



Impact of Human Factors in Emergency Evacuations during Building Fires: A Systematic Review

Kiana Rezaeipour¹, Vida Zaroushani^{2,3*}, Mohammad Amerzadeh⁴

- 1. B.Sc. in Occupational Health and Safety Engineering, Dept. of Occupational Health and Safety Engineering, Student Research Committee, School of Public Health, Qazvin University of Medical Sciences, Qazvin, Iran.
- 2. Assistant Prof., Social Determinants of Health Research Center, Research Institute for Prevention of Non-Communicable Diseases, Qazvin University of Medical Sciences, Qazvin, Iran.
- 3. Assistant Prof., Dept. of Occupational Health Engineering, Faculty of Health, Qazvin University Of Medical Sciences, Qazvin, Iran.
- 4. Assistant Prof., Non-communicable Diseases Research Center, Research Institute for Prevention of Non-Communicable Diseases, Qazvin University of Medical Sciences, Qazvin, Iran.



Citation: Rezaeipour K, Zaroushani V, Amerzadeh M. Impact of Human Factors in Emergency Evacuations during Building Fires: A Systematic Review. J Occup Health Epidemiol. 2025;14(3):194-204.

Copyright: © 2025 The Author(s); Published by Rafsanjan University of Medical Sciences. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Article Info

*** Corresponding author:**
Vida Zaroushani,
E-mail:
v.zaroushani@qums.ac.ir

Article history
Received: Nov 2024
Accepted: Mar 2025

10. 61882/johe.14.3.194

Print ISSN: 2251-8096
Online ISSN: 2252-0902

Peer review under responsibility of
Journal of Occupational Health
and Epidemiology

Abstract

Background: Effective emergency response programs are critical for minimizing casualties during fire incidents. This systematic review aims to identify and categorize the human factors affecting emergency evacuations in building fires, providing a comprehensive overview of current knowledge in this field.

Materials and Methods: A comprehensive search was performed for English-language articles published between 2010 and 2022 across PubMed, Science Direct, and Google Scholar, following PRISMA guidelines. The initial search yielded 426 articles, of which 34 studies fulfilled the inclusion criteria following rigorous screening and quality assessment. The final selection included 24 descriptive studies, seven experimental studies, two case studies, and one systematic review, with a concentration of 17 articles from China.

Results: The analysis identified six critical categories of human factors affecting emergency evacuations: demographic and physiological parameters, supportive evacuation tools, individual capabilities, stress and personal characteristics, human behavior, and emergency response plans. Notably, stress and personal characteristics emerged as the most frequently discussed factors, highlighting their substantial impact on evacuation behavior and decision-making processes.

Conclusion: This systematic review underscores the significance of these six human factors in shaping effective emergency evacuations during fire incidents. Insights from this review can inform the development of tailored evacuation strategies, particularly for vulnerable populations such as the elderly and individuals with health challenges. A multidisciplinary approach integrating psychology, sociology, and engineering perspectives is essential for ameliorating evacuation protocols, ultimately aiming to save lives and lower financial losses in emergencies.

Keywords: Behavior, Buildings, Safety, Fire, Emergencies

Introduction

Fires are prevalent incidents that incur substantial economic and social costs while posing serious threats to individual safety. A fire can rapidly jeopardize both property and personal well-being. According to the National Fire Protection Association (NFPA), local fire

departments in the United States responded to approximately 1.5 million fires in 2022, leading to 3,790 fatalities, 13,250 injuries, and an estimated financial loss of \$18 billion [1]. One of the most effective strategies for mitigating the consequences of fire incidents is developing emergency evacuation

plans, which are integral to emergency response programs. To create these plans, it is critical to understand the factors that influence individuals' responses along emergencies [2].

A deeper comprehension of how individuals react during fire emergencies can enhance the design of safer structures. Further, recognizing human behavior in fire situations can support decision-makers in establishing the most effective processes for emergency evacuations [3]. Research into human behavior in fire scenarios is critical, as it has significant implications for individual safety, evacuation management, and disaster preparedness. The term "human behavior in fire" encompasses the actions of individuals during fire incidents, whether in buildings or larger outdoor scenarios, such as wildfires affecting communities. Understanding individual responses along a fire can help authorities guide and evacuate people more efficiently, resulting in improved crisis management [4]. Conducting a systematic review can help identify and categorize the factors affecting emergency evacuations, potentially lowering casualties among both residents and rescue personnel. It can also provide foundational insights based on human behavior to enhance building design and reinforce policies set forth by the International Labor Organization (ILO) [5].

A review of existing literature indicates that previous systematic studies have addressed human factors in a fragmented manner, with no comprehensive studies identified. Earlier reviews suggest that research has primarily focused on various factors affecting emergency evacuations, particularly human factors, but did so in a disjointed fashion. For instance, Mirsaedi et al. (2018) explored factors influencing emergency evacuations during building fires, concluding that evacuation success depends on human characteristics, building features, and fire characteristics. Nevertheless, this study provided only a general overview of the factors, discussing human characteristics mainly in terms of movement speed, while overlooking other relevant dimensions [6].

Another study by Maguire-Koehler et al. (2010) explored building safety and human behavior along fires. They found that critical factors influencing residents' fire response performance include fire characteristics, human factors, and building features. Nonetheless, this study focused exclusively on human behaviors, ignoring other human factors such as demographic characteristics and stress levels [7].

In a different study, Ding et al. (2021) dealt with emergency evacuation behaviors in high-rise buildings. Their findings primarily addressed group behaviors, with less emphasis on individual behaviors and other human factors [8]. Likewise, Selcuk Sater et al. (2020) examined evacuations from tall buildings, reporting a relationship between evacuation time, occupant load, and human behaviors. Nevertheless, this study also

focused solely on human behavior without considering the influence of other human factors, such as demographic characteristics, stress levels, and personal traits during evacuation [9].

Given these observations and the necessity for effective implementation of emergency response programs to minimize casualties in fire incidents, as well as the importance of understanding human factors in the emergency evacuation process, this study aims to undertake a systematic review to identify and classify the human factors affecting emergency evacuations during building fires. It also seeks to address existing research gaps in focused reviews.

Materials and Methods

The search was performed in accordance with PRISMA guidelines in July 2023 using the PubMed and Google Scholar search engines, and in August 2023 in the Science Direct database. English-language articles published from 2010 to 2022 were identified using keywords selected based on the PICO framework, either individually or in combination.

The selection of the time frame from 2010 to 2022 for this systematic review was based on the aim of examining more recent articles and those most relevant from the past 12 years. The objective of this approach was to provide results that are closer to current conditions and new findings, thereby offering a more accurate representation of the present state. Further, based on the conducted searches, no systematic review published prior to 2010 was found that specifically addressed the human factors affecting emergency evacuation.

The some searched keywords included "emergency evacuation AND fire," "fire," "fire AND emergency set," "exit emergency in fire," "human behavior AND fire," "human behavior AND emergency evacuation", "building fire OR workplace fire", "emergency evacuation OR emergency exit", "fire evacuation OR fire exit", and "human behavior in fire."

The evaluation of studies was conducted in two stages. In the first stage, the abstracts of the articles were reviewed based on the inclusion and exclusion criteria. In the second stage, the articles whose abstracts met the criteria were assessed through their full texts and re-evaluated according to the inclusion and exclusion criteria. Ultimately, the eligible studies were included in the analysis phase.

Articles were selected for review if their titles or abstracts contained the terms "emergency evacuation," "fire," and "human." The titles, abstracts, and keywords of the identified articles were meticulously reviewed. To boost the sensitivity of the search, we also utilized keywords and references from the selected articles. Following an initial review of the abstracts, relevant articles were separated from those deemed irrelevant,

with duplicates removed. The full texts of the screened articles were collected, while articles lacking available full texts were excluded.

The screening of articles was conducted according to the inclusion and exclusion criteria displayed in Fig. 1, following PRISMA methodology.

The Hawker tool encompasses nine criteria for ascertaining the quality of articles, addressing elements such as clarity of study objectives, suitable design and analysis, accuracy in data collection, attention to ethical considerations, and transparent presentation of results. The tool developed by Hawker and colleagues was employed to ascertain the quality of qualitative studies. It consists of nine questions, each of which can be rated as "good," "fairly good," "poor," or "very poor." These ratings were then converted into scores ranging from 1 to 4. The minimum possible score for each study is 9,

while the maximum is 36. The quality of the studies was categorized into three levels: high quality (30-36 points), moderate quality (24-29 points), and low quality (9-24 points). Only studies classified as high or moderate quality were included in the final analysis [10]. The PRISMA method provides a framework for conducting systematic reviews, which involves identifying sources, screening based on criteria, selecting the final studies, and transparently reporting the steps as well as results. These tools were employed to ensure the quality and transparency of this study.

Further, considering the qualitative nature of the studies, the Hawker et al. tool was used to evaluate the quality of the screened articles. Ultimately, only those articles with high and moderate quality were included in the study. Note that gray literature was not utilized in this review [11-13].

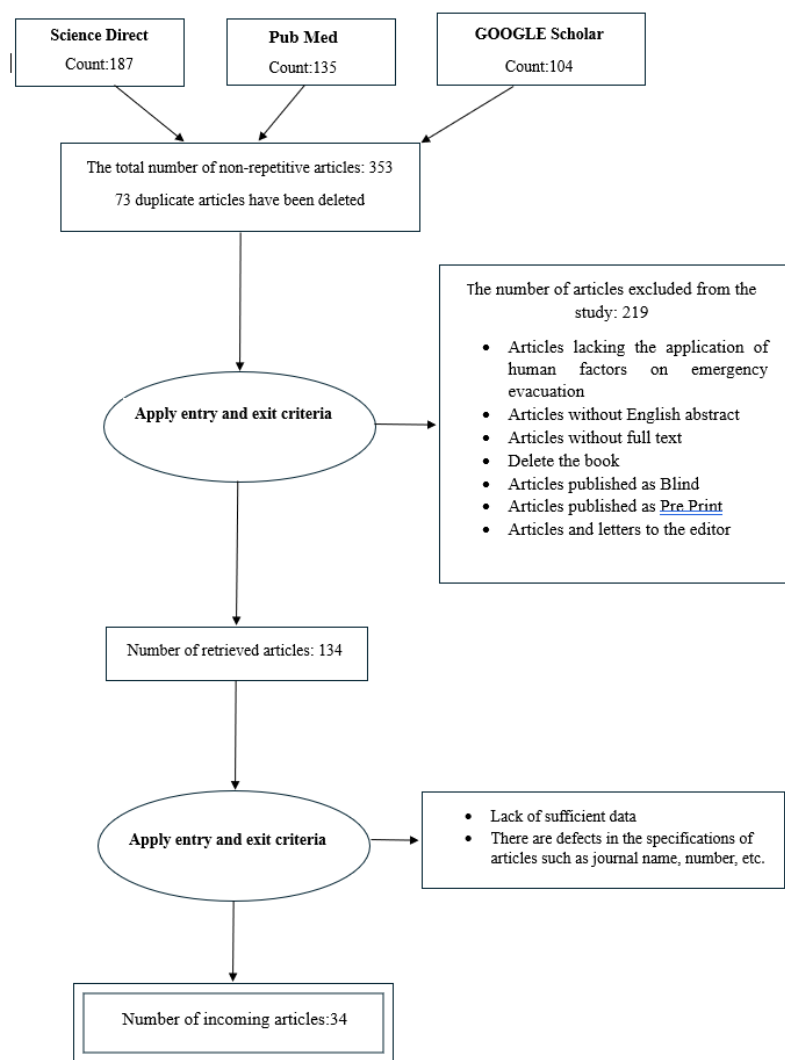


Fig. 1. The search path of the selection of input studies in the current review based on the 2009 PRISMA method [13]

Results

Study Search and Selection Results: In the initial search, a total of 426 studies published between 2010 and 2022 were identified from the Google Scholar, PubMed, and Science Direct databases. Following removal of duplicate articles, 353 studies were selected based on their titles, abstracts, and keywords. After applying the inclusion and exclusion criteria, an additional 219

studies were eliminated, leading to 134 remaining articles. Next, 104 studies were further excluded during the full-text review and data extraction process, ultimately leaving 34 studies for inclusion in the final analysis.

Study Characteristics: The final selection comprised 34 articles that fulfilled the specified inclusion and exclusion criteria.

The inclusion criteria for the study involved research that examined emergency evacuation during fires, factors influencing emergency evacuation, human behaviors along evacuation, and the impact of human factors on the evacuation process. Conversely, studies were excluded if their full text was not available, if they were not published in reputable journals indexed in Scopus, PubMed, or Web of Science, or if their reported results were unclear or non-transparent.

Among these, 24 were descriptive studies, seven were experimental studies, two were case studies, and one was a systematic review. The articles originated from a diverse range of countries, including China (17 articles), Australia (3 articles), the United States (3 articles), Canada (2 articles), Italy (2 articles), and Iran (2 articles). Further, studies from other countries such as Saudi Arabia, Singapore, Turkey, Jordan, and Portugal each contributed one article to the review. Notably, one of the included articles resulted from collaborative research between the United Kingdom and the United States.

Table 1 summarizes the characteristics of the included studies is presented in. The human factors identified in the included studies that would influence emergency evacuations were categorized as follows:

- Demographic or Physiological Parameters:

This category includes factors such as age, gender, physical ability, and health status that may affect individuals’ evacuation performance.

- Supportive Tools for Emergency Evacuation: This covers technologies and systems designed to aid evacuation, including alarms, signage, and emergency lighting.
- Individual Capabilities: This refers to personal skills and competencies, such as decision-making abilities and familiarity with the building layout.
- Stress and Personal Characteristics: This category is comprised of the psychological responses and traits of individuals along emergencies, including anxiety levels and coping mechanisms.
- Human Behavior: This includes the actions and reactions of individuals during evacuations, influenced by social dynamics and situational awareness.
- Presence of Emergency Response Plans: It deals with existence and effectiveness of established evacuation plans and procedures within buildings.

Table 1. Characteristic of studies in systematic review

No	Author	Year	Country	Type of study	Study environment	Tools	Human factors
1	Kaifeng Deng [14]	2022	China	Experimental	Train Station	Simulation/Questionnaire	Supportive tools for emergency evacuation (alarm and visual stimuli)
2	Max Kinateder [15]	2019	Canada	Experimental	Laboratory Environment	Simulation (VR) / Questionnaire	Supportive tools for emergency evacuation (warning signs)
3	Mohammadreza Shokouhi [16]	2019	Iran	Systematic Review	Residential Buildings	Database Search	Demographic or physiological parameters affecting evacuation (age, race, physical and mental health, education level, marital status)
4	Reza Rostami [17]	2020	Iran	Experimental	Schools	Simulation	Emergency response plan
5	Majed Almejmaj [18]	2014	USA and UK	Descriptive	Various data from Saudi Arabia	Simulation	Previous training (training in public places)
6	Qin Luo [19]	2018	China	Case Study	Metro Station	Simulation	Previous training (familiarization with exit routes) Demographic or physiological parameters affecting evacuation (physical and mental health, education level)
7	Sh. F. Abu-Safieh [20]	2011	Jordan	Experimental	Virtual Environment	Individual capabilities (Decision-making ability)	Supportive tools for emergency evacuation (architectural cues)
8	Zihao Wang [21]	2022	Portugal	Descriptive	Virtual Environment	Questionnaire / Virtual Reality	Emergency response plan
9	W. G. Song [22]	2014	China	Descriptive	Underground Store	Questionnaire	Emergency response plan Previous training (familiarization with exit routes)

10	Nan Li [23]	2020	China	Descriptive	Metro Station	Simulation	Human behavior (movement with the crowd)
11	Nan Li [24]	2019	China	Experimental	Museum	Simulation	Individual tendencies/inherent tendencies (culture and social characteristics)
12	Yuan Cheng [25]	2018	China	Descriptive	Any Environment	Simulation	Stress and personal characteristics (stress and panic)
13	Nan Li [26]	2020	China	Experimental	Metro Station	Modeling	Previous training (familiarization with exit routes)
14	Guolei Tang [27]	2021	China	Descriptive	Terminal Building	Emergency response plan	Demographic or physiological parameters affecting evacuation (age and gender)
15	Adrian Munteanb [28]	2012	Italy	Descriptive	Building	Network Model	Stress and personal characteristics (stress and panic)
16	Majed Almejmaj [29]	2017	USA	Descriptive	School	Survey/Design	Individual tendencies/inherent tendencies (culture and social characteristics)
17	Xia Zhang [30]	2013	Canada	Experimental	Building	Emergency response plan	Demographic or physiological parameters affecting evacuation (age, gender)
18	Milad Haghani [4]	2016	Australia	Descriptive	Complex	Simulation	Stress and personal characteristics (stress and panic)
19	Jiang Lixue [31]	2020	China	Descriptive	Any Environment	Virtual Environment	Demographic or physiological parameters affecting evacuation (education level)
20	Yuchun Zhangb [32]	2020	China	Descriptive	Any Environment	Questionnaire/Simulation	Stress and personal characteristics (effects of smoke on mental state)
21	Yuan Weifeng [33]	2011	Singapore	Case Study	Building	Simulation	Emergency response plan
22	Coshkan shahin [34]	2019	Turkry	Descriptive	Building and Area	Simulation	Demographic or physiological parameters affecting evacuation (age)
23	Ning Ding [8]	2021	China	Descriptive	Building	Virtual Reality	Stress and personal characteristics (in high-rise buildings)
24	JIN Hong-yu [35]	2011	China	Descriptive	Subway	Emergency response plan	Stress and personal characteristics (stress and panic)
25	Sun J Ha [36]	2013	China	Descriptive	Any Environment	Article Review and Fire	Individual capabilities (understanding ability)
26	Jing-hong Wang [37]	2016	China	Descriptive	Metro Station	Questionnaire	Demographic or physiological parameters affecting evacuation (age, gender)
27	Lovreglio R [38]	2014	Italy	Descriptive	Any Environment	Modeling/Interview	Human behavior (herd behavior)
28	Wu He [39]	2019	China	Any Environment	Modeling	Human behavior (Movement with the crowd)	Stress and personal characteristics (stress and panic)
29	Nirajan Shiwakoti [40]	2017	Australia	Descriptive	Train	Survey	Human behavior (herd behavior) Previous training (training in public places)
30	Mohammed Mahmod Shuaib [41]	2018	Saudi Arabia	Descriptive	Any Environment	Simulation	Human behavior (herd behavior)
31	Sandra Vaiciulyte [42]	2021	England	Descriptive	Any Environment	Simulation	Demographic or physiological parameters affecting evacuation (age, gender, marital status)
32	Anthony Chun Yin Yuen [43]	2021	Australia	Descriptive	Any Environment	Modeling	Stress and personal characteristics (stress and panic)
33	Rui Liu [44]	2021	USA	Descriptive	Building	Questionnaire/Virtual Reality	Individual tendencies/inherent tendencies (exit selection)

34	Ying Liu [45]	2021	China	Descriptive	University Gym	Questionnaire	Demographic or physiological parameters affecting evacuation (gender, physical and mental health)
----	---------------	------	-------	-------------	----------------	---------------	---

Discussion

When individuals recognize a threat, their first step is to accurately ascertain the danger before deciding on a course of action [32, 34]. In emergencies, people may choose various actions, including protecting their lives and health, safeguarding property, collecting essential documents, seeking information, and executing an emergency evacuation [40]. Thus, before the operational phase of evacuation, two critical phases—risk perception and decision-making—must occur [32, 34]. A considerable percentage of individuals do not immediately initiate evacuation [34].

The findings of this systematic review revealed that several human factors significantly influence emergency evacuations. These factors included demographic or physiological parameters, supportive tools for emergency evacuation, individual capabilities, stress and personal characteristics, human behavior, emergency response plans, and individual or inherent tendencies. Notably, most of the included studies were undertaken by researchers from China and Australia, with stress and personal characteristics, together with demographic or physiological parameters, being the most frequently discussed topics.

Age: Individuals at different life stages exhibit distinct characteristics and capabilities. Previous studies have reported significant relationships between age and emergency evacuation [13, 44], including variations in action speed and evacuation time [32]. Older individuals tend to perceive emergencies and make decisions more effectively [24, 27]. Nevertheless, as age increases, the number of actions taken along an emergency may rise, which can be problematic if these actions do not align with safe evacuation [40]. Interestingly, age does not correlate with panic or fear responses [35], though advancing age is associated with diminishing walking speed, posing challenges during evacuations [32].

Race: Certain races and ethnic groups may be at greater risk of fire emergencies and may confront more challenges during the evacuation process owing to factors such as low economic status, poor living conditions, limited access to safety education, and socio-economic inequalities. Physical differences among races and ethnicities may also influence physical ability, but this impact requires further investigation in future studies.

Some studies have suggested that race and ethnicity may affect emergency evacuations, but the nature of this relationship remains unclear [13, 44]. Research in this area is limited, suggesting a need for more comprehensive studies to understand how cultural factors, language barriers, and community dynamics

influence evacuation behaviors across different racial and ethnic groups.

Gender: Findings indicate that during fire incidents and emergency evacuations, men generally move faster than women [15, 24, 27], resulting in longer evacuation times for women [32]. Men tend to be more familiar with emergency evacuation processes, which may facilitate their efforts [43]. Other studies have shown that gender correlates with factors such as fear responses [35], the average number of actions taken in emergencies [40], and speed of action [32], potentially explaining the advantages observed in men regarding evacuation speed.

Physical disabilities and mental health status: Physical disabilities and mental health status significantly affect emergency evacuations, especially concerning evacuation time [13, 43, 44]. Those with physical disabilities often struggle to move toward exit routes, severely hindering their ability to evacuate effectively. Further, those with unstable mental health may find it challenging to make sound decisions during emergencies, complicating the evacuation process [16].

Education Level: Several studies have shown a significant relationship between education level and emergency evacuation [13, 16, 29, 44]. Higher education levels are linked to reduced fear responses [35]. As individuals attain higher education, their knowledge about emergencies and their potential consequences grows, leading to lower anxiety levels compared to those with less education. This enhanced awareness can enhance decision-making during emergencies, contributing to a smoother evacuation process.

Marital Status: Marital status, including an individual's roles and responsibilities, significantly relates to emergency evacuations [13, 44]. Single individuals tend to navigate the evacuation process more easily due to fewer personal dependencies than those who are married or have families. Further, the size of a household correlates with the average number of actions taken during evacuations. As family size grows, the complexity of the evacuation process also rises, leading to longer evacuation times during fire incidents [40]. This dynamic highlights the need for tailored evacuation strategies that capture the unique challenges faced by families and individuals with varying marital statuses.

Type of Clothing: One included study reported the impact of clothing type on the emergency evacuation process during a fire. Findings revealed that long and loose clothing, as well as clothing that restricts movement, significantly affect movement speed during an evacuation. The type of clothing is meaningfully

linked to evacuation speed and, consequently, the effectiveness of emergency evacuations [15].

Supportive Tools for Emergency Evacuation: Individuals are alerted to emergencies through alarms and visual stimuli, serving as critical components in prompting timely evacuations [11]. The effectiveness of these supportive tools is affected by various factors that shape individuals' decisions to evacuate or remain in place. Understanding these factors is essential for improving evacuation protocols and ensuring safety during emergencies.

Warning Signs: Clear and visible warning signs are paramount in guiding individuals toward safe exit routes. Research has shown that well-placed signage can significantly lower confusion and improve evacuation times [12]. Effective signage should utilize universally recognized symbols and concise instructions to ensure quick comprehension of necessary actions. Studies have demonstrated that the strategic placement of signs in high-traffic areas can boost visibility and accessibility, thereby facilitating smoother evacuations [46]. Furthermore, incorporating digital signage that provides real-time updates about the emergency can further aid decision-making. Lighting along exit routes has been identified as a key factor in guiding individuals during evacuation. Adequate lighting helps occupants easily identify exit paths and become aware of obstacles or hazards caused by smoke and fire. Optimizing lighting pathways is useful to enable individuals to exit the building quickly and safely [47].

Lighting is highlighted as an integral part of fire management system design. User behavior analysis reveals that appropriate lighting can positively influence decision-making and reactions of individuals in emergency situations. By applying Building Information Modeling (BIM), designs can be developed to ensure improved lighting in exit routes, thereby boosting safety and efficiency during evacuations [48].

Familiarity with the Environment: Familiarity with the building layout plays a key role in evacuation decision-making. Individuals who are well-acquainted with their surroundings are more likely to respond swiftly to alarms and other cues, allowing for faster and more efficient evacuations [35]. Regular drills and training exercises can enhance this familiarity, ensuring that occupants know the best escape routes and procedures beforehand. A recent study emphasizes that individuals who participate in regular evacuation drills manifest enhanced confidence and quicker response times along actual emergencies [49].

Assistance from Neighbors and Staff: The presence of supportive individuals, such as neighbors or staff members, can significantly influence evacuation outcomes. In emergencies, the social dynamics of the environment can either facilitate or hinder evacuations. Research indicates that individuals are more likely to evacuate promptly when they receive assistance or

encouragement from others [35]. This highlights the importance of fostering a community-oriented approach to emergency preparedness, where occupants are encouraged to look out for one another during crises. Studies have indicated that social support networks can reduce panic and improve collective decision-making during emergencies. Researches showed trust dynamics within social networks influence emergency decision-making in large groups and highlights the significance of establishing and maintaining dual-trust relationships—both interpersonal and institutional—during emergencies. By understanding these trust dynamics, organizations can boost collaborative decision-making processes, resulting in more effective and timely responses along critical situations. The findings suggest that fostering trust within social networks can significantly ameliorate consensus-building, ultimately contributing to better outcomes in emergency management and response strategies [49].

Architectural Cues: The design of the physical environment, including architectural features such as exit signs, lighting, and the layout of corridors, can heavily influence evacuation efficiency. Architectural cues that are strategically placed can guide individuals toward exits and help lower panic during emergencies [17]. For instance, well-lit pathways and clearly marked exits can enhance visibility and aid in directing individuals to safety, particularly in low-visibility situations such as smoke-filled environments. Recent research has suggested that incorporating smart building technologies, such as automated lighting systems that activate during emergencies, can further boost evacuation effectiveness by illuminating pathways and exits. Properly designed emergency lighting enhances visibility in smoke-filled or dark environments, enabling occupants to clearly see escape routes and exits, thereby reducing confusion and facilitating efficient evacuations. The psychological impact of adequate lighting cannot be overstated; it helps mitigate panic and anxiety, fostering a sense of security among building occupants. When illuminated paths are present, individuals are more likely to remain calm and follow evacuation procedures. Further, emergency lighting can influence group dynamics, encouraging occupants to assist one another and move collectively toward exits [46].

Technological Innovations: The integration of advanced technologies into emergency response systems can significantly boost the effectiveness of supportive tools. For instance, mobile applications that provide real-time alerts and evacuation instructions can empower individuals to make informed decisions rapidly. These applications can also include features such as location tracking and interactive maps to guide users to the nearest exits [46]. Further, the utilization of virtual reality (VR) training simulations has proved to improve individuals' preparedness and response times along

emergencies by providing immersive experiences that familiarize them with evacuation procedures. Usage of virtual reality simulations can enhance the design and management of building exits in fire scenarios. This method analyzes individuals' behavior under stressful and crowded conditions, enabling designers and safety managers to evaluate various scenarios as well as propose effective strategies to reduce casualties and improve safety. Ultimately, this simulation can support better training for staff and enhance preparedness for emergencies [50].

Movement Ability: Several studies have revealed that an individual's movement ability significantly boosts action speed, thereby shortening evacuation time. Individuals with greater mobility can evacuate more quickly during emergencies [32]. In essence, enhanced movement ability is a key factor in effective emergency evacuations during fire incidents [44].

Decision-Making Ability: Those with strong decision-making skills in emergencies experience shorter evacuation times and reach safe areas more quickly [29, 44]. Environmental cues can also influence decision-making and the effectiveness of responses [17]. A well-developed ability to ascertain risks and make timely decisions can significantly enhance evacuation outcomes.

Situational Awareness: Previous studies have indicated that individuals need to accurately recognize danger and comprehend the emergency before initiating an evacuation. The ability to quickly analyze the situation and understand the conditions results in reduced evacuation times [34, 44]. Those who can promptly assess their environment and associated risks are more likely to choose the correct evacuation routes and act swiftly.

Stress and Panic: When individuals perceive danger, their initial reactions often include panic, worry, and stress [35]. These responses can spread among the crowd, resulting in collective panic, which frequently culminates in irrational decision-making [28]. Panic and stress can reduce action speed and prolong evacuation times [21, 32]. However, no studies have demonstrated a negative impact of stress on the quality of evacuations. Physical threats, such as obstacles or falling objects, can heighten fear and panic among individuals [41].

Conversely, panic can sometimes foster a sense of competition among individuals to exit quickly. If individuals can manage their emotional responses, they may transition to cooperative behavior, boosting the flow of evacuation and successfully navigating emergencies [22, 25]. A study noted that, in fire situations, women exhibited a greater tendency to panic than men, leading to slower evacuation times for women [33]. Thus, managing panic, stress, and emotional behaviors can mitigate their negative impacts along emergency evacuations [21, 22].

Stress plays a critical role in the emergency evacuation process, and its impacts depend on an individual's ability to manage the situation. If a person can control their stress and maintain sufficient composure over their behavior as well as decision-making in critical situations, stress can positively influence the evacuation process. Nevertheless, when an individual is unable to control their stress, it can result in reduced efficiency, poor decision-making, and ultimately elevate the risks associated with the evacuation process.

Effects of Smoke on Mental State: One study reported that smoke exposure not only lowers visibility and slows movement speed but also impacts individuals' mental states, potentially inducing panic. However, smoke exposure can also augment residents' motivation to evacuate, causing greater participation in emergency exits [30].

Past Experiences: Experiences from similar past incidents can result in two distinct outcomes: In the first scenario, individuals draw upon previous evacuation experiences, enhancing their knowledge and familiarity with procedures, ultimately shortening evacuation time. This familiarity can lead to quicker decision-making and more efficient movement toward safety. Conversely, negative past experiences, particularly traumatic events during previous evacuations, can induce significant stress and panic, disrupting the evacuation process and potentially prolonging evacuation times. For those who have faced traumatic past experiences, implementing management and support strategies along emergencies is crucial [16].

Movement with the Crowd: Most individuals prefer to move with the flow of the crowd and tend to select exits employed by the majority. This behavior emanates from the belief that other exits may be faulty or less accessible, leading to congestion at a single exit and thus increasing evacuation time. Conversely, a few individuals may opt for alternative exits, which, owing to lower traffic, can facilitate quicker evacuations [20, 30]. Nevertheless, if some individuals experience stress and panic, this can create a contagious atmosphere of fear within the crowd, rapidly escalating the situation and slowing the evacuation process [35, 37].

Herd Behavior: The impact of others' decisions on evacuees is known as the herd effect [28]. People tend to engage in herd behavior, often following the actions of those around them [36, 38]. This can be so powerful that, during emergencies requiring quick decision-making, individuals predominantly rely on herd behavior rather than independent judgment [39]. Herd behavior is particularly evident when individuals move toward exits perceived as less congested. However, there remains uncertainty regarding whether this behavior results in competitive or cooperative interactions among individuals along emergency evacuations [38].

Exit Selection: Previous studies have identified three criteria that individuals rely on when choosing an exit during emergency evacuations in fire incidents: The first criterion is the preference for shorter routes. Individuals tend to choose pathways that minimize travel distance [23]. The second criterion involves following herd behavior, conforming to the actions of the crowd. People often select routes utilized by the majority of evacuees, believing that other exits may be faulty or less accessible. Very few individuals opt for less trafficked exits [36]. The third criterion involves the inclination to take shortcuts; some individuals may choose shortcuts even if these paths are filled with smoke. Nevertheless, if the smoke becomes too dense, they will avoid those routes. There is a correlation between individuals' risk-taking abilities and their choice of shortcut paths; those with higher risk tolerance are more likely to select shortcut routes [42].

Presence of Emergency Response Plans: This factor describes the existence and effectiveness of established evacuation plans and procedures within buildings.

Culture and Social Characteristics: Several studies have reported that social characteristics, such as levels of cooperation, social roles, and collective stress, significantly affect overall evacuation times [20, 32]. Some research has revealed that societal culture influences individual tendencies, such as individualism and collectivism, impacting emergency evacuations [15]. For instance, in certain occupations, cultural factors have been found to shorten evacuation times. In groups such as teachers and students, culture has a meaningful effect on stress levels, calmness, and decision-making; nevertheless, its significant influence on reducing confusion during evacuations remains unestablished. Culture can also affect reaction times and hazard recognition times [26]. Nonetheless, another study found no significant relationship between emergency evacuation and culture [20].

Identified Information Gaps: In spite of the research conducted on emergency evacuation, significant gaps remain in understanding the relationship between factors such as race, clothing type and style, culture, as well as individuals' social characteristics and crowd movement patterns along emergencies. These factors, either directly or indirectly, influence individuals' behavior when faced with critical situations, but existing studies have not comprehensively explored these connections.

In particular, the influence of socio-cultural variables on individual decision-making, movement patterns in emergencies, and the interaction of these factors with environmental conditions as well as existing infrastructure require deeper examination based on comprehensive data. Further, exploring the interactions between individual and group characteristics and how these interactions affect the speed as well as efficiency

of emergency evacuation could support improving planning and reducing harm in future crises.

To address these scientific gaps, future research should focus on multidimensional, data-driven analyses, particularly across diverse cultural and social environments, to develop a comprehensive and practical model for predicting and managing emergency evacuations.

Future research should deal with developing innovative technologies and training programs that boost individual preparedness and resilience in the face of emergencies. By fostering a comprehensive understanding of the human factors at play, we can ameliorate evacuation protocols and ultimately save lives during critical incidents.

The limitations of this study primarily related to access to the full texts of certain articles. Although some of the studies identified in the search fulfilled the inclusion criteria, they were excluded from the final review and analysis owing to the unavailability of their full texts. This limitation may have had a minor impact on the comprehensiveness of the study's findings.

Conclusion

This systematic review highlighted the complex interplay of human factors affecting emergency evacuations during fire incidents. Key demographic and physiological parameters, such as age, gender, physical ability, and education level, would significantly affect individuals' threat perception and responses. While not strictly "human factors," technological innovations, architectural features, and supportive tools such as alarms and signage also shape behavior and decision-making during emergencies. The review emphasizes the need for tailored evacuation strategies that deal with the diverse needs of vulnerable populations, including the elderly and those with health challenges. Understanding psychological dimensions, such as stress and panic, is critical for developing interventions that ameliorate situational awareness and decision-making skills. Ultimately, a multidisciplinary approach integrating psychology, sociology, and engineering is essential for effective emergency management.

Conflict of interest

None declared.

Funding

Qazvin University of Medical Sciences provides funding (grant number 403000323) and research support.

Ethical Considerations

This systematic review was conducted in accordance with the highest standards of academic integrity and

ethical guidelines for systematic reviews and meta-analyses. Since this study involved the synthesis and analysis of previously published data, no direct contact with human or animal subjects occurred, and thus, obtaining ethical approval from an institutional review board was not required

Code of Ethics

This research was approved by Qazvin University of Medical Sciences under the ethical code IR.QUMS.REC.1402.159.

Authors' Contributions

Kiana Rezaeipour: Literature Search, Study Selection, Data Extraction, Data Curation, Formal Analysis, Investigation, Writing – Original Draft, Writing – Review & Editing; Vida zaroushani: Conceptualization, Methodology, Literature Search, Study Selection, Data Extraction, Validation, Supervision, Project Administration, Writing – Original Draft, Writing – Review & Editing; Mohammad Amerzadeh: Writing – Review & Editing.

References

- Hall S. Fire loss in the United States. Quincy, Massachusetts, United States: National Fire Protection Association; 2023.
- Jiang A, Mo Y, Kalasapudi VS. Status quo and challenges and future development of fire emergency evacuation research and application in built environment. *J Inf Technol Constr.* 2022;27:781-801.
- Kuligowski ED, Gwynne SM, Kinsey MJ, Hulse L. Guidance for the model user on representing human behavior in egress models. *Fire technol.* 2017;53(2):649-72.
- Haghani M, Sarvi M. Human exit choice in crowded built environments: Investigating underlying behavioural differences between normal egress and emergency evacuations. *Fire Saf J.* 2016;85:1-9.
- Ronchi E, Nilsson D. Fire evacuation in high-rise buildings: a review of human behaviour and modelling research. *Fire Sci Rev.* 2013;2.
- Mirsaeedie L, Shamsi A. Identifying the Effective Factors on Emergency Evacuation the Buildings in the case of Fire. *J Disaster Prev Manag Knowl.* 2018;8(1):42-53.
- Kobes M, Helsloot I, de Vries B, Post JG. Building safety and human behaviour in fire: A literature review. *Fire Saf J.* 2010;45(1):1-11.
- Ding N, Chen T, Zhu Y, Lu Y. State-of-the-art high-rise building emergency evacuation behavior. *Physica A Stat Mech Appl.* 2021;561:125168.
- Satr MS, Topraklı AY. A review of evacuation of high-rise buildings. *Gazi Univ J Sci Part B Art Humanit Des Plan.* 2020;8(1).
- Hawker S, Payne S, Kerr C, Hardey M, Powell J. Appraising the evidence: reviewing disparate data systematically. *Qual Health Res.* 2002;12(9):1284-99.
- Mahdavi M, Mortazavi SB, Khavanin A, Zaroushani V, Hajizadeh R. A systematic review on active noise control technologies in the window. *Iran Occup Health.* 2024;20(2):134-52.
- Zaroushani V. Occupational safety and health and response to COVID-19 using the fourth industrial revolution technologies. *J Health Saf Work.* 2020;10(4):329-48.
- Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA). PRISMA 2009 Checklist [Internet]. 2009. Available from: https://legacyfiles.elsevier.com/promis_misc/PRISMA-2009-Checklist1.pdf
- Deng K, Li M, Wang G, Hu X, Zhang Y, Zheng H, et al. Experimental study on panic during simulated fire evacuation using psycho-and physiological metrics. *Int J Environ Res Public Health.* 2022;19(11):6905.
- Kinateder M, Warren WH, Schloss KB. What color are emergency exit signs? Egress behavior differs from verbal report. *Appl Ergon.* 2019;75:155-60.
- Shokouhi M, Nasiriani K, Cheraghi Z, Ardalan A, Khankeh H, Fallahzadeh H, et al. Preventive measures for fire-related injuries and their risk factors in residential buildings: a systematic review. *J Inj Violence Res.* 2019;11(1):1-14.
- Rostami R, Alaghmandan M. Performance-based design in emergency evacuation: From maneuver to simulation in school design. *J Build Eng.* 2021;33:101598.
- Almejmaj M, Meacham B, Skorinko J. The effects of cultural differences between the west and Saudi Arabia on emergency evacuation—clothing effects on walking speed. *Fire Mater.* 2015;39(4):353-70.
- Zhang X, Zhong Q, Li Y, Li W, Luo Q. Simulation of fire emergency evacuation in metro station based on cellular automata. Paper presented at: The 3rd IEEE International Conference on Intelligent Transportation Engineering (ICITE); 2018 Sep 3-5; Singapore,
- Abu-Safieh SF. Virtual reality simulation of architectural clues' effects on human behavior and decision making in fire emergency evacuation. In: Peacock, R., Kuligowski, E., Averill, J. (eds). *Pedestrian and evacuation dynamics*. Boston, United States: Springer; 2011.
- Wang Z, He R, Rebelo F, Vilar E, Noriega P. Human interaction with virtual reality: investigating pre-evacuation efficiency in building emergency. *Virtual Reality.* 2023;27(2):1039-50.
- Huo FZ, Song WG, Liu XD, Jiang ZG, Liew KM. Investigation of human behavior in emergent evacuation from an underground retail store. *Procedia Eng.* 2014;71:350-6.
- Lin J, Zhu R, Li N, Becerik-Gerber B. Do people follow the crowd in building emergency evacuation? A cross-cultural immersive virtual reality-based study. *Adv Eng Inform.* 2020;43:101040.
- Cao L, Lin J, Li N. A virtual reality based study of indoor fire evacuation after active or passive spatial exploration. *Comput Human Behav.* 2019;90:37-45.

25. Yuan Ch, Xiaoping Z. Emergence of cooperation during an emergency evacuation. *Appl Math Comput.* 2018;320:485-94.
26. Lin J, Cao L, Li N. How the completeness of spatial knowledge influences the evacuation behavior of passengers in metro stations: A VR-based experimental study. *Autom Constr.* 2020;113:103136.
27. Tang G, Zhao Z, Yu J, Sun Z, Li X. Simulation-based framework for evaluating the evacuation performance of the passenger terminal building in a Ro-Pax terminal. *Autom Constr.* 2021;121:103445.
28. Cirillo ENM, Muntean A. Can cooperation slow down emergency evacuations? *Comptes Rendus Mecanique.* 2012;340(9):625-8.
29. Almejmaj M, Skorinko JLM, Meacham BJ. The effects of cultural differences between the us and saudi arabia on emergency evacuation—Analysis of self reported recognition/reaction times and cognitive state. *Case Stud Fire Saf.* 2017;7:1-7.
30. Zhang X, Li X, Hadjisophocleous G. A probabilistic occupant evacuation model for fire emergencies using Monte Carlo methods. *Fire Saf J.* 2013;58:15-24.
31. Zhiming F, Huisheng G, Lixue J, Xiaolian L, Wei L. Human movement characteristics during emergency evacuations in a virtual environment. *Fire Saf J.* 2020;115:103147.
32. Xie W, Lee EWM, Cheng Y, Shi M, Cao R, Zhang Y. Evacuation performance of individuals and social groups under different visibility conditions: Experiments and surveys. *Int J Disaster Risk Reduct.* 2020;47:101527.
33. Yuan W, Tan KH. A model for simulation of crowd behaviour in the evacuation from a smoke-filled compartment. *Physica A.* 2011;390(23-24):4210-8.
34. Şahin C, Rokne J, Alhajj R. Human behavior modeling for simulating evacuation of buildings during emergencies. *Physica A.* 2019;528:121432.
35. Xiao-Xia GE, Wei D, Hong-Yu J. Study on the social psychology and behaviors in a subway evacuation drill in China. *Procedia Eng.* 2011;11:112-9.
36. Mu HL, Wang JH, Mao ZL, Sun JH, Lo SM, Wang QS. Pre-evacuation human reactions in fires: An attribution analysis considering psychological process. *Procedia Eng.* 2013;52:290-6.
37. Wang JH, Yan WY, Zhi YR, Jiang JC. Investigation of the panic psychology and behaviors of evacuation crowds in subway emergencies. *Procedia Eng.* 2016;135:128-37.
38. Lovreglio R, Fonzone A, Dell'Olio L, Borri D, Ibeas A. The role of herding behaviour in exit choice during evacuation. *Procedia Soc Behav Sci.* 2014;160:390-9.
39. Mao Y, Fan Z, Zhao J, Zhang Q, He W. An emotional contagion based simulation for emergency evacuation peer behavior decision. *Simul Model Pract Theory.* 2019;96:101936.
40. Shiwakoti N, Tay R, Stasinopoulos P, Woolley PJ. Likely behaviours of passengers under emergency evacuation in train station. *Saf Sci.* 2017;91:40-8.
41. Shuaib MM. Incorporating intelligence for typical evacuation under the threat of fire spreading. *Saf Sci.* 2018;106:1-9.
42. Vaiciulyte S, Hulse LM, Veeraswamy A, Galea ER. Cross-cultural comparison of behavioural itinerary actions and times in wildfire evacuations. *Saf Sci.* 2021;135:105122.
43. Cao RF, Lee EWM, Yuen ACY, Chan QN, Xie W, Shi M, et al. Development of an evacuation model considering the impact of stress variation on evacuees under fire emergency. *Saf Sci.* 2021;138:105232.
44. Fu M, Liu R, Zhang Y. Why do people make risky decisions during a fire evacuation? Study on the effect of smoke level, individual risk preference, and neighbor behavior. *Saf Sci.* 2021;140:105245.
45. Liu Y, Yu J, Yin Q, Sun C, Sun A. Impacts of human factors on evacuation performance in university gymnasiums. *Physica A.* 2021;582:126236.
46. Fang W. Application of fire emergency lighting and evacuation instructions in buildings. In: Ross D, Editors. *Proceedings of the International Conference on Management, Finance and Social Sciences Research (MFSSR 2019); 2019 2-4 Aug; Lyon, France.*
47. Mirahadi F, McCabe BY. EvacuSafe: A real-time model for building evacuation based on Dijkstra's algorithm. *J Build Eng.* 2021;34:101687.
48. Ma G, Wu Z. BIM-based building fire emergency management: Combining building users' behavior decisions. *Autom Constr.* 2020;109:102975.
49. Liu Z, Wang W, Liu P. Dynamic consensus of large group emergency decision-making under dual-trust relationship-based social network. *Inf Sci.* 2022;615:58-89.
50. Guo Y, Zhu J, Wang Y, Chai J, Li W, Fu L, et al. A virtual reality simulation method for crowd evacuation in a multiexit indoor fire environment. *ISPRS Int J Geoinf.* 2020;9(12):750.