation strategy depending on the type of vulnerability

Evacuation Strategies	**Vulnerability**											
	Visual impairment		Hearing impairment		Language difficulties		Mobility impairment		Learning disabilities		Age-related difficulties	
	O	B	O	B	O	B	O	B	O	B	O	B
Defend-in-place	22%	26%	21%	25%	16%	27%	21%	23%	20%	24%	17%	23%
Stay put	16%	41%	7%	41%	10%	47%	15%	39%	10%	44%	14%	39%
Simultaneous evacuation	7%	5%	17%	7%	21%	5%	10%	5%	17%	8%	16%	3%
Phased evacuation	16%	13%	15%	15%	16%	10%	15%	15%	20%	10%	18%	13%
Delayed evacuation	13%	8%	10%	7%	8%	5%	14%	13%	8%	7%	9%	13%
Partial evacuation	5%	3%	6%	3%	3%	3%	2%	3%	2%	3%	2%	5%
High Rise Immediate Resident Evacuation	11%	3%	11%	3%	11%	3%	14%	3%	11%	3%	13%	3%
Immediate Building Evacuation	9%	0%	11%	0%	14%	0%	9%	0%	10%	0%	9%	0%

O: Occupants, B: BSM

Table by authors

March 3rd, 2025

Dear

Dr. Joseph Lai

Editor-in-Chief

Facilities

Based on the reviewers' comments on the paper, we are submitting a revised version, initially titled " Enhancing Safety and Inclusivity in High-Rise Building Evacuation Strategies: A Comparative Study of Building Safety Manager and Occupant Perspectives". We thank you and the reviewers for the helpful and constructive feedback that you have provided to us.

We are glad one out of the two reviewers is already satisfied with the edits we made. We followed all your suggestions and have made key changes to the manuscript. Please refer to the point-by-point response for further details. We believe these improvements have upgraded the manuscript substantially, and we look forward to hearing from you.

Thank you very much for your consideration.

Sincerely,

The authors

A point-by-point response to reviewers' comments (Reviewers' comments are labeled with R# and in black font. Authors' responses are labeled with A# and in *Italics*):

Note: Pages in the paper are specified by **P**, and lines by **L.**

Response to Reviewer # 1

R2. 1. Originality: Does the paper contain new and significant information adequate to justify publication?: The study has provided new and significant information, especially on high-rise fires. 2. Relationship to Literature: Does the paper demonstrate an adequate understanding of the relevant literature in the field and cite an appropriate range of literature sources? Is any signficant work ignored?: The author did provide relevant literature in the field and amended it based on the comments previously mentioned. 3. Methodology: Is the paper's argument built on an appropriate base of theory, concepts, or other ideas? Has the research or equivalent intellectual work on which the paper is based been well designed? Are the methods employed appropriate?: All methods employed are appropriate and well-designed. 4. Results: Are results presented clearly and analysed appropriately? Do the conclusions adequately tie together the other elements of the paper?: The results are presented clearly and analyzed appropriately. However, I could not access the new Supplementary Material. 5. Implications for research, practice and/or society: Does the paper identify clearly any implications for research, practice and/or society? Does the paper bridge the gap between theory and practice? How can the research be used in practice (economic and commercial impact), in teaching, to influence public policy, in research (contributing to the body of knowledge)? What is the impact upon society (influencing public attitudes, affecting quality of life)? Are these implications consistent with the findings and conclusions of the paper?: ?: Yes, the paper mentions all the implications of the research. It is consistent with the findings and conclusions mentioned in the paper. 6. Quality of Communication: Does the paper clearly express its case, measured against the technical language of the field and the expected knowledge of the journal's readership? Has attention been paid to the clarity of expression and readability, such as sentence structure, jargon use, acronyms, etc.: The paper did discuss all related information with clear and commonly used. All acronyms used are commonly used and include the full name, too.
A2. We are glad the reviewer is fully satisfied with the manuscript. We added the Supplementary Material, accordingly.

Response to Reviewer # 2

R3. The study's hypothesis that demographics like disability status significantly influence awareness levels is unsupported by statistically significant results (ANOVA, $p > 0.05$). This weakens the foundation of the study's claims. While the mixed-methods approach is thorough, the quantitative data (ANOVA and regression) does not directly align with the qualitative findings. For example, uniform awareness levels conflict with interviews indicating significant gaps in stakeholder knowledge.

A3. It is worth noting that the mixed-methods approach proposed was purposely designed to contrast self-perceived awareness (assessed in the surveys) and actual understanding (evaluated in the interviews) when taking into account occupant's vulnerabilities. In this regard, the results in Hypothesis 1 (ANOVA, $p>0.05$) support the gap between self-perceived awareness and actual understanding. Therefore, what the analysis is unraveling is a systematic barrier that diminishes occupants' ability to act effectively in fire emergencies in High-Rise Residential Buildings. Moreover, this gap also explains why Building Safety Managers often overlooks the lack of awareness, considering their reliance on occupants' self-perceived awareness. This methodological design is common in education studies to contrast self-reported and actual knowledge understanding. To explain better this aspect in the manuscript, we edited the Methods and Results sections as follows:

In the revised **3. Methods** section

This research employed a sequential mixed-methods approach, incorporating both quantitative (survey) and qualitative (interview) data collection techniques to explore the efficacy and awareness of evacuation strategies and alert systems in HRRBs, especially concerning the inclusion and safety of disabled or vulnerable groups. Data collection followed a structured sequence: first, self-reported awareness through a questionnaire survey, and subsequently, interviews were conducted to evaluate participants' actual understanding of evacuation hazards and procedures. This two-stage approach enabled a comprehensive analysis by identifying gaps between perceived and demonstrated awareness.

3.1 Questionnaire Survey

The first phase of data collection involved a questionnaire survey, designed to capture self-reported awareness of evacuation strategies and hazards among participants. Data from ….

3.2 Group Interviews

After the survey phase, semi-structured interviews were conducted to further investigate participants' understanding of key evacuation hazards beyond their self-reported awareness. These interviews aim to provide an in-depth exploration of potential knowledge gaps.

In the 4. **Results** section

In the "**Considerations regarding occupants' vulnerabilities**" subsection

Hypothesis 1 posited that demographic factors, particularly disability status, significantly influence individuals' actual understanding and self-perceived awareness of evacuation strategies. To assess this, our methodological design deliberately contrasted self-reported awareness (survey) with demonstrated understanding (interviews) across a

diverse nationwide sample of building occupants. Results showed no statistically significant differences in self-reported awareness, with ANOVA's p-values exceeding 0.05 across all categories. However, interview findings revealed a contrast as 66% of occupants with no disability status demonstrated unawareness of the evacuation policy specific to their buildings while none of the occupants with vulnerabilities exhibited such unawareness. Moreover, renters exhibited lower awareness of occupants with no disability due to systemic communication barriers, as critical safety information is often directed to landlords rather than tenants. These findings suggest that while self-perceived awareness of evacuation strategies appears uniform, systemic gaps exist in actual understanding, particularly among non-vulnerable groups. The lack of hands-on participation in drills and real-life evacuation exercises exacerbates this issue, diminishing occupants' ability to act effectively in emergencies.

R4. Although the study highlights a gap in policy awareness, this does not represent a novel scientific advance but reiterates known issues in evacuation strategy implementation.
The methodology for selecting participants lacks detail, particularly for ensuring diversity in the sample. For example, the number of BSM respondents is low (n=7), which limits generalizability.

A4. We acknowledge that interviewing seven Building Safety Managers (BSMs) may appear to be a small sample size. However, we emphasize that their representativeness and expertise make them highly suitable for this study. Each of these BSMs has managed between 22,000 and 75,000 properties in high-rise residential buildings, providing a comprehensive and authoritative perspective on evacuation policies and implementation challenges.
Additionally, their geographical distribution enhances the generalizability of our findings, as they represent key urban and regional areas across the UK: two in London, two in Manchester, one in Cambridge, one in Scotland, and one in the West Midlands. This ensures that our study captures insights from a diverse range of high-rise residential settings in the UK, reflecting variations in policy implementation, building types, and local regulatory approaches.
Overall, the depth of expertise and the scale of properties managed by these participants provide a strong and meaningful foundation for understanding the systemic gaps in evacuation strategies and policy awareness.
Moreover, it is worth noting that the first methodological phase involved quantitative surveys with 51 Building Safety Managers before the qualitative phase based on the interviews.

R5. Phrases like "this research bridges substantial knowledge gaps" and "redefines requirements for effective evacuation" are overly self-promotional and lack evidence-based justification.

A5. We recognize the importance of maintaining an evidence-based tone throughout the study. In response to this concern, we have carefully edited the **Introduction** section to ensure that the language remains focused on the research's contributions while being grounded in the findings. Please see the edited the **Introduction** section:
This study aims to bridge these gaps by examining the awareness and effectiveness of evacuation

strategies and alert systems in HRRBs, with a focus on the inclusion and safety of disabled and vulnerable populations. By contrasting the viewpoints of both BSMs and occupants, this research contributes to the literature on disaster preparedness and response in urban settings, expanding the understanding of how HRRB evacuation strategies can be optimized for inclusivity and effectiveness.

R6. The regression analysis highlights accommodations as the most significant predictor (p = 0.0149), but the lack of significant findings for other predictors undermines the emphasis on systemic gaps.

A6. As explained in our answer to **R3**, the mixed-methods approach proposed was purposely designed in order to contrast self-perceived awareness (assessed in the surveys) and actual understanding (evaluated in the interviews). This supports the findings of Hypotheses 1 and 2 supports the claim of systemic gaps between self-perceived awareness and actual understanding, while Hypothesis 3 (p=0.0149) found systemic gaps in self-perceived awareness. To explain better this aspect in the manuscript, we improved the explanation of Hypothesis 1 findings (as shown in our answer to **R3**), while the Hypothesis 2 explanation was also improved as follows:

Hypothesis 2 investigated whether disability status significantly influences awareness of specific hazards, such as falling debris, during evacuation. A Chi-Square test was performed to analyze the relationship between disability status and awareness of falling debris dangers, yielding an X^2 of 2.019 with 4 degrees of freedom and a p-value of 0.732. These results support no statistically significant association between disability status and self-perceived awareness. However, a critical discrepancy emerged in the actual understanding assessed during the interviews: while 44% of non-disabled residents were aware of the risks posed by falling debris, none of the disabled residents demonstrated this awareness. Conversely, 100% of disabled residents identified smoke as the primary hazard during evacuation, compared to only 56% of non-disabled residents. This suggests that while disabled occupants may have a heightened awareness of immediate environmental threats, their understanding of secondary but equally dangerous hazards -such as falling debris- remains alarmingly low. This contrast highlights a crucial gap in safety education, particularly for those who may face greater challenges in reacting to such falling debris due to physical or sensory limitations.

R7. Conclusions suggesting practical applicability for policy and management lack detailed actionable steps based on study findings.

A7. In order to enhance the practical implications of our findings, we edited the manuscript as follows:

The results of this study carry significant practical implications for building safety management, emergency preparedness, and policy development, in the context of HRRBs. These implications address critical gaps in evacuation strategy awareness, the integration of alert systems, and accommodations for disabled or vulnerable populations.

This study identified a notable gap in the awareness of evacuation strategies across HRRB occupants, which underscores the necessity for building managers and safety officials to enhance their educational outreach and training programs. Building managers should implement systems for informing all residents regardless of their housing arrangement about evacuation procedures through accessible channels such as digital platforms, printed materials, and verbal communication to ensure clarity.

The limited implementation of evacuation alert systems, with 71% of BSMs reporting no installation. In case no subsidies are feasible, a phased implementation plan for the installation of alert system may allow to start with most at-risk buildings.

Given the high consensus around defend-in-place strategies among disabled or vulnerable groups and the general preference for immediate evacuation in emergency scenarios, it is critical that PEEPs are reviewed annually and whenever significant changes occur in the building's occupancy. Building management must maintain an up-to-date repository of these plans, ensuring they are accessible to all relevant parties, including emergency responders.

The absence of practice evacuations among occupants further highlights the need for mandatory annual evacuation drills. These drills should include all residents, with special attention given to accommodating the needs of vulnerable groups. Such drills not only familiarize occupants with evacuation procedures but also provide opportunities to gather feedback and refine protocols. In tandem with drills, housing policies must mandate the availability of evacuation instructions in accessible formats, including braille, audio recordings, and translations into common languages spoken by residents. These measures ensure that every occupant has the tools to understand and execute the necessary actions during an emergency.

R8. The results tables are not sufficiently detailed to allow verification. For instance, Table I's means and standard deviations do not adequately support claims of significant differences in strategy awareness.

A8. We thank the reviewer for the valuable feedback. We have now updated Table I to include the t-statistic and p-value for each evacuation strategy, providing a more detailed statistical comparison between Building Safety Managers (BSMs) and Occupants. These additions allow for a clearer verification of the significant differences in strategy awareness, reinforcing our claims. The revised table explicitly demonstrates that all differences are statistically significant ($p < 0.0001$ across all strategies), ensuring transparency and rigor in our analysis. Please see below the updated analysis:

In the "**4.1.Awareness of evacuation strategies**" subsection

BSM demonstrated a significantly greater awareness of all evacuation strategies compared to occupants (Table I). However, their awareness was notably varied for immediate evacuation strategies, according to the higher mean values (2.11 and 2.14) and substantial standard deviations ($\sigma>1.4$) (Table I). Occupants demonstrated moderate awareness of defend-in-place according to their means (2.44), which can be explained considering that defend-in-place is significantly understood as a synonym of stay-put for occupants. An immediate evacuation was also the least familiar strategy with BSM. Occupants preferred to defend-in-place, stay-put, and phased evacuation as their preferred alternatives.

Table I. Mean and Standard Deviation values from the responses of BSM and occupants regarding their awareness of evacuation strategies Data Set Summary

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* Likert scale: 5–Not at all aware, 4-Slightly aware, 3-Somewhat aware, 2–Moderately aware, 1-Extremely aware

Table by authors

R9. The focus on legislation-based adoption of alert systems overlooks real-world feasibility issues, such as technical compatibility with existing infrastructure.

A9. To address this, we have refined our discussion on evacuation alert systems to emphasize the

core principles behind the recommendations rather than focusing exclusively on specific legislative mandates. By doing so, our analysis remains relevant beyond a single regulatory framework and is more applicable to diverse contexts, including countries with different fire safety policies and building infrastructures.
Our study highlights critical challenges related to implementation, including the reluctance of private stakeholders to invest in these systems without legal mandates, concerns about false alarms, and the need for tailored solutions that accommodate the needs of vulnerable populations. Furthermore, our findings suggest that adapting existing infrastructure—such as repurposing communal alert systems—may provide a feasible pathway for gradual adoption. This perspective ensures that our analysis remains applicable to a wide range of real-world scenarios while still recognizing the importance of structured evacuation alerts in improving fire safety outcomes.

Previously subsection "4.2. Evacuation alert systems" started with:
Although it is generally acknowledged that the increased use of domestic smoke alarms has resulted in a reduction in the number of household fires [16], there is a lack of scientific research evidence to reveal the impact of alert systems on evacuation strategies in the UK. Overall, there is low awareness of evacuation alert systems for HRRB as ruled in the BS8629.

The updated version of the manuscript is:
Although it is generally acknowledged that the increased use of domestic smoke alarms has resulted in a reduction in the number of household fires [16], there is a lack of scientific research evidence to reveal the impact of alert systems on evacuation strategies in the UK. Overall, there is low awareness of dedicated, tamper-proof evacuation alert systems recommended to ensure clear, managed evacuation signals for emergency responders and prioritize accessibility for vulnerable populations.

R10. Methodological and Analytical
1: Lack of a control group or baseline for comparison in evacuation awareness studies diminishes result validity.

A10. We fully acknowledge the importance of baseline comparisons in establishing the validity of research findings. However, we would like to clarify that the purposeful design of our mixed-methods approach was aimed at contrasting self-perceived awareness (assessed through the surveys) with actual understanding (evaluated through the interviews), rather than directly comparing groups with a control (as detailed in our answers to **R3** and **R6)**. This design was deliberately chosen to explore the gap between perceived and demonstrated knowledge, which is critical in the context of fire safety awareness in High-Rise Residential Buildings (HRRBs).
In this study, all participants reside in HRRBs and are subjected to similar environmental and structural factors (such as evacuation strategies, fire hazards, and building policies). The focus of the study was on the awareness and understanding of evacuation strategies within this shared context. Introducing a control group with a different context (e.g., participants from different building types or non-residential settings) would introduce variables that could dilute the results. Instead, we opted for a comprehensive approach that focused on differences within the same context (HRRBs), as this is where the awareness gaps are most relevant and impactful.
Rather than comparing different groups, our study was designed to identify within-group differences, such as how occupants' self-reported awareness (from surveys) did not align with their demonstrated understanding (from interviews). Our interest lies in the differences across various types of occupants, including those with disabilities, renters, and owners, to understand how their awareness levels vary within the same environment. This emphasis on within-group comparisons

underscores that the main research aim is to assess awareness gaps, not compare groups that have inherently different contexts (e.g., different building types, geographic locations).

R11. 2: The limited regional scope (UK-centric) reduces the generalizability of findings to global contexts.

A11. While the study focuses on the UK, its findings are broadly applicable to global HRRB evacuation challenges. UK's leadership in fire safety regulation, the heterogeneous participant pool from diverse urban areas, and the universal nature of evacuation awareness and preparedness gaps ensure that the insights gained are highly transferable to other international contexts. Thus, rather than being a limitation, the UK-centric focus strengthens the study's impact on global HRRB safety discourse.

The UK's leadership in HRRB fire safety policy and evacuation strategy development makes it an ideal case study for understanding best practices and challenges in high-rise residential evacuations. While the study focuses on the UK, its findings have broad relevance to other countries, particularly those with high-density urban housing and evolving fire safety regulations. The UK has been at the forefront of fire safety research, regulations, and policy reforms, particularly following major fire incidents such as the Grenfell Tower tragedy.

Although the study is UK-focused, it incorporates diverse geographical perspectives within the UK, enhancing its applicability to a variety of high-rise settings, including large urban centers (e.g., London, Manchester) and smaller cities (e.g., Cambridge, West Midlands, Scotland).

The inclusion of these heterogeneous locations ensures the study does not focus solely on one type of high-rise setting but instead accounts for varied building typologies, socioeconomic backgrounds, and governance structures—making the findings transferable to other international contexts with similar urban structures.

The UK shares key high-rise residential fire safety challenges with many global urban environments, including (1) aging building stock with fire safety concerns (similar to New York, Toronto, Paris, Hong Kong) and (2) policy transitions from passive to active evacuation strategies (mirroring discussions in countries such as Germany, Australia, and the UAE).

R12. 3: Over-reliance on qualitative data from a small sample (interviews) may lead to bias in identifying awareness gaps.

A12. It is worth noting that the methodological approach was purposely designed to prevent exclusive reliance on qualitative interviews (as explained in our answer to **R4**). Our study employed a sequential mixed-methods approach, which strategically combines the strengths of both quantitative and qualitative data collection. The quantitative phase (the survey) allowed us to obtain broad, statistical insights into self-reported awareness across a large sample (127 occupants and 51 Building Safety Managers). This was essential for understanding overall trends and patterns in evacuation awareness. The qualitative phase, using semi-structured interviews, served to complement the survey data by offering deeper insights into the actual understanding of evacuation strategies, especially when considering the complexities introduced by participants' vulnerabilities. This two-stage process was designed to provide a holistic view of the research topic, with the interviews being a necessary component to reveal the nuanced gaps between perceived and demonstrated awareness.

The qualitative interviews involved multiple stakeholder groups, including tenants with and without disabilities, as well as BSMs. The inclusion of diverse perspectives provided a comprehensive exploration of awareness gaps that could not be fully captured through quantitative data alone. While the interview sample size might seem small (18 interviewees), the diversity of the groups provided rich insights, enabling us to discern significant patterns in the understanding of evacuation strategies. Moreover, the interviewees came from various geographical regions, adding to the representativeness of the data. Through cross-case analysis, we were able to draw meaningful comparisons between different groups, such as tenants versus BSMs, and vulnerable versus non-vulnerable groups, providing a deep understanding of how awareness gaps manifest

across different populations.
We took specific steps to minimize any potential bias in the qualitative data analysis. All interviews were recorded and transcribed verbatim, and two members of the research team conducted the interviews to ensure consistency and reliability in data collection. Additionally, the qualitative analysis involved a rigorous coding process, with a focus on identifying patterns across stakeholder groups and taking into account factors such as age, disability status, and housing situation. The use of QSR NVivo allowed for a systematic comparison of responses across multiple cases, reducing the risk of overemphasis on any one participant's view and ensuring that the findings were not skewed by individual biases.
It is also important to recognize that the qualitative component was never intended to be representative of the entire population, but rather to explore in-depth the awareness gaps identified in the survey phase. Qualitative research is not always about achieving statistical generalizability; instead, it is about gaining insights into complex issues that cannot be captured by quantitative data alone. The small sample allowed for a more focused exploration of specific issues related to vulnerable groups and the practical challenges of evacuation, which are crucial for informing future policy and safety measures.
In evacuation research, particularly in the context of high-rise residential buildings with diverse occupants, understanding the context of awareness is critical. A small sample size in the qualitative phase allowed for an in-depth examination of context-specific factors, such as how tenants' vulnerabilities (e.g., disability status, housing tenure) influence their understanding of evacuation procedures. These factors are not easily captured through large-scale surveys alone, and would have likely been overlooked without the qualitative follow-up. By contrasting these perspectives with the survey data, we were able to identify systemic gaps in the communication and dissemination of evacuation strategies.

R13. 4: Inadequate exploration of cultural or socioeconomic factors influencing evacuation strategy awareness.

A13. To maintain the rigor and depth of the analysis, this study adopted a targeted approach that prioritized the most pressing factors influencing evacuation awareness—namely, disability and physical vulnerability. Exploring cultural and socioeconomic influences in depth would have expanded the research beyond its feasible scope, requiring a different methodological framework and additional data collection to adequately capture the complexity of sociocultural variables. Given the need for a focused and actionable investigation, the study intentionally narrowed its scope to evacuation awareness among vulnerable populations, ensuring a comprehensive and meaningful analysis within this domain.
While the study did not directly explore cultural or socioeconomic factors, these elements were indirectly incorporated through the demographic data collected. For example, participants were asked about their housing tenure, which provides insight into socioeconomic status. A large portion of the occupant sample (64.6%) were tenants, which implies a potentially different relationship to evacuation information compared to homeowners, as tenants may have limited control over building safety measures and may not be the primary recipients of safety communication (which often targets landlords or building managers). Additionally, the study highlighted how renters (who tend to come from a broader socioeconomic spectrum) exhibited lower awareness of evacuation strategies, which can be linked to the systemic communication barriers they face in receiving safety information. This finding suggests that socioeconomic status indirectly plays a significant role in awareness and accessibility, even if it was not explored as a standalone factor in the research.
The research considered vulnerable populations, including individuals with disabilities or long-term health conditions, who may face distinct cultural and socioeconomic challenges in emergency situations. For example, disabled residents or those with health conditions may face communication barriers related to their specific needs, whether these are cultural or socioeconomic in nature. While the study didn't conduct a formal analysis of cultural backgrounds, we did recognize that vulnerabilities (e.g., sensory impairments, mobility issues) can overlap with socioeconomic status, particularly in how individuals access or are excluded from safety information. Moreover, the group of Building Safety Managers (BSMs) interviewed were asked questions related to the inclusion of vulnerable groups, which can indirectly highlight how cultural

and socioeconomic factors are integrated into safety protocols.

R14. 5: Absence of real-world drill data to corroborate theoretical evacuation scenarios and preferences.

A14. A real-world drill component was not included in this study due to practical, ethical, and methodological considerations, but this does not diminish the validity of the findings. Conducting full-scale evacuation drills in High-Rise Residential Buildings, particularly involving vulnerable populations (e.g., individuals with disabilities, elderly residents, families with young children), raises ethical and safety concerns in terms of potential health risks. For individuals with limited mobility, sensory impairments, or chronic conditions, participating in an evacuation drill could pose physical risks, particularly if evacuation routes involve stairs rather than elevators.

The sequential mixed-methods approach used in this study is a well-established method in risk perception and safety research, allowing for a robust assessment of evacuation awareness without the need for real-world drills.
Moreover, drills are often impractical in real-world settings, particularly in high-occupancy high-rise residential buildings. Even if real-world drills were feasible, they often fail to fully replicate emergency conditions because occupants may treat the drill as a low-risk exercise, making more rational choices than they would in a high-stress real emergency (e.g., failing to account for panic, congestion, smoke, or limited visibility). Participants know they are being observed, leading to a Hawthorne effect where they behave differently than they would in an actual crisis. A drill involving vulnerable residents would require emergency personnel to assist or provide guidance, whereas in a real fire scenario, residents may have to act independently under intense pressure. Given these limitations, a drill alone would not fully capture the gaps in evacuation awareness that were uncovered through the study's mixed-methods approach.

Supplementary Material

Survey Design

Questionnaire for Building Managers

The data will be anonymised. The participants will be identified by the category and name provided only if they ask for access to the information provided or requested the destruction of that information.

Name: _____

1. Gender
- Male
- Female
- Other
- Prefer not to say

2. How many years have you been working as a Building Manager?
- Less than 3 years
- 4-9 years
- More than 10 years

3. How many HRRBs do you currently manage?
- Only 1
- 2 – 5
- More than 5

4. What type of staircase HRRB are you managing?
Please tick many, if you are managing more than one building.
- Single staircase HRRB
- Dual staircase HRRB
- Multi staircase HRRB
- Do not know

5. Have you experienced any fire evacuations in HRRB in the past?
- Yes
- No

6. How do the occupants know, in general, when to evacuate in case of a fire?
- Fire alarm
- Neighbour prompt
- Smoke
- Flames
- Smell
- Other

7. Have you been given training to building occupants on fire evacuation?
- Yes
- No

8. If you answered YES to the above question, how long ago?

- 1-2 years
- 3-5 years
- More than 5 years

9. How often the training occurs?
- Every year
- Every 2-3 years
- Every 4-5 years
- Every 6 years or more

10. If training occurs occasionally or frequently, who organises it?
Please tick as appropriate
- In-house training
- Outsourced training
- Other (Please specify) ……

11. What is your role as a building manager in case of a fire evacuation?
Please tick as appropriate
- Give information to fire fighters/officers
- Take part in decision making
- Check from legislation
- Other (Please specify) ……

12. Are you aware of the different evacuation strategies for HRRB in case of a fire incident?
- Yes
- No

13. Is adequate information provided to occupants regarding the evacuation of their building in case of a fire?
- Yes
- No

14. If you answered YES to the above question, in what form is that information provided?
- Written
- Paper based
- Premise's Information Box (PIB)
- MODAS
- Oral/General briefing
- HRRB Register
- Any other

15. Are you aware of any of the following strategies?

	Level of awareness				
Evacuation strategy	Not at all aware 1	Slightly aware 2	Somewhat aware 3	Moderately aware 4	Extremely aware 5
Defend-in-place *(sometimes referred to 'stay-*	☐	☐	☐	☐	☐

in-place' in): a strategy which seeks to minimise the number of people evacuating by instructing occupants to remain in their homes, close and seal doors, and do not evacuate unless directed.					
Stay put: *where all residents not directly affected by a fire are expected to remain in their flat.*	☐	☐	☐	☐	☐
Simultaneous evacuation: *where all occupants vacate the building at the same time regardless of what threat they are exposed to prior to evacuation*	☐	☐	☐	☐	☐
Phased evacuation: *where only occupants who are at an elevated risk are initially evacuated (such as those in the immediate vicinity of the fire), while others remain in place for later evacuation*	¨	☐	☐	☐	☐
Delayed evacuation: *where occupants who need assistance to*	☐	☐	☐	☐	☐

evacuate wait in designated refuge areas to be rescued					
Partial evacuation: *where only a proportion of occupants are immediately evacuated, while others move to or remain in a place or area of safety.*	☐	☐	☐	☐	☐
High Rise Immediate Resident Evacuation (HIRE): *procedure for the management of emergency evacuation of a high rise building where the decision to move from 'stay put' to full evacuation is required.*	☐	☐	☐	☐	☐
Immediate Building Evacuation (IBE): *If it is determined by an Incident Commander that a building which would be expected to have a stay put strategy in place, requires immediate evacuation due to the building not behaving as would be*	..	☐	☐	☐	☐

expected, the IC can send an IBE message to control room, then all occupants of the building are assumed as at risk and evacuation is commenced.					

16. Which strategy/ies is in place in the buildings you are managing in case of a fire? Please tick relevant boxes.

- Defend-in-place (sometimes referred to 'stay-in-place' in): a strategy which seeks to minimise the number of people evacuating by instructing occupants to remain in their homes, close and seal doors, and do not evacuate unless directed.
- Stay put: where all residents not directly affected by a fire are expected to remain in their flat.
- Simultaneous evacuation: where all occupants vacate the building at the same time regardless of what threat they are exposed to prior to evacuation
- Phased evacuation: where only occupants who are at an elevated risk are initially evacuated (such as those in the immediate vicinity of the fire), while others remain in place for later evacuation
- Delayed evacuation: where occupants who need assistance to evacuate wait in designated refuge areas to be rescued
- Partial evacuation: where only a proportion of occupants are immediately evacuated, while others move to or remain in a place or area of safety.
- High Rise Immediate Resident Evacuation (HIRE): procedure for the management of emergency evacuation of a high rise building where the decision to move from 'stay put' to full evacuation is required.
- Immediate Building Evacuation (IBE): If it is determined by an Incident Commander that a building which would be expected to have a stay put strategy in place, requires immediate evacuation due to the building not behaving as would be expected, the IC can send an IBE message to control room, then all occupants of the building are assumed as at risk and evacuation is commenced.
- I do not know

17. During fire evacuation what preparation/resources are in place to ensure occupants' safety?

- Identify the nearest EXIT door/route
- Evacuation chair for vulnerable people
- Portable fire extinguishers
- Identify the assembly place
- All the above
- None of the above
- Other (Please specify) ……

18. Have you made the occupants aware of the evacuation routes they should follow in case of a fire?

- Yes
- No

19. In your view, what do you think about evacuation routes in the buildings?
- 1. Very clear
- 2. Clear
- 3. Neutral
- 4. Unclear
- 5. Very unclear

20. How often do you revise fire evacuation plans to make sure they are up to date with current government regulations?
- Never
- Annually
- When needed (e.g., in case there is a regulatory change)
- Other (Please specify) ……

21. Who is responsible for revising fire evacuation plans as per government's regulations?
- Building Manager
- Consultant
- Technical service/Facility Manager
- Landlords
- Owners
- Fire Risk Assessor
- Other (Please specify) ……

22. Are you aware of the different housing practice/policy regarding residents with disabilities/vulnerabilities for evacuation purposes?
- Yes
- No

23. In the current building you manage do you have occupants with disabilities/vulnerabilities?
- Visual impairments
- Hearing impairment
- Language difficulties
- Mobility impairment
- Learning disabilities
- Age-related difficulties
- Infants/Children
- Other (Please specify) ……
- Do not know

24. What is the procedure you have in your building for the occupants to declare disability/vulnerability?
- Rent contract
- Local Authority register
- Check list
- Other (Please specify) ……
- Do not know

25. Is adequate information made available regarding different housing practice/policy for residents with disabilities/vulnerabilities?

- Yes
- No
- Do not know

26. What support/resources are available for people with disabilities/vulnerabilities in the buildings that you manage?

Please, tick as appropriate.

Disability /Vulnerability	Support	Tick all that applies
Person with visual impairments	Fire Marshal Personal Emergency Evacuation Plan (PEEP) Person in charge Audio/Instructions Handrails on the escape stairs Tactile map of the escape routes Step edge markings on the escape stairs Colour contrasting on stairways Information on Braille Specialist Training	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Person with a hearing impairment	Fire Marshal Personal Emergency Evacuation Plan (PEEP Vibrating pager Visual alarm system Text messaging Local beacon Person in charge Training	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Mobility Impairment (Including people who have heart disease, asthma or heart conditions)	Fire Marshal Personal Emergency Evacuation Plan (PEEP) Handrails on the escape stairs Evacuation Chairs Evacuate lifts Training	☐ ☐ ☐ ☐ ☐ ☐
Learning disabilities	Fire Marshal Personal Emergency Evacuation Plan (PEEP) Fire instructions provided in accessible formats Step edge markings on the escape stairs Person in charge Training	.. ..

Age-related Difficulties	Fire Marshal Personal Emergency Evacuation Plan (PEEP) Handrails on the escape stairs Evacuation Chairs Evacuate lifts Person in charge Audio/Instructions Handrails on the escape stairs Step edge markings on the escape stairs Colour contrasting on stairways Vibrating pager Visual alarm system Text messaging Local beacon Training	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

27. Which evacuation strategy do you think best fit for people with disabilities/vulnerabilities? Tick the relevant box/es.

Evacuation strategy	**Disability/vulnerability**					
	Person with visual impairment	**Person with a hearing impairment**	**Language Difficulties**	**Mobility Impairment**	**Learning disabilities**	**Age-related Difficulties**
Defend-in-place *(sometimes referred to 'stay-in-place' in): a strategy which seeks to minimise the number of people evacuating by instructing occupants to remain in their homes, close and seal doors, and do not evacuate unless directed.*	☐	☐	☐	☐	☐	☐
Stay put: *where all residents not directly affected by a fire are expected to remain in their flat.*	☐	☐	☐	☐	☐	☐
Simultaneous evacuation: *where all occupants vacate the building at the same time regardless of what threat they are exposed to prior to evacuation*	☐	☐	☐	☐	☐	☐
Phased evacuation: *where only occupants who are at an elevated risk are initially evacuated (such as those in the immediate vicinity of the fire), while others remain in place for later evacuation*	☐	☐	☐	☐	☐	☐
Delayed evacuation: *where occupants who need assistance to evacuate wait in designated refuge areas to be rescued*	☐	☐	☐	☐	☐	☐

Partial evacuation: *where only a proportion of occupants are immediately evacuated, while others move to or remain in a place or area of safety.*	☐	☐	☐	☐	☐	☐
High Rise Immediate Resident Evacuation (HIRE): *procedure for the management of emergency evacuation of a high rise building where the decision to move from 'stay put' to full evacuation is required.*	☐	☐	☐	☐	☐	☐
Immediate Building Evacuation (IBE): *If it is determined by an Incident Commander that a building which would be expected to have a stay put strategy in place, requires immediate evacuation due to the building not behaving as would be expected, the IC can send an IBE message to control room, then all occupants of the building are assumed as at risk and evacuation is commenced.*	☐	☐	☐	☐	☐	☐

28. Which of the following building features do you think are a best fit for people with disabilities/vulnerabilities?
Tick the relevant box/es.

Building feature	Disability/vulnerability					
	Person with visual impairment	Person with a hearing impairment	Language difficulties	Mobility impairment	Learning disabilities	Age-related difficulties
Use of Refuge Areas	☐	☐	☐	☐	☐	☐
Use of Fire Evacuation Lifts	☐	☐	☐	☐	☐	☐
Use of stairwells	☐	☐	☐	☐	☐	☐

29. While evacuating a building is it important for the occupants to be aware of the associated hazards with falling debris?

- 1. Strongly disagree
- 2. Disagree
- 3. Neither agree or disagree
- 4. Agree
- 5. Strongly agree

30. In your buildings have the occupants been given information about a 'safe zone'/assembly point (where to go to be safe) when they evacuate a building in case of a fire?

- Yes
- No

31. Do you know what equipment/resources are available for occupants to mitigate risks in case of fire evacuation?

Please tick as appropriate

- Fire extinguishers
- Sprinklers
- Carry-Chair
- Door seals
- Fire escape ladders
- Evacuation chutes
- Evacuation sheets and sledges
- Escape hoods and masks
- Other (Please specify) ……
- Do not know

32. Which of the following concerns do you have regarding the use of stairwells/staircases during fire evacuation?

- Safety concerns due to fire and smoke entering the stairwells/staircases.
- Poor visibility and navigation due smoke entering the stairwells/staircases.
- Fatigue and evacuation time (especially for higher floor levels).
- Concerns that stairwells/ staircase would be blocked or congested.
- Mobility issues for people with disabilities/vulnerabilities
- Other (Please specify)

Questionnaire for Occupants

The data will be anonymised. The participants will be identified by the category and name provided only if they ask for access to the information provided or requested the destruction of that information.

Name: _____

1. Gender
- Male
- Female
- Other
- Prefer not to say

2. Age
- 18-25
- 26-35
- 36-45
- 46-55
- 56-65
- 65+
- Prefer not to say

3. Are you a British national?
- Yes
- No

4. How would you describe your physical condition?
- Excellent
- Good
- I have a chronic disease
- I have long-term illness, health problem or disability that limits my daily activities
- Prefer not to say

5. Are you a homeowner or a tenant?
- Homeowner
- Tenant
- Other (e.g., Airbnb etc.)

6. How many people live in the apartment?
- 1
- 2
- 3
- 4
- 5
- More than 5

7. Do you have any children under the age of 12 living with you?
- Yes
- No

8. Do you have any older people over the age of 60 living with you?
- Yes
- No

9. How many rooms are in the apartment?
- Studio
- 1 bedroom
- 2 bedrooms
- 3 bedrooms
- More than 3 bedrooms

10. How many storeys has the building you live in?
Type the response here in numbers …….....

11. Which floor do you live in?
Type the number of the floor here in numbers ……...

12. How many staircases does your building have?
- 1
- 2
- 3
- More than 3

13. If you were notified of a fire in your building, which of the following actions will you take immediately?
Tick all that apply
- I will investigate whether there is a real fire
- I will attempt to tackle fire prior to evacuating
- I will call Fire and Rescue Service immediately
- I will alert other residents
- I will evacuate immediately
- I will evacuate after gathering important belongings
- I will spend time ensuring wellbeing of others (including pets)
- I would stay in my apartment with the door shut
- Other

14. Which of the following would make you evacuate your building in case of fire?
Tick all that apply
- Fire alarm
- Smoke
- Flames
- Smell
- Neighbour prompt
- Instruct from a member of the emergency services
- Instruct from a member of the building staff
- Receiving a text message/phone call from stranger/friend/person in authority
- Other

15. Have you been given a copy of your building's fire evacuation plan?
- Yes
- No

16. Are you aware of different evacuation strategies for High Rise Residential Building (HRRB) in case of fires?
- Yes
- No

17. Have you been provided with enough information about strategies to enable you to evacuate from your building in the event of a fire?
- 1. Never • 2. Rarely • 3. Sometimes • 4. Often • 5. Always

18. Are you aware of any of the following strategies?

	Level of awareness			
Evacuation strategy	Not at all aware 1	Slightly aware 2	Somewhat aware 3	Moderately 4
Defend-in-place *(sometimes referred to 'stay-in-place' in): a strategy which seeks to minimise the number of people evacuating by instructing occupants to remain in their homes, close and seal doors, and do not evacuate unless directed.*	☐	☐	☐	☐
Stay put: *where all residents not directly affected by a fire are expected to remain in their flat.*	☐	☐	☐	☐
Simultaneous evacuation: *where all occupants vacate the building at the same time regardless of what threat they are exposed to prior to evacuation*	☐	☐	☐	☐
Phased evacuation: *where only occupants who are at an elevated risk are initially evacuated (such as those in the immediate vicinity of the fire), while others remain in place for later evacuation*	..	☐	☐	☐
Delayed evacuation: *where occupants who need*	☐	☐	☐	☐

assistance to evacuate wait in designated refuge areas to be rescued				
Partial evacuation: *where only a proportion of occupants are immediately evacuated, while others move to or remain in a place or area of safety.*	☐	☐	☐	☐
High Rise Immediate Resident Evacuation (HIRE): *procedure for the management of emergency evacuation of a high rise building where the decision to move from 'stay put' to full evacuation is required.*	☐	☐	☐	☐
Immediate Building Evacuation (IBE): *If it is determined by an Incident Commander that a building which would be expected to have a stay put strategy in place, requires immediate evacuation due to the building not behaving as would be expected, the IC can send an IBE message to control room, then all occupants of the building are assumed as at risk and evacuation is commenced.*	..	☐	☐	☐

19. Which strategy/ies is in place in the buildings you live in, in case of a fire?

- Defend-in-place (sometimes referred to 'stay-in-place' in): a strategy which seeks to minimise the number of people evacuating by instructing occupants to remain in their homes, close and seal doors, and do not evacuate unless directed.
- Stay put: where all residents not directly affected by a fire are expected to remain in their flat.
- Simultaneous evacuation: where all occupants vacate the building at the same time regardless of what threat they are exposed to prior to evacuation.
- Phased evacuation: where only occupants who are at an elevated risk are initially evacuated (such as those in the immediate vicinity of the fire), while others remain in place for later evacuation.
- Delayed evacuation: where occupants who need assistance to evacuate wait in designated refuge areas to be rescued.

- Partial evacuation: where only a proportion of occupants are immediately evacuated, while others move to or remain in a place or area of safety.
- High Rise Immediate Resident Evacuation (HIRE): procedure for the management of emergency evacuation of a high rise building where the decision to move from 'stay put' to full evacuation is required.
- Immediate Building Evacuation (IBE): If it is determined by an Incident Commander that a building which would be expected to have a stay put strategy in place, requires immediate. evacuation due to the building not behaving as would be expected, the IC can send an IBE message to control room, then all occupants of the building are assumed as at risk and evacuation is commenced.
- I do not know.

20. During fire evacuation what preparation/resources do you have to ensure your safety?
- Identify the nearest EXIT door/route
- Evacuation chair for vulnerable people
- Portable fire extinguishers
- Identify the assembly place
- All the above
- None of the above
- Other (Please specify) ……

21. Is adequate information provided (by the building manager or any other relevant personnel) to all the occupants how to evacuate the building in case of fire?
- 1. Never • 2. Rarely • 3. Sometimes • 4. Often • 5. Always

22. Are you aware of the evacuation routes you should follow in case of a fire?
- 1. Not at all aware
- 2. Slightly aware
- 3. Somewhat aware
- 4. Moderate aware
- 5. Extremely aware

23. In your view, what do you think about evacuation routes in your building?
- 1. Very clear
- 2. Clear
- 3. Neutral
- 4. Unclear
- 5. Very unclear

24. Do you or someone living with you have a disability that may have an effect on the evacuation of your building in case of a fire?
- Yes
- No

25. If YES, what type of disabilities/vulnerabilities.
- Hearing impairment
- Language difficulties
- Mobility impairment
- Learning disabilities
- Age-related difficulties
- Other (Please specify) ……

26. Are you aware of the different housing practice/policy regarding residents with disabilities/vulnerabilities for evacuation purposes?

- Yes
- No

27. Is adequate information made available to you regarding the different housing policies for residents with disabilities/vulnerabilities?

- Yes
- No

28. What support/resources are available for people with disabilities/vulnerabilities in the building that you live in?

Please, tick as appropriate.

Disability/Vulnerability	**Support**	**Tick all that applies**
Person with visual impairments	Fire Marshal Personal Emergency Evacuation Plan (PEEP) Person in charge Audio/Instructions Handrails on the escape stairs Tactile map of the escape routes Step edge markings on the escape stairs Colour contrasting on stairways Information on Braille Specialist Training	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Person with a hearing impairment	Fire Marshal Personal Emergency Evacuation Plan (PEEP Vibrating pager Visual alarm system Text messaging Local beacon Person in charge Training	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Mobility Impairment (Including people who have heart disease, asthma or heart conditions)	Fire Marshal Personal Emergency Evacuation Plan (PEEP) Handrails on the escape stairs Evacuation Chairs Evacuate lifts Training	☐ ☐ ☐ ☐ ☐ ☐
Learning disabilities	Fire Marshal Personal Emergency Evacuation Plan (PEEP)	☐ ☐ ☐

	Fire instructions provided in accessible formats Step edge markings on the escape stairs Person in charge Training	☐ ☐ ☐
Age-related Difficulties	Fire Marshal Personal Emergency Evacuation Plan (PEEP) Handrails on the escape stairs Evacuation Chairs Evacuate lifts Person in charge Audio/Instructions Handrails on the escape stairs Step edge markings on the escape stairs Colour contrasting on stairways Vibrating pager Visual alarm system Text messaging Local beacon Training	.. ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ .. ☐ ☐ ☐ ☐

Scenario A

Below is a fictitious situation regarding evacuation techniques.

A big fire of unknown reason has been reported in your building a short time ago, and you can smell and notice the smoke coming out. It has been suggested that the fire will spread fast and is likely to cut off the power supply to the building you live in. People are being advised to evacuate their apartments immediately as the fire is causing fumes to spread fast, and the flames could soon cause explosions to flammable materials. Everyone knows that this time, it is not a drill, tensions are high, and some occupants begin to get visibly upset. The fire brigade has arrived, but fire services are likely to be stretched as they deal with those affected and try to contain the area around the fire. The fire marshals and firefighters cannot provide suitable carriers or special help to the people with disabilities or vulnerabilities to evacuate, and there is no equipment available. Transport, police and ambulances have been provided to help people.

29. Which evacuation strategy do you think best fit for people with disabilities/vulnerabilities? Tick the relevant box/es.

Evacuation strategy	**Disability/vulnerability**					
	Person with visual impairment	**Person with a hearing impairment**	**Language Difficulties**	**Mobility Impairment**	**Learning disabilities**	**Age-related Difficulties**

Defend-in-place *(sometimes referred to 'stay-in-place' in): a strategy which seeks to minimise the number of people evacuating by instructing occupants to remain in their homes, close and seal doors, and do not evacuate unless directed.*	☐	☐	☐	☐	☐	☐
Stay put: *where all residents not directly affected by a fire are expected to remain in their flat.*	☐	☐	☐	☐	☐	☐
Simultaneous evacuation: *where all occupants vacate the building at the same time regardless of what threat they are exposed to prior to evacuation*	☐	☐	☐	☐	☐	☐
Phased evacuation: *where only occupants who are at an elevated risk are initially evacuated (such as those in the immediate vicinity of the fire), while others remain in place for later evacuation*	☐	☐	☐	☐	☐	☐
Delayed evacuation: *where occupants who need assistance to evacuate wait in designated refuge areas to be rescued*	☐	☐	☐	☐	☐	☐
Partial evacuation: *where only a proportion of occupants are immediately evacuated, while others move to or remain in a place or area of safety.*	☐	☐	☐	☐	☐	☐
High Rise Immediate Resident Evacuation (HIRE): *procedure for the*	☐	☐	☐	☐	☐	☐

management of emergency evacuation of a high rise building where the decision to move from 'stay put' to full evacuation is required.						
Immediate Building Evacuation (IBE): *If it is determined by an Incident Commander that a building which would be expected to have a stay put strategy in place, requires immediate evacuation due to the building not behaving as would be expected, the IC can send an IBE message to control room, then all occupants of the building are assumed as at risk and evacuation is commenced.*	..	☐	☐	☐	☐	☐

Scenario B

Below is a fictitious situation regarding falling debris.

A big fire has been reported in your building after an explosion caused by a gas leak a short time ago, and you can smell and notice the smoke coming out. It has been suggested that the fire is likely to cut off major supply routes to the area where you live and that both clean water and food supplies cannot be guaranteed. The explosion that occurred could lead to falling debris. People are being advised to evacuate their homes as soon as possible as the fire is only getting worse and more structural damages are expected. Some occupants and children are getting panicked. The emergency services are likely to be stretched as they deal with those affected, and firefighters attempt to control pockets of fire on the higher floors. Transport has been provided to help people evacuate. The emergency services are able to provide special help to all people with disabilities or vulnerabilities using special equipment. Transport, police and ambulances have been provided to help people outside the building.

30. While evacuating a building, are you aware of the associated hazards with falling debris?
- 1. Not at all aware
- 2. Slightly aware
- 3. Somewhat aware
- 4. Moderate aware
- 5. Extremely aware

31. Have you been given information about a 'safe zone'/assembly point (where to go to be safe) after evacuating the building in case of a fire?

- Yes
- No

32. Do you know what equipment/resources are available to mitigate risks in case of fire evacuation?
Please tick as appropriate
- Fire extinguishers
- Sprinklers
- Carry-Chair
- Door seals
- Fire escape ladders
- Evacuation chutes
- Evacuation sheets and sledges
- Escape hoods and masks
- Other (Please specify) ……
- Do not know

33. Which of the following concerns do you have regarding use of stairwells/staircases during fire evacuation?
- Safety concerns due to fire and smoke entering the stairwells/staircases.
- Poor visibility and navigation due smoke entering the stairwells/staircases.
- Fatigue and evacuation time (especially for higher floor levels).
- Concerns that stairwells/staircase would be blocked or congested.
- Mobility issues for people with disabilities/vulnerabilities
- Other (Please specify) ……

Interview Questions

This research project is seeking to establish the most effective methods of evacuating high-rise residential buildings and is focusing on how residents behave and make decisions about evacuation in a fire situation. We are aiming to engage and include a wide range of occupants to ensure we capture and use the valuable information to enhance our research. Based on this insight we will devise, test, and validate a range of evacuation strategies.

Egress Considerations

1. Do you know what is the current evacuation strategy for your building? If so, can you describe it? What actions does the evacuation strategy suggest you should take? Are there particular parts that are clear? Unclear? Can you tell me which parts? Why do you find them clear/unclear?

2. Can you please tell us about yours and your family experience(s) of having been involved in practising evacuation in your building? [If any have been in a practise evacuation of the building]

3. Can you describe what happened? What can be done to improve the evacuation strategy?

4. Have you ever been involved in evacuation because of a fire incident in your HRRB [Building] or block of flats? Can you please tell us about your experience during the evacuation? Why do you think you reacted that way? What improvements can you suggest here?

5. Once you are outside the building, do you know a safe place where you can go to? Have you identified this yourself? If so, how?

6. Do you know whether your HRRB has an evacuation assembly point? If so, where is it located?

7. During a fire incident, where there is a need for evacuation, are you aware of the dangers associated with falling debris? What are the main challenges to safe evacuation from this building?

8. Are you aware of the safe route to use during an evacuation of the building during a fire incident particularly from falling debris?

Prevalence of Evacuation Alert Systems

Definition of evacuation alert systems

9. Are you aware of evacuation alert systems for HRRBs or block of flats?

10. Do you know whether your building has one fitted?

11. In your opinion, do you think such a system will improve evacuation procedures? Why?

Housing Practice/Policy With Regard to Resident's Vulnerabilities Impact on Evacuation Strategies

12. Are you aware of any housing policies with regard to residents' vulnerabilities where you live? If so, can you describe it?

13. In your view, does the policy in place support effective evacuation for the residents with vulnerabilities? Why do you think so?

14. Do you know if any of your neighbours have any vulnerabilities that may affect their safe evacuation from fire? If so, can you describe it?

15. Do you know of any help or support they would need help in case of fire occurrence? If so, can you describe it? Is there anything that you would change/improve?

16. As you know, we are going to be developing strategies to assist those who might experience a fire in the future. Think back on your experiences and our discussions today and tell us what we can do to improve the safety of residents of HRRB or block of flats during a fire.

Is there anything else that anyone feels that we should have talked about but didn't?

Coding Process of Interviews in NVivo

The following subsections will develop each of the steps of the interview process and analysis, Figure S1. The coding process involved in-depth exploration of the interview comments so filtering only the most meaningful contributions, based on content and contextual analysis. This micro-analysis enhances awareness of the contributions of each respondent and lessens biased analysis based on preconceptions. The information gathered for each of the codes was re-read to develop findings and recommendations.

To comprehensively explore the interviewees' insights, different interview protocols were designed to steer in-depth semi-structured interviews for building safety managers and occupants, respectively. A semi-structured methodology is useful for its flexibility for gathering further information and clarification during the interview. Each interview protocol was made of open-ended questions enabling stakeholders to provide the deepest information possible for each one of the sections established. The qualitative analysis relies on a systematic coding process used for organising information and developing content and contextual analysis.

Each interview session was also recorded and transcribed in Microsoft Teams. During the meetings, the live automatic transcription performed resulted in more than 40 hours of recorded interviews, with their automatic transcription resulting in almost 700 pages of text. However, the accuracy of the transcriptions could not be guaranteed by automatic transcription algorithms because (1) the software relies on a general language and does not include specific common terms of the firefighters; (2) some interviewees have regional accents as the aim was to interview stakeholders from different regions of the UK; (3) some interviewees spoke quickly, which reduced the accuracy of the software; (4) some interviewees had poor audio quality or low internet quality; (5) some interviewees had ambient noise.

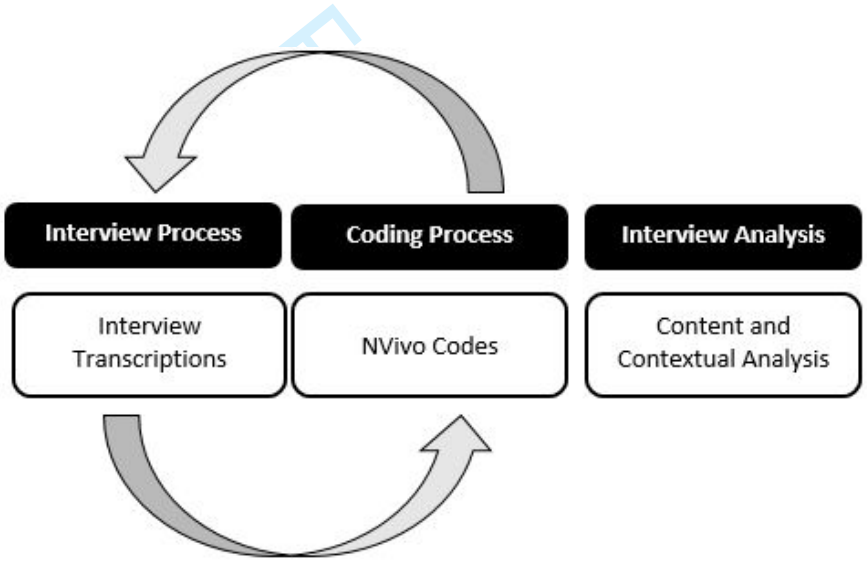

Figure S1. Interviews' methodological approach.

To overcome the accuracy limitations of the automatic transcriptions, an analyst (one of the coauthors) focused on the qualitative analysis interview review of each of the automatic transcriptions by playing the videos and editing the raw transcription to correct the errors. The revision of the transcription is a task that consumes considerable time and resources, but it is necessary to achieve a high-quality analysis. This process allows for greater reliability of the transcripts. A systematic coding procedure was conducted by the analyst to improve the internal validity and reliability of the research using NVivo software. First, the reviewed transcriptions of the interview sessions were imported to NVivo. Second, group interview sessions were unbundled in individual interviewees comments for establishing each interviewee as an individual case. This individualisation enabled cross-case analysis in NVivo, contrasting thoughts among interviewees within the same stakeholder group or across diverse stakeholder groups. Each of the cases had attributes related to their roles and demographics, among other factors. Colours were assigned

to each case to identify its role (e.g., blue for occupants). Third, a comprehensive line-by-line reading of the comments of each interview allowed the identification of patterns relating to each of the sections analysed in the interviews. Nodes were created according to each research question, and sub-codes to each specific question. Each of the nodes allowed storing of the most significant comments of each of the interviews for further analysis in an iterative way. The objective was to code passages to provide enough context.

At the start of the interviews, demographic information was recorded. The BSM were asked to state the years they had worked as a BSM in a high-rise residential building and whether their role included attendance during a fire incident.

The analysis of the interviews utilised a systematic approach where themes were developed from the data. NVivo was used to manage data but the raw data was still accessible. Semi-structured interviews were carried out with participants in a group setting. The interviews were conducted using Microsoft Teams in the following categories, Building Safety Managers (BSM) and Occupants (O).