

Students' evacuation behavior during an emergency at schools: A systematic literature review

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ABSTRACT

Disasters and emergencies frequently happen, and some of them require population evacuation. Children can be severely affected during evacuations due to their lower capability to analyze, perceive, and answer disaster risks. Although several studies attempted to address the safety of children during the evacuation, the existing literature lacks a systematic review of students' evacuation behavior during school time. Therefore, this study aims to conduct a systematic literature review to explore how students' evacuation behavior during school time has been addressed by previous scholars and identify gaps in knowledge. The review process included three steps: formulating the research question, establishing strategic search strategies, and data extraction and analysis. The studies have been identified by searching academic search engines and refined the recognized publications unbiasedly. The researchers have then thematically analyzed the objectives and findings of the selected studies resulting in the identification of seven themes in the field of students' evacuation behavior during school time. Finally, the study put forward suggestions for future research directions to efficiently address the recognized knowledge gaps.

1. Introduction

In 2021, the total number of natural disasters and their economic loss, including drought, earthquake, extreme temperature, flood, landslide, storm, volcanic activity, and wildfire, was higher than the average of annual disasters from 2001 to 2020 [1]. Moreover, the world population is at the mercy of other man-made disasters such as industrial or transportation accidents and terrorist attacks, and wars [2,3]. Despite several studies to predict emergencies, especially earthquakes, most of them can not be predicted beforehand; however, early warnings and potential or immediate evacuation [4] could save dozens of lives during emergencies [5,6].

It must, however, be borne in mind that evacuation safety should be carefully considered in emergency planning to prevent secondary hazards threatening public safety. It is generally agreed that individuals' behavior during an evacuation can positively or negatively affect the group's/crowd's evacuation process. Pushing others, staring and making obstacles, negligence of exits and evacuation routes, congestion, and blindly following the crowd are some of the commonly observed behaviors during evacuation [7]. The abnormal public behaviors during evacuation [8] have been proven to cause cascading disasters inside buildings where an anxious population occupies narrow spaces and corridors, possibly affected by obstacles such as fallen people and other objects [9,10]. Therefore, there is an increasing need to study human behavior and evacuation decision-making [4]. Researchers from different majors have studied human behavior and the effectual factors on public emergency evacuation behavior.

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Some scholars believe that not only the imminent impacts of the disaster perceived by people could affect their behavior, but the built environment features also have considerable effects on the occupants' evacuation behavior [11,12]. Studies generally revealed that human behavior during an emergency varies based on risk perception [11,13]. People's risk perception can be affected by many factors, including individual characteristics and environmental factors. However, the built environment's impact is not limited to the layout of the building [14], and scholars have proposed several suggestions regarding the appropriate design of evacuation signs [15–17].

Albeit the existence of studies focused on addressing social vulnerability by proposing a social vulnerability index [18], vulnerable groups' needs after emergencies [19], and their influence on evacuation decision-making [20], emergency risk perception among different groups of occupants requires further investigation because it can be significantly different among individuals with special needs [21]. The existing studies proved that children are among the vulnerable groups to disasters due to low-risk perception, mobility limitations, and dependency on adults for help, affecting their evacuation behavior [22,23]. Emergencies during school time, such as the Wenchuan earthquake in China in 2008, have resulted in the death or missing of 5000 students [24]. Although the majority of the students' casualties were caused by school structure failure [25], evidence proved that evacuation saved the lives of dozens of students in Sangzao middle school that experienced the Wenchuan earthquake [26]. Moreover, schools are highly populated, and emergencies can severely endanger students' safety. Stampedes that occurred at primary schools in recent years in China have caused deaths and casualties among students [27]. Schools' evacuation plan and students' preparedness was also the subject of several studies. The previous studies have assessed not only students' and schools' disaster preparedness by assessing the impact of disaster training and evacuation drills [21,28,29], but also literature has taken advantage of new technologies such as Artificial Intelligence and gaming to improve the students' disaster risk reduction knowledge [30,31]. Despite relevant studies exploring school evacuation safety, Shoji et al. [32] believe that children's response to emergencies is not well-understood. The studies in this field have addressed children's movement and speed during an evacuation [33–35], the school environment and obstacles that impact evacuation [36,37], and pupils' risk perception and emergency behavior [38,39]. The simulation study based on vast evacuation drills at four schools by León et al. [40] has proved that following nation-level evacuation strategies at schools in Chile might lead to significant human losses if indoor evacuation takes longer.

The vast and scattered body of knowledge regarding the students' evacuation behavior at schools lacks research to review these studies systematically and enlighten the current research trends and shortcomings. Despite the widespread use of the traditional literature review in existing studies, the method is pertinent to several shortcomings, such as protocol transparency and bias, which might question whether these studies' findings are valid [41]. However, a systematic literature review is a systematic, comprehensive, and transparent procedure representing relevant research related to the research question by improving clarity, validity, and audibility [41]. Scholars have conducted a systematic literature review on prediction methods for emergency management [2], human behavior facing floodwater [42], community preparedness for earthquakes [43], and natural disaster evacuation behavior [44]. However, given the rising prevalence of research on students' evacuation behavior, there is an increasing need and scope for a systematic review of the literature in the domain of students' evacuation behavior during schooltime.

This study aims to conduct a systematic literature review focusing on pupils' evacuation behavior during schooltime. Therefore, the literature's findings can be presented holistically throughout applying this research to illustrate research gaps and open avenues for future research. This study established a research protocol and thematically analyzed the data by engaging with this question about how the existing literature has perceived students' evacuation behavior during an emergency at school. The remainder of the paper is structured as follows. Section 2 presents the research methodology by establishing the research question, systematic searching strategies, and data extraction and analysis. The study findings are given in section 3, and section 4 is allocated to the conclusion. Finally, the paper will finish by stating the study's contributions, implementation, and limitations, and suggesting guidelines for future research.

2. Research process and methodology

The systematic review enables the studies to improve their clarity, validity, and audibility [45]. Therefore, this study has applied a systematic review of the existing literature to analyze the scholars' trends in studying students' evacuation behavior at schools. The review process has three major steps based on the suggestion provided by Gough et al. [46]: structuring the research question, systematic searching strategies establishment, and data extraction and analysis.

2.1. Structuring the research question

The research question has been formulated based on Population, Interest, and Content theory (PICo) [47]. Per the mentioned concept, the authors have included “school students” as the population, “emergencies” as interest, and “evacuation behavior during school time” as content. Therefore, the research question is formulated as follows: “How has students' evacuation behavior at schools been studied previously?” and “What are the major findings and potential knowledge gaps?”

2.2. Systematic searching strategies establishment

To ensure the transparent reporting of systematic reviews, this study has applied Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). PRISMA has been applied in a wide range of studies, such as urban resilience [48], health care [49], disaster resilience [50], safety management [51], and community engagement in disaster recovery [52]. PRISMA framework has three steps: “Identification”, “Screening”, and “Eligibility assessment”. Fig. 1 highlights the systematic review procedure applied in this study based on the PRISMA framework.

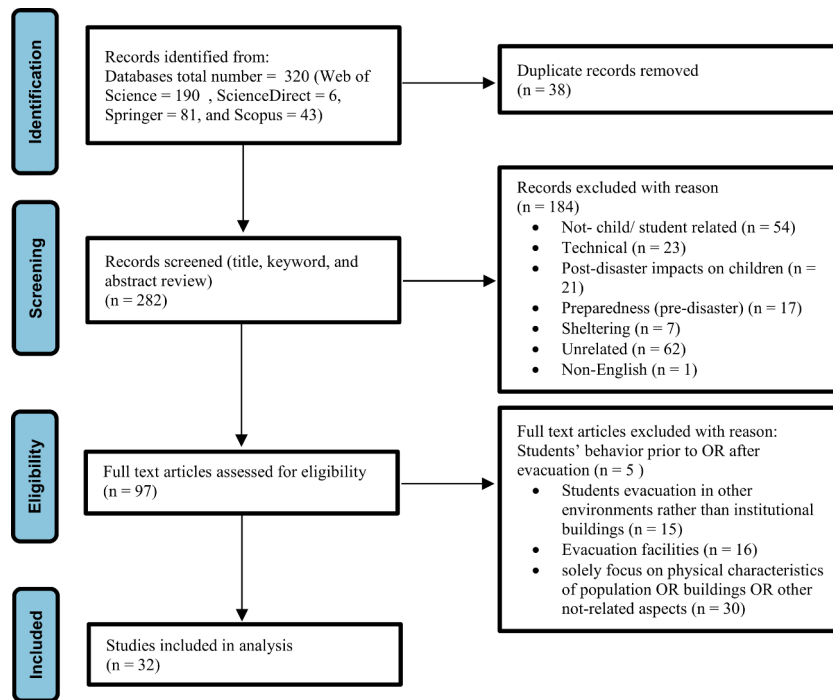


Fig. 1. Flowchart of systematic review (PRISMA framework) Preparedness.

2.2.1. Identification

The database sources used were Web of Science, ScienceDirect, Scopus, and Springer. English articles, including conference papers and early access published during 2008–2022, were collected by searching titles, abstracts, and keywords. “Evacuation behavior”, “decision-making”, “students”, “school”, and “disaster” were the main keywords searched from 28th –31st August 2022. Other similar keywords such as pupils, college, campus, hazard, and emergency have also been used as search alternatives. Table 1 illustrates search strings based on the combination of the main keywords by using Boolean operations and searching rules in each database. This stage has resulted in the identification of 320 studies.

2.2.2. Screening

The second refinement step was performed in the Rayyan platform [53] by first removing 38 duplications among the documents. Afterward, the paper's title, keywords, and abstract were analyzed in a hierarchical logic. First, the title has been assessed. In case of failure to meet the inclusion criteria listed in Table 2, the researchers have assessed the keywords' inclusion criteria. Similarly, if the study's keyword did not match the inclusion criteria, we evaluated the abstract to make the final decision. The screening step resulted in the exclusion of 184 articles and the confirmation of the most relevant papers (n = 97) to undergo eligibility evaluation.

2.2.3. Eligibility assessment

The researchers evaluated the eligibility of the studies by reading the introduction, methodology, and conclusion sections based on the methodology presented by Pranugrahaning et al. [54] while applying more detailed inclusion and exclusion criteria, as shown in Table 2. Finally, 32 papers have been and gone through data extraction and analysis.

2.3. Data extraction and analysis

The thematic analysis aims to identify and interpret the data's critical features regarding the research question. However, this procedure does not simply attempt to summarize the data content [55]. In this study, the 32 included articles were analyzed through the-

Table 1
Search strings used in the selected databases.

Database	Search string
Scopus	“Evacuat*” AND “Behav*” OR “Decision-making” AND “Student” OR “Pupil” AND “School” OR “Campus” OR “College” AND “Disaster” OR “Emergency” OR “Hazard”
ScienceDirect	Evacuation AND (Behavior OR Decision-making) AND Student AND (School OR College) AND (Disaster OR Hazard)
Web of Science	(Evacuat* AND Behav* AND School) OR (Evacuat* AND Behav* AND Student) OR (Evacuat* AND Behav* AND campus) OR (Evacuat* AND Behav* AND college) OR (Evacuat* AND decision-making AND School) OR (Evacuat* AND decision-making AND Student) OR (Evacuat* AND decision-making AND campus) OR (Evacuat* AND decision-making AND college) AND (Disaster OR Emergency OR Hazard)
Springer	evacuation AND behavior AND student AND school AND (disaster OR emergency OR hazard)

Table 2

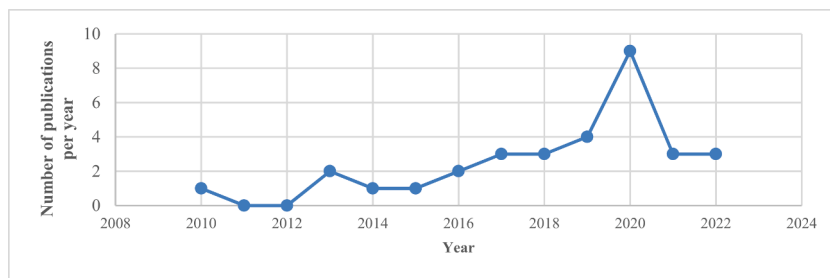
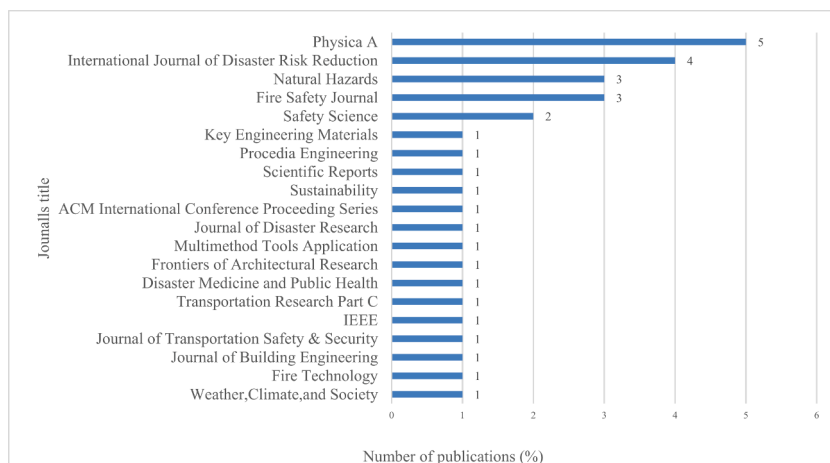
Inclusion and exclusion criteria for each step of systematic searching.

Screening (Rayyan platform)		
	Inclusion criteria	Go to the next step
1- Title Screening	The title included all these keywords: “evacuation, student (school/college/university/campus/class)”.	The title was unclear or included one of these keywords: “evacuation, student (school/college/university/campus/class)”
2- Keywords screening	“Evacuation, student (school/college/university/campus/class)” was found in the article's keywords.	The keywords were unclear or included one of these keywords: “evacuation, student (school/college/university/campus/class)”
3- Abstract Screening	The problem statement clearly delved into students' evacuation behavior.	The problem statement delved into a) not child/student-related, b) technical issues, c) post-disaster impacts on children, d) pre-disaster topics, e) sheltering, f) other unrelated topics
Eligibility assessment		
	Inclusion criteria	Exclusion criteria
Introduction, methodology, and conclusion review	Studies discuss a) students' evacuation behavior, b) factors affecting students' evacuation behavior, c) from social sciences perspective, and d) considered built environment impact and physical features of the population alongside the social aspect.	Studies discuss: a) students' evacuation in other environments rather than institutional buildings, b) solely focus on physical characteristics of population OR buildings, and c) study students' behavior before OR after evacuation.

matic analysis, which attempts to identify patterns among the studies' findings and provide an integrated picture of the studied concepts [56] in the field of students' evacuation behavior during schooltime. The researchers initiated the analysis by repeated readings and generating several coding frameworks using NVivo 2020. The first coding round identified the main research questions, aims, applied methodologies, and findings of the selected studies. Later, the authors conducted the second round of codification to identify the patterns among the studies' aims and findings.

3. Results; background of the selected studies

The included publications show that from 2013 onwards, there has been an increased interest in students' evacuation behavior, and nine of the 32 selected studies have been published by 2020, as shown in Fig. 2. On the other hand, the selected studies have been published in 20 journals, among which “Physica A” has owned the highest number of publications, followed by “International Journal of Disaster Risk Reduction”, as demonstrated in Fig. 3. One should note that some of the journal's scope is emergency and safety stud-

**Fig. 2.** Annual distribution of the included articles.**Fig. 3.** Number of publications and the journal titles.

ies (such as Safety Science, Natural Hazards, and International Journal of Disaster Risk Reduction), while the primary focus of some other journals, such as Physica A, is the behavior of systems. Moreover, some journals have more general scope covering various topics. The studies have been conducted globally, among which China (44%) owns the highest number of publications, followed by Japan, Romania, and the USA (each owns 9% of the publication). Other contributions belong to New Zealand, Denmark, Ireland, Australia, Chile, Italy, Iran, and the Czech Republic. It is noteworthy that school evacuation studies in China have gained significant importance because of several stamped school accidents related to crowd density [57].

On the other hand, most studies (35%) did not particularly focus on the type of emergency, neglecting that students' behavior can be directly affected by the level of threat they feel [58]. Students' evacuation behavior during earthquakes is vastly discussed by scholars (27%). Fire accidents (16%), floods (8%), and tsunamis (5%) are the other highly discussed disasters, while bomb threats, shooting incidents, and landslides are among the other studied emergencies.

According to World Health Organization, people under 18 years old are considered children [59]. On the other hand, some studies have categorized childhood specifically into newborns (0 days–1 month), infants (1 month–1 year), toddlers (1–3 years), pre-school (3–6 years), school-aged children (6–12 years), and adolescent (12–18 years) [60]. In this research, however, we have divided the students' age groups based on schooling level, as shown in Fig. 4. Almost one-third of the identified studies have chosen college or university students as the selected sample, while studies evaluating elementary students' evacuation behavior are in the second rank. Four studies have not explicitly mentioned the students' age group, and two of the studies have considered a wide range of ages.

The majority of the included studies have fallen under the category of quantitative research. However, this research has categorized the studies into four groups to present the applied methodologies concisely. Fig. 5 illustrates the applied methodology for the included studies.

- **Evacuation drills and observations:** This methodology has been observed in six studies, in which the aim was to evaluate the speed and behavior of the students during evacuation. Some studies have focused on the difference between evacuation time and the speed of students considering different evacuation scenarios [58,61], which can provide a comprehensive database of children's evacuation speed and time [62,63]. All studies in this group collected information through recorded videos by checking the actual scene of evacuation recorded by the schools' cameras or conducting evacuation drills. The most significant finding of this group is providing numerical analysis of pre-evacuation time, movement time, and speed and the effect of age and gender on that factor. The results of this category can be input for evacuation simulation studies.
- **Surveys:** Widely observed among the included studies, this group of studies usually aimed at exploring students' evacuation decision-making [64,65], disaster education impacts on evacuation behavior [32,66], risk perception [67], and risk analysis [38,68] by using questionnaires or interviews. The data were analyzed using quantitative analysis methods that demonstrated how different factors might affect the mentioned topics.
- **Modeling and simulation:** Human evacuation behavior during an emergency is a complex matter that can be affected not only by individuals' characteristics but also interactions among individuals, and the built environment can influence people's behavior [69,70]. The first group of the included studies in this research has contributed to how individuals' characteristics and

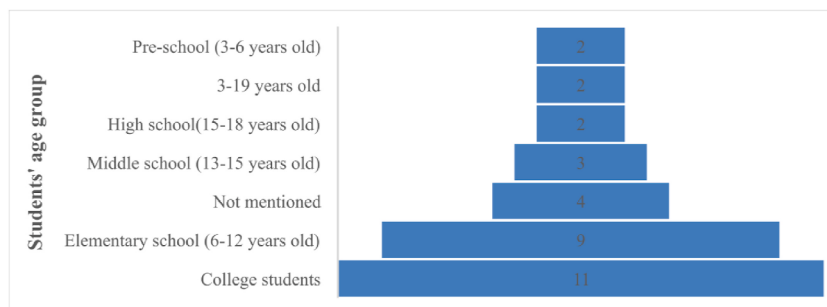


Fig. 4. Children's age groups among the included papers.

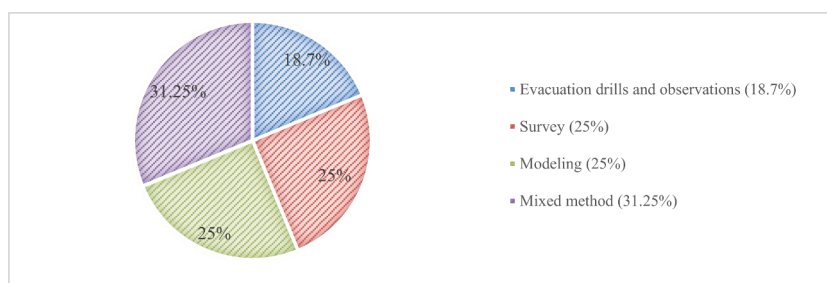


Fig. 5. Applied methodologies among the included papers.

their interactions impact evacuation time and speed [71,72]. Secondly, the effects of the built environment on students' evacuation behavior have been studied by several scholars [26,73]. Thirdly, the geometric features of schools and classroom layouts have been explored in combination with individuals' characteristics and their interactions [11,74–76]. This category's most widely applied methodologies are agent-based modeling, cellular automata, and equation-based modeling.

- **Mixed method studies:** The studies in this group, which is the most frequently applied method, have applied a combination of methods mentioned earlier to evaluate how group behavior, social relationships, and geometric features of buildings may affect evacuation time, speed, and efficiency. Interestingly, eight of the ten mixed-method studies have used surveys in combination with other methods to obtain data. Three studies have illustrated the same pattern in methodologies and defined goals since all aim at analyzing social relationships and guidance's role in evacuation efficiency. Video-recorded data, questionnaires, and social network analysis were commonly used to collect and analyze the data [77–80]. Evacuation simulation, however, has been implemented in three different ways. While the simulation of building layout considering different feature geometric attributes for staircase has been modeled based on recorded data of an evacuation drill [37], another study has combined a questionnaire and agent-based modeling to increase students' evacuation awareness [81]. Research conducted by Poulos et al. [82] has validated the building evacuation agent-based simulation by comparing the results with the recorded evacuation drills. Personality traits' effects on students' route choices have been examined by questionnaires and evacuation drills in the study by Zhan et al. [77]. On the other hand, one qualitative research in this group used case studies, interviews, questionnaires, and triangulation methodology to identify the influential factors on the effective emergency response at schools [83].

4. Discussion; thematic analysis

Thematic analysis has been conducted to identify the research objectives and findings of the included papers. To evaluate the main objective of the studies, the researchers first mapped the most frequently used keywords stated in the studies' goals using the “Word Cloud” function in Nvivo 2020. Afterward, to recognize the context in which the keywords have been used, “Text Search Query” analysis for two main recognized keywords was conducted (Fig. 6). Note that we have contextually analyzed both “behavior” and “behavior” since their spelling differed in the study's resources. The query results demonstrated that the research objectives of the selected papers could be categorized into a) route choice decision-making, b) group behavior, c) impact of social relationship and personality features on evacuation behavior, d) evacuation efficiency analysis, and e) impact of building design on evacuation behavior.

In the second step, the study thematically analyzed the papers' findings based on the method applied by Shaffril et al. [43]. The researchers re-read and manually coded the studies' findings to ensure that the themes obtained from the objectives comprehensively render the discussed topics in the selected literature. This process has been done twice, and some codes have been grouped or added in the second step. Furthermore, considering two codification sets, the study has put forward seven main themes and 21 sub-themes, as presented in Table 3.

4.1. Built environment effects

The first sub-theme in the built environment theme is the impact of building design on students' evacuation behavior. Firstly, the evacuation process regarding the number of floors in the building and the classroom door's width has been evaluated. Simulation of a successful evacuation process of students from a middle school in Sichuan province during the Wenchuan earthquake in 2008 has demonstrated that students on the school's second floor were more at risk of emergency due to congestion in corridors and staircases during evacuation. Similarly, the limited width of the classroom's doors was identified as the second reason for negatively affecting evacuation time and efficiency because of congestion at door gates [26]. Another study similarly simulated pupils' evacuation from a primary school during the Ludian earthquake in China in 2014. The study has concluded that insufficient gate width and inappropriate staircase design on the upper floors could cause congestion and influence evacuation efficiency [73]. A series of visual experiments have studied the negative impacts of safety countermeasures during shooting incidents on students' behavior [75]. The findings revealed that blocking gates (to increase safety) or removing storage rooms (to prevent the hiding of shooters) during active shooting incidents could negatively affect buildings' occupants' choice of hiding.

The other exciting topic related to human-environment interaction is the impact of classroom layout on the students' evacuation behavior and route choice. Specifically, regarding the desk layout, Delcea et al. simulated and compared students' evacuation behavior from one-exit classrooms with traditional and collaborative layouts [84]. The results have indicated that students could evacuate faster from collaborative classrooms than traditional ones. The researchers have also proved that the evacuation time of a collaborative classroom with two exits has significantly decreased. In another study, the students' choices obtained by questionnaires revealed that students in the middle zone of classrooms are more likely to return to the classroom during the evacuation, possibly due to the distance between the desk and the exit. Moreover, most students in the middle section of the classroom did not choose the rear exit because of the habit of looking forward during class time [81].

Apart from the width of the exit gates [26], some studies examined the impact of exit layout. Classrooms with two exits can be more efficient in reducing evacuation time than single-exit classrooms [74,84]. Additionally, evacuation time considering different scenarios of openness of classroom doors has been simulated by Ionescu et al. [11]. Moreover, the researchers have conducted experiments on different exit layouts compositions and pre-school students' evacuation behavior [86]. The results manifested that the short distance between two exits can cause an imbalance in crowd density at each exit resulting in increased evacuation time.

Several scholars have studied the role of staircases in successful evacuation. Xiao et al. simulated a pre-school building and evacuation process and found that properly locating the staircase should be emphasized during the design phase to avoid destruction during

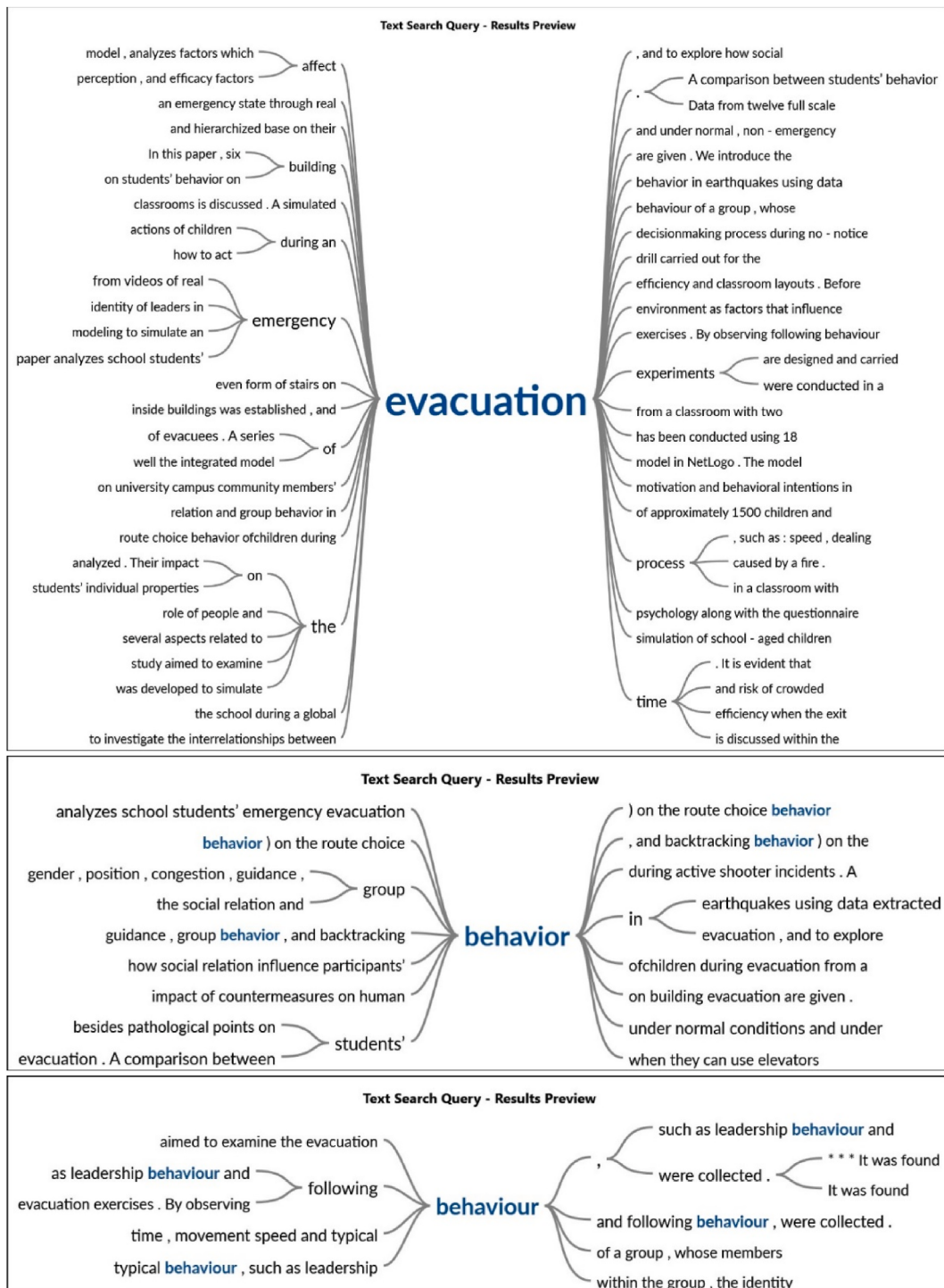


Fig. 6. Text search query of the most frequently used adjectives' keywords.

earthquakes [73]. Other studies evaluating students' evacuation behavior have identified the staircase geometry, such as shape and the staircase slope, and the stair configuration can affect total evacuation time and travel speeds [37,62,63]. A study by Li et al. [87] has proven that elevator egress during evacuation affected students' evacuation choices to evacuate through a staircase or an elevator.

The last sub-theme points to the presence of obstacles impeding evacuees from evacuating smoothly. The obstacles can cause by structure failure, human casualties, or smoke resulting in low visibility. Structural failure [73] and physical obstacles such as desks

Table 3
Identified themes.

Selected studies/ themes	Built environment effects					Disaster information					Evacuation behavior					Individuals' characteristics		Preparedness			Threat appraisal			Travel features		
	BD	CL	EL	SE	VO						BTB	EG	FSE	HHB	HB	SGB	PR	AG	DE	DK	ED	PS	PV	GW	PE	TS
(Chang, Cui and Huang, 2020) [26]	☑																		☑☑							
(Lovreglio and Kuligowski, 2022) [61]																									☑	
(Liu, Jiang and Shi, 2016) [74]				☑								☑														☑
(Delcea et al., 2020) [84]		☑	☑									☑														
(Tang et al., 2015) [72]																☑										
(Najmanová and Ronchi, 2017) [63]				☑								☑		☑				☑		☑					☑	☑
(Mehmood, Ahmed and Kristensen, 2019) [85]					☑																					
(Shoji, Takafuji and Harada, 2020a) [32]						☑														☑			☑			
(Raine and Lin, 2021) [38]																						☑	☑			
(Ionescu, Nica and Chiriță, 2021) [11]			☑															☑								
(Feng and Ji, 2014) [67]																				☑						
(Adiyoso and Kanegae, 2013) [66]																							☑			
(Chen et al., 2018) [65]											☑	☑						☑								
(Xie et al., 2020)					☑							☑				☑									☑	
(Shi et al., 2022) [86]		☑																								☑
(Ding and Sun, 2020) [79]					☑							☑			☑	☑	☑									
(Zhan et al., 2013) [77]																	☑									
(Shoji, Takafuji and Harada, 2020b) [39]																			☑	☑			☑			
(Bandecci et al., 2019) [64]												☑						☑		☑						
(Hamilton, Lennon and O'Raw, 2017) [62]				☑								☑		☑											☑	☑
(Zheng et al., 2020) [68]						☑									☑			☑		☑						
(Delcea and Cotfas, 2019) [81]		☑	☑								☑	☑									☑					
(Tipler et al., 2018) [83]																				☑						
(Rostami and Alaghmandan, 2021) [37]				☑																						
(Mao et al., 2020) [71]																	☑									
(Zhou and Wei, 2010) [76]															☑		☑		☑							
(Xiao, Zhang and Liu, 2017) [73]	☑			☑	☑																					
(Li et al., 2020) [87]				☑											☑											
(Zhu et al., 2022) [75]	☑																		☑	☑						
(Poulos et al., 2018) [82]																										☑
(Gu et al., 2016) [58]												☑						☑					☑			☑
(Fu et al., 2019) [88]																								☑		

BD = Building design, CL = Classroom layout, EL = Exit layout, SE = Staircase/elevator, VO = Visibility/obstacles, BTB = Backtracking behavior, EG = Evacuation guidance, FSE = Faster is slower effect, HHB = Hand-holding behavior, HB = Herding behavior, SGB = Social relationships & group behavior, PR = Personality fea-

tures, AG = Age & gender, DE = Disaster experience, DK = Disaster knowledge or education, ED = Emergency drills & use of technology, PS = Perceived severity, PV = Perceived vulnerability, GW = Group walking, PE = Pre-evacuation, TS = Travel speed & time.

and tables [85] have been proven to increase evacuation time, especially for people who are less familiar with the environment. On the other hand, observations demonstrated that smoke has significantly affected evacuation effectiveness by increasing evacuation time, decreasing evacuees' speed, and disturbing exit flow [79,80].

4.2. Disaster information

The role of the disaster information dissemination system in the students' evacuation decision-making has been explored in two studies [38,68]. More credibility of the disaster information has positively affected college students' evacuation intention and decision-making. In addition, the students' trust in the disaster information resulted in higher perceived vulnerability and lowered perceived self-efficiency in coping with the disaster [38]. Although the studies mentioned earlier in this sub-section have agreed on the effect of the credibility of disaster information on several issues, their results regarding the impact of individuals' trust in disaster information on evacuation decision-making contradicted each other.

4.3. Evacuation behavior

One of the most observed behaviors during evacuation is "backtracking behavior," meaning the individuals tend to return to the building to pick up the forgotten or missing belongings. This phenomenon has been observed among adults [89,90] and children; however, the visual questionnaire-based study of primary students declared that younger children are more likely to return to the classroom to pick up forgotten things [65]. Another study has found that students in the middle zone of the classroom showed more intention to return to the classroom after evacuation, which can be related to the distance between the exit and their desks [81].

The role of evacuation guidance has been studied in several studies concerning its various impacts on the evacuation process. Evacuation drills among pre-school and middle school students have shown that the presence of proper instructions during evacuation could reduce evacuation time by increasing students' speed [63,74]. However, *Chen et al.* found no relationship between evacuation guidance and route choice among elementary students [65]. Another research has identified that groups of primary students led by one of them have experienced faster evacuation than those guided by an adult [62]. The researchers have also examined whether evacuation leaders chosen among university students impact students' route evacuation choices. Their findings indicate that individuals' behavior and familiarity with routes affected evacuation route choice rather than leaders' choice [79]. Simulation research conducted by *Delcea et al.* [84] revealed that volunteer guidance increases the speed of individuals as long as the guide gives students instructions. The study has also proven that the guidance can effectively increase the speed of students close to the guide. Therefore, the presence of more guides may smoothen the evacuation process.

On the other hand, *Xie et al.* have examined evacuees' group structure with and without evacuation leaders [80]. Their study illustrated that the groups guided by a leader showed a vertical structure, while non-leader groups had a horizontal structure. In addition, the researchers have identified that leadership is less effective in students' evacuation route choices when the visibility is weakened [79,80]. Considering the role of evacuation guidance for young students and their tendency to follow the teachers' guidance during an emergency [81], school staff should be competent enough to prepare and guide students during emergencies [64].

The other widely-observed phenomenon during evacuation is "Faster-is-slower effect", meaning that the greater desired speed among the evacuees usually results in a slower flow rate through the exit [91]. However, recorded earthquake evacuation videos did not identify the faster-is-slower effect among primary school and high school students in China [58]. On the other hand, hand-holding behavior has been observed among younger pre-school and primary school children especially passing through staircases, which could result from the teachers' instructions [62,63].

Herding behavior, referring to following the direction of most of the crowd [86], can influence the risk perception of individuals facing an emergency [76]. However, herding behavior has only been studied among college students. Ding and Sun believe that students cannot form stable groups to evacuate during an emergency, which might increase the chance of blindly following others, especially the ones ahead of them [79]. A study conducted among university students showed that herding behavior did not affect evacuation decision-making, and students seeking additional information about the disaster are less likely to follow others blindly [68].

Moreover, they have identified the relationship between demographical characteristics such as age and gender and students' herding behavior. Besides, the findings of one study have demonstrated that social relationships and group behavior can influence evacuation time [87]. *Xie et al.* identified the patterns of social relationships among university students and concluded that students who usually walk together in daily life tend to form the same group during an evacuation [80]; however, the emergency may not allow them to do so [79].

4.4. Individuals' characteristics

A vast amount of literature examines movement ability regarding humans' age [92,93]. The impact of students' age on movement ability has been studied by conducting evacuation drills among pre-school students [63]. Besides, a study by *Ionescu et al.* [11] has simulated students' evacuation considering different groups of individuals based on movement ability driven by age and gender. Moreover, a comparison of the evacuation process between children (primary and high school students) and adults demonstrated that although children's response time is relevantly shorter, adults evacuate less chaotically [58]. On the other hand, several researchers have discussed the impacts of age on disaster awareness and preparedness [64] and herding behavior [65,68].

Second, the relationship between personality factors (individuals' psychological factors, emotions, and roles) and evacuation behavior has been focused on by some scholars. An experience-based evacuation of university students manifested a strong association between evacuation choice and individuals' psychological factors, personal sense, and route choice [79]. More specifically, *Tang et al.* pointed out that the proportion of irrational students who tend to follow the crowd can affect evacuation efficiency [72]. The matter of an individual's personality has been examined by applying OCEAN¹ model to structure individuals with different personalities in an agent-based model and identify how different ways of emotional contagion among the individuals can affect the evacuation process [71].

4.5. Preparedness

The existing disaster management literature includes numerous studies addressing the association between disaster experience and evacuation behavior. Among this research's selected publications, the mentioned question has different answers. Although *Zheng et al.* [68] have identified that disaster experience did not influence university students' evacuation choice, having a shooting incident experience is associated with the appropriateness of their response to virtual shooting incidents based on a study by *Zhu et al.* [75]. In addition, scholars have demonstrated that parents' past experiences coping with disasters can positively affect their children's perceived coping ability, risk perception, and disaster response [39].

Several studies have discussed the role of disaster knowledge in the effectiveness of evacuation and survival [67]. The necessity and the effects of disaster training for school students have also been addressed in various publications. The compulsory disaster education program for school students in Indonesia has shown significant improvement in elementary and high school students' risk perception, awareness, and disaster response [32,39,66]. The study conducted by *Tipler et al.* [83] has put forward a six-step framework for effective school-based emergency response based on the lessons learned from schools in New Zealand. On the other hand, several researchers came to a consensus on the role of students' familiarity with the school environment in facilitating their movement during an emergency [62,63,75], illustrating the necessity of providing sufficient spatial data during preparedness stage to experience safer evacuation. However, *Chang et al.* believed that a lack of real emergency evacuation experience has resulted in panic even among trained students [26]. One possible solution to overcome this problem would be increasing schools' staff disaster coping abilities. The more prepared the teachers and school staffs are for emergencies, the more influential the evacuation will be [64]. Secondly, researchers have proven that students' awareness can be significantly enhanced by using evacuation simulations [81].

4.6. Threat appraisal

Referring to the risk management framework [94] and human evacuation decision-making mechanism [95], this study has identified two sub-themes for students' threat appraisal, perceived severity and perceived vulnerability. *Rainear and Lin* [38] have identified that the credibility of emergency information sources could affect students' perceived vulnerability but not the perceived severity. Moreover, although higher perceived vulnerability was negatively associated with evacuation motivation, the higher the perceived severity of the emergency, the higher the students' motivation to evacuate. On the other hand, although the studies have evaluated the relationship between disaster education and students' vulnerability perception [32,66], those studies' findings showed contradicting results. Besides the effect of education, vulnerability perception is affected by students' attitudes toward learning science, parents' experience coping with disasters, and students' perception of their ability to control disaster outcomes [32].

4.7. Travel features

The effect of group walking during evacuation on the speed and structure of groups has been widely discussed in the selected literature. A study by *Li et al.* [87] identified that existing social relationships among college students generated three types of evacuees: leader, follower, and lonely. Observations showed that the groups' walking speed was steady during evacuation since the group members attempted to have the same speed [88]. This study found that the larger the group size, the slower the speed. Moreover, the combination of two male evacuees has a lower speed than two females. Another publication's findings pointed to the structure of evacuees' groups during evacuation [80]. During an evacuation, large groups or those without a leader have shown a horizontal pattern, while smaller groups or groups led by a leader have demonstrated a vertical pattern.

On the other hand, studies have usually concluded that total evacuation time is an aggregation of pre-evacuation and movement time. The pre-evacuation time for the students at school is the total duration since students/teachers identify risk until decision-making and starting action [96]. The pre-evacuation time can be affected by age and evacuation guidance [58,62,63], while age [62], gender [86], body size [82], population density [74], and evacuation routes including staircase geometry, class and floor location [61,63,74,86] can affect movement time and travel speed.

5. Conclusions; making sense of the literature

This study aimed to provide a consolidated thematic framework of the studies in the domain of students' evacuation behavior during schooltime. Simultaneously, the emergency reaction significantly differs based on the individuals' age and the content of the emergency [7,97,98]. This research attempted to provide a comprehensive understanding of students' evacuation behavior and applied methodologies.

The existing literature on "students' evacuation behavior during school time" was selected and reviewed by applying for a systematic literature review. The first stage was to structure a straightforward research question based on the PICo method. Second, the ba-

¹ Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism.

sis research and review protocols were set up by applying PRISMA framework, and Rayyan platform was used for screening. After duplication removal, the study hierarchically selected 282 papers and went through the screening phase, and afterward, 97 papers were selected for eligibility assessment. The researchers then decided whether to keep or remove each paper based on the detailed inclusion and exclusion criteria. In the end, 32 studies remained for text analysis. From here, codifying the papers' basic information and thematic analysis of the studies' objectives and findings have been conducted. Thematic analysis identified seven main themes: a) built environment effects, b) disaster information, c) students' evacuation behavior, d) individuals' features, e) preparedness, f) threat appraisal, and g) travel features.

Among the recognized themes by this study, the schools' built environment features affecting students' evacuation behavior is the second highly mentioned topic among the included studies. The researchers have put forward suggestions about gate width, space design, classroom layout, exit layout, and staircase design and have examined the hypotheses using experiments and simulations. This group's findings can be especially beneficial for institutional space designers. Although evacuation sign design has been conducted previously, to our best knowledge, the literature lacks research on the impacts of evacuation signs in institutional space and their appropriate position and design by considering students' age on students' evacuation behavior.

Regarding the importance of emergency and evacuation alerts, their content, and their dissemination way [4], scholars have studied the credibility of emergency information resources and their impact on students' evacuation decision-making. In this regard, Protection Motivation Theory (PTM) [99], considering an integrated process of disaster decision-making, have been evaluated, focusing on the information sources and students' attitude toward seeking disaster information and evacuation behavior. The literature in this regard misses which emergency and evacuation alarms type (voice, text, visual messages, and others) are more effective for different students' age groups. Additionally, there is a need to study emergency alerts' efficiency for young children since their risk identification capability is not well-improved.

The theme of evacuation behavior comprises broader sub-themes and explores the influential factors on behavioral phenomena during an emergency evacuation. A study by *Xenidis and Kaltsidi* [13] listed the most frequent human reactions during disasters; however, emergency reactions slightly differ among children. Backtracking behavior has been widely observed among young students. However, the studies did not identify patterns of the faster-is-slower effect among children. Studies have also proven that students' evacuation, especially at young ages, is more chaotic than adults, possibly due to underlying reasons such as the faster-is-slower effect. Therefore, there is a need to conduct more research on this topic. On the other hand, herding behavior also requires further study to identify how age and social networks can affect blindly following others.

Another exciting topic broadly discussed by the selected literature is evacuation guidance or leadership. The scholars explored the role of proper guidance in the evacuation efficiency of young students. On the contrary, group leadership has been considered an alternative to evacuation guidance within the context of university students' evacuation, which corresponds to the student's age and ability to recognize and answer risks. The researchers also examined the guides' age and proved that young pupils' evacuation would be faster if the guide were chosen among same-aged students. Although scholars have delved into modeling the efficiency of the evacuation process by changing the guides' number, further research is needed to understand the sufficient number of evacuation guides and their location.

Searching in the evacuation behavior literature, a vast number of studies addressed individuals' characteristics considering different emergency types. Research conducted by *Lee et al.* [100] has categorized the effectual factors on evacuation decision-making into demographic features, socio-economic characteristics, and disaster experience and knowledge. However, since this research studied the students' evacuation behavior at school, some influential parameters may not be applicable here. Therefore, the included publications identified that age, gender, and personality influence students' evacuation behavior, among which the impact of psychological issues such as panic and anxiety and personality traits on travel speed and the evacuation process requires further study. Referring to the role of age in emotion control, future research may be devoted to perceiving the differences in students' evacuation behavior resulting from age differences.

Much disaster-related literature broadly discusses preparedness and its significance in disaster management [101,102]. However, in the context of schools where children spend the majority of their time, it necessitates particular attention. This study identified three sub-patterns of preparedness of schools and students. First, disaster education has a long history of research in disaster-prone countries such as Japan and Indonesia. The selected publications analyzed how effective formal disaster education was in improving students' risk perception, perceived coping ability, and disaster response. Second, disaster experience has significantly impacted adults' disaster response [103,104]. However, the included papers in this study have identified different results regarding the disaster experience and improvement of children's disaster response. Lastly, the role of using state-of-the-art technologies, such as simulation of evacuation, to enhance students' disaster knowledge formed the last sub-theme in this group. To this end, studies have mainly focused on survey-based research to examine the effectiveness of disaster training. It is recommended that future studies develop child-friendly methods such as Virtual Reality and evacuation-scenario games corresponding to different age groups to improve students' disaster knowledge.

In addition, this study has recognized two patterns for threat appraisal. First, perceived severity assessing the disaster risk likelihood has been explored by applying PMT among university students. Future studies need to evaluate to which extent emergency severity perception differs among students in different grades. Second, although perceived vulnerability referring to vulnerability assessment of the disaster risk has been intensely discussed by examining the associations between different steps of PMT, the literature can be enhanced by studying the role of students' social relationships on vulnerability perception.

Lastly, the scholars whose research falls under the theme of travel features have studied students' evacuation, usually by observing evacuation drills or recorded evacuations, to provide travel features database based on students' age, gender, evacuation routes, and group walking. Moreover, the researchers have predominantly focused on distinguishing factors affecting students' pre-evacuation

and movement time. Although the literature on those subjects is relatively well-developed, future studies may find beneficial results explaining the impact of social context and emotional contagion on students' pre-evacuation time.

6. Implementations, limitations, and recommendations for future studies

6.1. Contribution and implementation of the study

The first key contribution of this study is conducting a systematic literature review of the literature in domain of students' evacuation behavior during school time which was the first attempt in this field to our knowledge. This study provided a valuable platform for the applied methodologies, objectives, and findings of the existing literature in this field and opened avenues for future research by suggesting possible beneficial research directions to improve students' safety during evacuation. The thematic framework is this research's second contribution, illustrating the pre-existing patterns of research directions. The thematic framework can be used as a research guide to get comprehensive access to the major themes studied in the literature.

This study has classified the various influential topics on students' evacuation behavior based on the findings of the systematic literature review. Therefore, the proposed thematic framework can be used by evacuation decision-makers who are in charge of schools' emergency evacuation to understand the intricate nature of students' evacuation behavior and improve the students' safety in case of evacuation by systematically resolving the shortcomings and enhancing the strengths of the schools' and students' evacuation performance.

6.2. Limitations of the study

The current study has some limitations which can be answered in future research. First, due to limitations in accessing other databases, the identification stage has been conducted through searching four academic search engines, Web of Science, ScienceDirect, Springer, and Scopus. Second, it is estimated that some aspects of the literature were not captured because of keyword choice or inclusion and exclusion criteria. Although this study tried to overcome those shortcomings by applying clear research and searching protocols based on the existing theories, there still remains the possibility of missing some related pieces of literature.

6.3. Recommendation for future study

While this research attempted to holistically present the discussed topics in the students' evacuation behavior literature by focusing on the context of emergencies at schools, there remain significant opportunities for future studies. Further studies could assist consolidation of this paper's proposed thematic framework. Future studies should consider children's evacuation behavior in a different context and focus on the commonly observed emergency behaviors among children at different ages. The other point of the spectrum of the vulnerable population during emergencies and evacuation is elderlies due to their physical limitations [105–107]. Therefore, elderlies' emergency decision-making and evacuation behavior can be a subject to be studied by future researchers.

Additionally, based on the findings of this research, studies dealing with pupils' evacuation behavior at schools can be enhanced by adopting the following recommendations.

- Use of observations or simulations for data collection due to difficulties in collecting data through surveys for young-age students. It is also necessary to develop a more refined evacuation behavior data collector.
- Focus on specific emergencies to study students' evacuation behavior since the nature of the disaster affects individuals' risk perception.
- Evaluating the role of culture in students' evacuation behavior
- Examining evacuation guidance's role, a sufficient number, and special location.
- Utilizing advanced methods and technologies, such as machine learning, for better preparing students for emergency evacuation.
- Assessing the relationship between students' evacuation efficiency and evacuation signs.
- Assessing impacts of emergency notification types on different students' grades.
- Assessing students' social relationship impacts on pre-evacuation time.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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