DIMENSI: Journal of Architecture and Built Environment, Vol. 53, No. 1, July 2026 DOI: https://doi.org/10.9744/dimensi.53.1.81-93
ISSN 0126-219X (print) / ISSN 2338-7858 (online)

Improving Fire Evacuation Routes: Non-Structural Barriers and Community Risk Perception

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Article Info:
Submitted: January 08, 2026
Revised: June 15, 2026
Accepted: June 20, 2026

Keywords:
fire evacuation;
structural barriers;
non-structural barriers;
risk perception;
community participation.

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Abstract

Highly populated areas are prone to fire hazards; hence, there is a need for proper evacuation routes. The high building density and limited access roads obstruct movement during emergencies. Most previous studies focused on structural barriers, while non-structural factors like community behavior, preparedness, and risk perception have received less attention. This paper will present an analysis of the impact of both evacuation barriers and community risk perception on recommended fire evacuation route improvements in highly populated areas. A sequential exploratory mixed-methods approach was used, with qualitative data from 111 respondents and quantitative data from 278 respondents analyzed through multivariate linear regression. The results indicate that non-structural barriers, preparedness levels, and community anxiety significantly influence recommendations for improving evacuation routes, while structural barriers have no effect. These findings confirm that behavioral and social barriers are more dominant than physical barriers in densely populated settlements. This study recommends improving risk literacy, conducting evacuation simulations, and establishing resident-based fire response teams to strengthen community-based mitigation.

INTRODUCTION

A major challenge facing cities in developing countries is the emergence of densely populated areas. High population density, closely packed buildings, and limited road access impact the effectiveness of evacuation processes. Fire cases in Dhaka (Adiba, 2023), San Jose (Arce et al., 2025), Nairobi (Hirst & Underhill, 2025), and Cape Town (Quiroz et al., 2021) A major challenge facing cities in developing countries is the emergence of densely populated areas. High population density, closely packed buildings, and limited road access impact the effectiveness of evacuation processes (Kobes et al., 2010; Zehra & Wong, 2024).

Previous research confirms that the effectiveness of fire evacuation depends on the physical design of evacuation routes and the behavior and preparedness of residents (Bakhshian & Martinez-Pastor, 2023; Suparto & Erwandi, 2024). According to Bakhshian & Martinez-Pastor (2023), individuals often react unpredictably in emergency situations due to fear, psychological stress, and limited information, which disrupts the evacuation process. According to Osman et al. (2022), low disaster literacy prolongs response time and increases the risk to residents' safety. Kobes et al. (2010) stated that the quality of passive protection systems – emergency lighting, evacuation signs, and alarms – directly affects the speed of the pre-movement phase. Zehra & Wong (2024) further note that in densely populated areas, the environmental infrastructure, path width, and distance between buildings — directly influences how smoothly people can evacuate. It is the involvement of the community in the planning of evacuation that can produce routes according to local spatial and social conditions. Fauzi et al. (2023), proved that the

Participatory Action Research (PAR) approach can improve preparedness in the community while addressing non-structural barriers that are usually left out by technical interventions. When communities utilize their local knowledge, participatory disaster mitigation becomes more effective, yielding inclusive, adaptive, and sustainable solutions. Collaboration between community initiatives and government policies ultimately results in evacuation routes that truly address real needs on the ground (Cvetković et al., 2026; Makhfud & Mursyidah, 2024).

Currently, many fire studies in congested areas are still focused on physical and technological innovations, such as smoke dispersion models (Xiao et al., 2025), digital-twin-based evacuation route optimization (Tan et al., 2025) and deep-learning fire detection systems (Shirwaikar et al. 2025). This approach does reinforce the technical aspects but considers evacuation to be just a physical and computational problem. In fact, there are often overlooked barriers to the interaction of non-structural barriers such as narrow alleys, modification of informal spaces, and the lack of safety infrastructure with citizens' risk perceptions that affect their readiness to propose evacuation improvements. Until now, the combined influence of environmental and psychological factors that come from community-based proposals has not been systematically studied. These limitations hinder efforts to design interventions that are appropriate to real conditions on the ground.

Although deep learning-based smoke spread simulations and fire detection continue to advance rapidly, most studies still narrow evacuation issues to mere physical issues and computational calculations. Researchers often ignore the behavioral and psychosocial dimensions that ultimately drive residents' decisions in densely populated settlements. Existing analyses also rarely link non-structural barriers to how communities perceive risk. This research addresses this gap by integrating environmental, behavioral, and perceptual aspects into a single analysis. A novel aspect of this study demonstrates that community recommendations not only highlight the limitations of physical infrastructure but also reflect residents' behavioral responses and emotional assessments of fire threats.

This study asks the question: to what extent do non-structural barriers and community risk perceptions influence suggestions for improving fire escape routes in densely populated urban organizations? In line with this question, the study analyzes the simultaneous influence of barriers and risk perceptions on community recommendations for improving infrastructure contributing to fires in densely populated urban areas. It covers a more complete approach in capturing the physical, behavioral, and perceptual aspects of how people perceive risk and, consequently, prepare their strategies for fleeing. This result of the study can be taken as solid evidence that enhances flexible evacuation planning responsive to people's needs and non-structural fire mitigation measures in densely populated areas.

LITERATURE REVIEW

Comprehension of fire evacuation response has changed, with modern studies integrating physical, behavioral, and social dimensions. Earlier research emphasized spatial configuration and route design; recent research has highlighted the importance of psychological factors such as perception and decision-making. For example, Kuligowski (2021) laid out how pre-movement time, visibility, and route layout inform the speed of evacuation, and subsequent research has furthered this by examining how these factors cue people’s interpretations of hazards in the field.

This has been addressed by researchers through different empirical approaches in behavioral and perceptual dimensions. One such approach was taken by Turgay (2025), who considered risk perception as a multidimensional construct involving cognitive and affective evaluations. Forrister et al. (2024) note that pre-evacuation preparation often results in delays but high evacuation speeds. Initial awareness may lessen the impulse to immediately evacuate because the residents feel more in control over the situation. This phenomenon underscores the fact that the success of timely evacuation is not entirely enforced by environmental stimuli but also mental readiness and pre-determined risk evaluations.

In terms of non-structural measures, Hawsawi et al. (2025); David et al. (2024); and Liu et al. (2023), all concur that training and social preparedness are the most effective tools. Constant public education has been proved to enhance community cooperation during crises, as noted by Fazeli et al. (2024), though this change in behavior needs regular interaction and the building of a strong safety culture, particularly in places with socio economic limitations.

This is where community participation acts as a link between the physical interventions and social adaptation. Through a participatory approach, the residents are guided to recognize hazards, map independent routes as well as design safer spatial plans, as recommended by Fauzi et al. (2023). Gong et al. (2026) add that making cultural values part of educational materials will strengthen collective memory and thus trust in authorities.

The paper will majorly use the analytical tools of Rogers' Protection Motivation Theory (PMT) (Rogers, 1975, 1983) and the Protective Action Decision Model later developed by Lindell & Perry (2012). Human protective behavior through threat is analyzed in PMT which involves the assessment of threats and coping strategies. On the other hand, PADM describes how individuals respond to warnings, test the validity of the information, and then determine the possibility of escape. In this research, these two theories will be used to map community perceptions of risk and formulate an evacuation blueprint in densely populated areas.

The study proposed a conceptual model that integrates three key variables: X1 (evacuation barriers), X2 (risk perception), and Y (community recommendations for route improvements). It was presumed that readiness and capacity of the community in the planning process of an evacuation would be developed together and that this would be influenced by structural and non-structural factors. This logical flow is mapped in Fig. 1 which shows the correlation between the dimensions of barriers and risk perception and the proposed route improvements. Each indicator within the latent variable box was validated using Principal Component Analysis (PCA) to provide an objective database for understanding the determinants behind community recommendations.

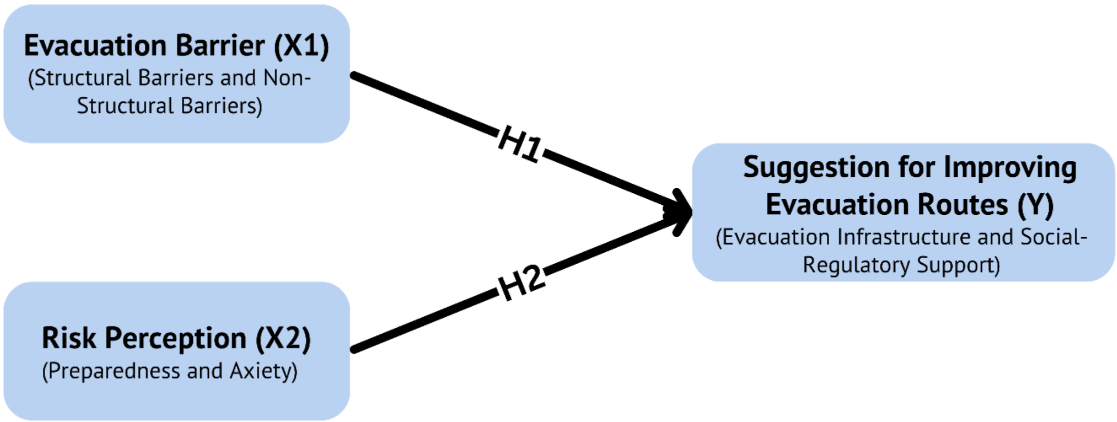

Fig. 1. Hypothesized Causal Model of the Relationship between Evacuation Barriers (X1), Risk Perception (X2), and Evacuation Route Improvement Suggestions (Y)
(Source: Authors)

METHODS

Research Approach

The researchers used mixed-methods, sequential explanatory design to integrate qualitative exploration and quantitative validation (Creswell & Creswell, 2022). In the first phase, a qualitative study was carried out to identify evacuation barriers as well as suggestions from the residents on how to improve the routes for evacuation in densely populated settlements. In the next phase, a quantitative survey was carried out to test relationships between variables that emerged from the qualitative findings. This approach gives a total picture of evacuation dynamics because it brings together measurable empirical data with contextual social data. The framework will enable the identification of structural and non-structural barriers and how risk perceptions influence community suggestions on improving the evacuation route. This design was based on a connection of qualitative insights of residents with a statistically validated quantitative model to ensure that the research results are both contextual and empirical. The architectural and disaster risk research design principles were based on evidence, emphasizing the integration of empirical data with user experiences (Lehmann, 2023).

For theoretical purposes, the researchers used Slovic (1987) psychometric model of risk perception, which emphasizes cognitive and affective components in the assessment of risk. It was not delved into in the qualitative phase because this is an abstract concept and one that can be better addressed with structured measurement. Rather, it was directly integrated by the researchers into the instruments to ensure that the research stays focused on the experiences of the residents and on being able to measure the pertinent data clearly.

Data Collection Method

The research was carried out in two consecutive stages. The first stage entailed qualitative exploration and quantitative validation in March 2025, using non-random sampling and snowball sampling techniques to collect responses from respondents who are acquainted with fire risks in densely populated areas. This method was chosen because random population surveys are hard to carry out in densely populated areas, so researchers have to depend on networks or recommendations from residents to find respondents.

An open-ended online questionnaire was participated in by 111 respondents that tapped (1) perceived evacuation barriers and (2) suggestions for improving evacuation routes. Most of them, 73.7%, were residents of urban areas; 61.5% were occupants of landed houses, and 32.5% had been staying there for less than five years. 48.2% said that they had an evacuation route, but only 21.1% had undergone training on fire evacuation. Full demographic characteristics of the qualitative respondents are shown in Table 1.

Table 1. Characteristics of qualitative research respondents

Variable	Classification	Frequency (%)
Location	Urban	73,7 %
	Suburban	21,9 %
	Far from city	4,4 %
Housing Type	Detached house	61,5 %
	Apartment (flat)	3,5 %
	Apartment (unit)	4,4 %
	Dense settlement	30,7 %
Length of Stay	< 5 years	32,5 %
	5-10 years	18,4 %
	10-20 years	24,6 %
	> 20 years	24,6 %
Evacuation Route Presence	Yes	48,2 %
	No	26,3 %
	Unknown	25,4 %
Evacuation Training Participation	Yes	21,1 %
	No	78,9 %

The second phase, named the quantitative phase, was carried out in April 2025 through a structured online questionnaire. The research sample was chosen on purpose. Respondents should be 17 years old or above, have been living in a densely populated settlement for at least six months, and be familiar with the local conditions as well as the evacuation routes. To ensure quality data, duplicate responses were detected and removed immediately by checking IP addresses and the time of questionnaire completion.

In the second phase, 278 respondents took part, meeting the recommended ratio for factor analysis (White, 2022). Complete characteristics of respondents in the quantitative phase are presented in Table 2.

Table 2. Characteristics of quantitative research respondents

Variable	Classification	Frequency (%)
Gender	Male	29%
	Female	71%
Age	17-25 years	89.2%
	26-35 years	10%
	> 35 years	0.8%
Number of Occupants	1-2 people	15.8%
	3-5 people	69.9%
	> 5 people	14.3%
Fire Experience	Yes	32.5%
	No	18.4%
APAR Knowledge	Know	48.2%
	Do not know	26.3%
Training/Simulation Participation	Yes	47.7%
	No	52.3%

All respondents participated voluntarily after we explained to them the fact that they were going to take part in a study. The data collection process was also in line with research ethics standards. We assure all respondents' identities will be kept confidential, and all data collected will be used for academic purposes only.

Data Analysis Method

The qualitative data was analyzed by first identifying the data, then conducting initial coding, developing themes, and iteratively refining them, using thematic analysis as described by Braun & Clarke (2006). This analysis will help in transforming narrative responses into measurable constructs that can then be used to inform the development of quantitative instruments. Thematic analysis was chosen to allow an in-depth exploration of the experiences of the residents and to reveal peculiarities of the problem of evacuation in densely populated settlements. The quantitative data was processed using Principal Component Analysis (PCA) to identify underlying dimensions of the barriers to evacuation, perceptions of risks, and proposed enhancements. The instrument reliability was tested using Cronbach's alpha, with a threshold of 0.60, as recommended by (Ghozali, 2021). Varimax rotation was applied to facilitate the interpretation of factor loadings. All quantitative analyses were analyzed using JMP software (version Pro 18) developed by SAS Institute Inc.

Researchers continued with multivariate linear regression analysis to examine the influence of evacuation barriers and risk perception dimensions on community suggestions for improving evacuation routes. Examples of questions in the quantitative questionnaire can be seen in Table 3.

Table 3. Example Questions with SD Method

Category	Example Question
Physical & Infrastructure Barriers	Evacuation routes are winding or indirect
	Strongly Disagree 1 2 3 4 5 Strongly Agree
Environmental Barriers	Smoke interference reduces visibility during evacuation
	Strongly Disagree 1 2 3 4 5 Strongly Agree
Psychological Barriers	Panic, rushing, or disorderly behavior during evacuation
	Strongly Disagree 1 2 3 4 5 Strongly Agree
Mobility Barriers	Crowding or traffic jams on evacuation routes
	Strongly Disagree 1 2 3 4 5 Strongly Agree
Preparedness Barriers	Lack of knowledge or training about evacuation procedures
	Strongly Disagree 1 2 3 4 5 Strongly Agree

A side-by-side comparison approach was used to integrate the qualitative and quantitative results. This strategy can help researchers find points of convergence as well as differences between the two datasets so that this study obtains strong internal validity and produces a comprehensive understanding of the social and structural dynamics that influence fire evacuation behavior in densely populated settlements.

RESULTS AND DISCUSSION

Evacuation Barriers Identified from Qualitative Analysis

The qualitative findings in Table 4, categorize the evacuation obstacles experienced by residents in densely populated settlements. Five main categories were identified: Physical and Infrastructure, Environmental, Psychological, Mobility, and Preparedness/Security. Physical and infrastructure barriers were the most frequently mentioned, particularly difficult access (33 mentions), minimal facilities (11 mentions), and obstructed or closed exits (10 mentions). Psychological constraints were similarly prominent, with emotional chaos such as panic and confusion cited 38 times. Environmental factors, including smoke interference (6 mentions) and rapid fire spread (4 mentions), also contributed to evacuation challenges. These findings confirm that the challenges of evacuation stem not only from structural limitations, but also from behavioral and environmental factors. Improvement efforts must target physical, psychological and situational aspects that affect residents' responses in emergencies.

Table 4. Results of coding evacuation obstacles

Category	Sub-Category	Frequency	Respondent Quote Example
Physical and Infrastructure Barriers	Poor layout	6	"The close proximity of houses, so surrounding houses must be secured so they are not affected."
	Building collapse	3	"When already hit by the building."
	Minimal facilities	11	"Does not have an APAR (fire extinguisher)."
	Closed access	10	"My house is covered with trellis."
	Difficult access	33	"Narrow streets in alleys; if a fire occurs, the evacuation route is hard to reach."
Environmental Barriers	Natural conditions	5	"Weather factors, especially if the wind blows strongly, the fire is feared to spread further."
	Fire outbreak	4	"The fire is already too large."
	Smoke interference	6	"Smoke covering the view."
Psychological Barriers	Emotional chaos	38	"Panic can make me confused about what action to take."
Mobility Barriers	Crowd mass	6	"Crowds of residents blocking the evacuation process."
	Traffic jam	9	"Traffic jams make it difficult for officers to arrive."
Preparedness Barriers	Lack of knowledge	14	"Lack of education for people around."
	Fire brigade delay	3	"The fire team usually arrives late at the scene."
Security Barriers	Asset safety	2	"People looting the victims' belongings."

Fire evacuation in dense settlements is greatly influenced by the interaction between spatial planning and residents' behavior. Non-structural barriers such as panic, confusion, and density are more dominant than physical barriers, indicating that environmental problems are closely related to gaps in knowledge, perception, and decision-making. This is in line with Kuligowski (2021) who emphasizes the importance of pre-movement behavior, and Turgay (2025), who highlights the role of perception and cognition in emergency response. Similar patterns are also seen in global informal settlements, where narrow pathways exacerbate behavioral reactions.

These insights confirm that evacuation planning is not enough with physical interventions such as lane widening or signage. Spatial strategies should be linked with behavioral approaches, such as community drill on evacuations, constant education, and simple communication systems to help the people manage panic. The structural interventions, including barrier removal and the installation of emergency signs, are still very necessary but should be implemented with social preparedness programs.

Community Suggestions for Evacuation Route Improvement

Table 5 summarizes the community priorities as suggested by the residents: better access to evacuation (53 mentions), training and community socialization (45 mentions), and clarity of evacuation signs (42 mentions). These underscore the paramount importance of accessible routes, informed citizens, and clear instructions during the time of emergency. Other suggestions were route improvement (26 mentions), emergency lighting (14 mentions), community cooperation (9 mentions) and local policy support (4 mentions). Results indicate that the residents perceive the improvement of evacuations as an effort with many aspects, where physical improvement is just one.

Table 5. Coding results suggest improvements to evacuation routes

Category	Sub-Category	Frequency	Respondent Quote Example
Education and Community Involvement	Training and community socialization	45	"Increase socialization regarding fire evacuation routes."
	Community cooperation	9	"Helping each other."
Policy and Regulation	Government policy	4	"The existence of policies from the local government."
Infrastructure and Evacuation Facilities	Route improvement	26	"Pay more attention to the condition of the routes so they remain in good condition."
	Assembly point creation	3	"Availability of assembly points."
	Emergency staircase creation	1	"Making an emergency staircase that directly accesses the outside."
	Evacuation access creation	12	"Create an effective evacuation route design."
	Evacuation security	6	"Safe evacuation routes and places for the surrounding community."
Evacuation Accessibility	Ease of evacuation access	53	"Provide easily accessible places."
	Clarity of evacuation route	9	"Clarify evacuation flow equipped with fire extinguishers."
	Clarity of evacuation signs	42	"Install clear evacuation signs."
Resource Safety	Fire-resistant building construction	1	"Use of fire-resistant materials."
	Water source availability	4	"Ensure there is water access."
	Safety equipment provision	19	"Availability of temporary fire extinguishers in the residential area."
Emergency Systems	Fire warning system	9	"Install fire warnings."
	Emergency lighting system	14	"Requires adequate lighting to find the way out."
	Emergency communication system	2	"Provide a call center from the fire team."

The relevance of community perspectives is high since they are the primary victims of wildfires and their experiences do not usually feature in formal planning. Recommendations for improved road access, visible evacuation signage, and community sensitization underscore that the process of evacuation is taken as joint action requiring both spatial improvement and social coordination. This is similar to the findings of Fauzi et al. (2023), in that participatory strategies enhance contextual relevance and citizen ownership of plans regarding emergency plans. Some other studies also highlighted the role of social cohesion and collective action in ensuring effective evacuation in densely populated areas.

This validates that physical enhancement by itself is not adequate without the improvement of the community. New infrastructure will only be useful if it comes with education, training, simple communication ways, signs, and proper lighting. Urban resilience needs a participatory approach with preparedness as a routine activity, clear gathering points, easily accessible emergency communication, and an official partnership between the people and local government.

They combined the quantitative indicators in the PCA by making direct use of the results of qualitative coding in Table 4 and Table 5. All themes from the qualitative phase were converted into questionnaire items, using a 1–5 Likert scale. For instance, the term "narrow alleys" was changed to the H-Access Obstruction indicator, "panic" was termed H-Panic Behavior, and "emergency lighting" was labeled S-Emergency Lighting Provision. In this manner, the researchers developed a quantitative instrument that remained grounded in residents' personal experiences; it was a qualitative exploration validated quantitatively, bringing the two together in a mixed-methods framework.

Dimensions of Evacuation Barriers

The Principal Component Analysis (PCA) extracted two latent dimensions of the evacuation barrier with a cumulative variance of 62.141% as shown in Table 6. The first component, which is labeled Structural Barriers, explains 32.382% variance. It is related to physical access limitation due to invisible exits, blocked paths, unclear routes, and winding alleys. The second component, labeled Non-Structural Barriers, explains 29.759% variance. It covers dynamic behavioral factors such as the condition of congestion at exits, the movement of objects, efforts to save goods, and panic. Both were highly reliable (Cronbach's Alpha values of 0.931 and 0.893), indicating that barriers to evacuation in dense settlements are made up of the combination of physical-spatial limitations and behavioral-reactive challenges.

Table 6. Latent Variables from Factor Analysis Results with Varimax Rotation of 2 Principal Components

	Structural Barriers	**Non-Structural Barriers**
Mean	3.928	4.020
Standard Deviation	0.907	0.780
Cronbach' Alpha	0.931	0.893
Eigenvalue/Variance	5.505	5.059
Cum. Percent	32.382	62.141
H-Exit not visible	**0.819**	0.277
H-Obstructed access	**0.816**	0.309
H-Unclear path	**0.794**	0.273
H-Winding evacuation path	**0.779**	0.278
H-Door hard to reach	**0.669**	0.483
H-Structural collapse	**0.650**	0.463
H-Lack of evacuation education	**0.581**	0.528
H-No buffer zone	**0.560**	0.493
H-Fire brigade delay	**0.543**	0.443
H-Obstacle at Exit	0.243	**0.775**
H-Moving objects	0.233	**0.761**
H-Congestion	0.399	**0.695**
H-Attempting to save belongings	0.210	**0.652**
H-Natural conditions	0.404	**0.627**
H-Smoke interference	0.444	**0.620**
H-Fire outbreak	0.493	**0.603**
H-Panic behaviour	0.440	**0.584**

These differences are very important in ascertaining intervention priorities, particularly in heavily populated areas with limited resources. The author defined structural barriers as related to physical inaccessibility and non-structural barriers as dynamic behavior of the people. This result is in line with Kuligowski (2021) and Bakhshian & Martinez-Pastor (2023), stressing the significance of the interaction between the built environment and human behavior. The dominance of behavioral factors also presents a general condition in informal settlements worldwide, where panic responses are reinforced by space constraints.

This also suggests the requirement of a dual approach in planning for evacuation, which includes improving the physical infrastructure to reduce the barriers to access and instilling a management focus on behavior through transparent signboards, communication that works, and readiness exercises. The evacuation effectiveness and overall urban resilience will be enhanced through the integration of barrier removal, better directions, community training, and a robust early warning system.

Dimensions of Risk Perception

Table 7 presents the results of PCA with two main components obtained for residents' perception of fire risk, which had a cumulative variance of 45.149%. The first component, which is labeled Preparedness (Cognitive

Appraisal) accounted for 23.319% variance. It consists of measures related to readiness for a fire outbreak, trust in the fire suppression system, and ability to prevent fires (Cronbach's Alpha 0.687). The second component, which is termed Anxiety (Affective Appraisal), explains the rest and is made up of items on worries due to the news, high levels of anxiety, and perception of fire as a serious threat (Cronbach's Alpha 0.643). This structure validates the assertion that people's perception of risk is a product of both cognitive appraisal and emotional reaction to danger.

Table 7. Latent Variables from Factor Analysis Results with Varimax Rotation of 2 Principal Components

	Preparedness	Anxiety
Mean	3.638	3.806
Standard Deviation	0.852	0.759
Cronbach' Alpha	0.687	0.643
Eigenvalue/Variance	1.866	1.746
Cum. Percent	23.319	45.149
PR-Ready to face fire	**0.828**	0.059
PR-Trust in fire system	**0.817**	0.192
PR-Capable of preventing fire	**0.668**	-0.014
PR-News increases worry	0.028	**0.840**
PR-High fire worry	0.207	**0.735**
PR-Fire is a serious threat	-0.011	**0.629**

This dual aspect is important because evacuation decisions are behavioral. Thus, the willingness of citizens to act depends not only on their knowledge of the facts but on the emotional conditions as well. Anxiety can drive urgency but it risks interfering with judgment if it's not balanced with readiness. These findings are consistent with Protective Motivation Theory (Rogers, 1975, 1983) and the psychometric paradigm (Slovic, 1987) in that they both make a distinction between cognitive and affective aspects in risk perception.

This means that fire mitigation programs should combine hands-on training with strategies for controlling emotions. Strong preparedness, coupled with community workshops, evacuation drills, and information dissemination, prevents anxiety from turning into maladaptive behaviors. The program should, therefore, be designed in such a way that it offers community-based workshops for the members, involving even evacuation exercises, and disseminating information to the community.

Dimensions of Suggestions for Evacuation Route Improvement

Table 8. Latent Variables from Factor Analysis Results with Varimax Rotation of 2 Principal Components

	Evacuation Infrastructure	Social and Regulatory Support
Mean	8.459	8.539
Standard Deviation	1.544	1.547
Cronbach' Alpha	0.970	0.960
Eigenvalue/Variance	8.431	8.239
Cum. Percent	38.324	75.776
S-Route slope reduction	**0.791**	0.277
S-Route optimization technology	**0.791**	0.304
S-Clarity of evacuation signs	**0.776**	0.462
S-Elderly-friendly paths	**0.757**	0.457
S-Route clarity	**0.739**	0.511
S-Provision of emergency lighting	**0.712**	0.543
S-Creation of emergency staircase	**0.701**	0.470
S-Provision of assembly point	**0.675**	0.579
S-Utilizing alternative routes	**0.671**	0.539
S-Barrier removal	**0.650**	0.553
S-Provision of fire warnings	**0.649**	0.639
S-Provision of emergency communication	**0.640**	0.604
S-Community training socialization	0.441	**0.787**
S-Community contribution	0.277	**0.782**
S-Availability of water sources	0.381	**0.762**
S-Path security enhancement	0.489	**0.760**
S-Government policy	0.348	**0.746**
S-Provision of safety equipment	0.545	**0.736**
S-Evacuation route creation	0.578	**0.688**
S-Evacuation path widening	0.551	**0.653**
S-Fire-resistant construction	0.483	**0.638**
S-Path separation	0.596	**0.610**

Table 8 presents the PCA analysis results on citizens' suggestions which identified two major components having a cumulative variance of 75.776%. The first component was named Evacuation Infrastructure with a variance of 38.324%, loading on $\alpha = 0.970$, which mainly highlighted physical aspects in the items- reducing lane slope, and sign clarity, elderly-friendly access, and emergency lighting. The second component was named Social and Regulatory Support, which had a variance of 37.452%, loading on $\alpha = 0.960$; it included all items that related to community readiness in terms of citizen training, and community contribution, availability of water, safety of the line, as well as government policy support. This dual structure indicates that the people conceptualize increased evacuation as a mix of physical enhancement and social-institutional reinforcement.

This perspective is key since community priorities often signify contextual needs that formal planning does not capture. PCA results confirm that citizens not only lay emphasis on accessibility, visibility, and technical facilities but also social coordination, readiness education, and supportive governance. This multilayered view conforms to the precepts of community-based risk reduction and the PADM framework. highlights the influence of social cues and institutional trust in motivating protective actions. Related results by Zehra & Wong (2024) also indicate that the success of evacuations relates to both individual preparedness and quality of infrastructure.

This, therefore, means that without community capacity and institutional support, physical modification alone is not adequate. The planning of the evacuation should cover both physical and institutional aspects, i.e., the routes, their, enhancing accessibility and lighting, while improving routine preparedness activities, emergency communication, and local governance that supports citizen participation.

Causal Relationship between Barriers and Risk Perception on Suggestions

Multivariate linear regression analysis was used to evaluate the impact of barrier dimensions (Structural and Non-Structural) and risk perception (Preparedness and Anxiety) on two dimensions of Suggestions for Evacuation Route Improvement — Evacuation Infrastructure and Social and Regulatory Support. Table 9 presents the results of this analysis.

Table 9. Causal Analysis of the Influence of Evacuation Barriers and Risk Perception on Suggestions for Improving Evacuation Routes

Dependent Variable	S. Evacuation Infrastructure		S. Social and Regulatory Support	
	RSq=0.23		RSq=0.23	
	PValue=<.0001		PValue=<.0001	
Independent Variable	β	p	β	p
Structural Barriers	0.0108	0.9093	0.0515	0.5909
Non-Structural Barriers	**0.2826**	**0.0056****	**0.2323**	**0.0242***
Preparedness	**0.1325**	**0.0246***	**0.1715**	**0.0042****
Anxiety	**0.1462**	**0.0088****	**0.1384**	**0.0142***

Note: *p < 0.05. **p < 0.01.

The results indicate that Non-Structural Barriers have a significant influence on both dimensions of suggestions ($\beta = 0.2826$; $p = 0.0056$ for Evacuation Infrastructure; $\beta = 0.2323$; $p = 0.0242$ for Social and Regulatory Support). The Preparedness and Anxiety dimensions also show significant effects on both types of suggestions, with β values ranging from 0.1325 to 0.1715 ($p < 0.05$). Structural Barriers do not show significant influence over any of the dependent variables ($p > 0.05$). The visualization Fig. 2 will confirm the dominance of non-structural, cognitive, and affective factors in shaping community advice, therefore placing greater importance on psychological preparedness in planning for the evacuation of fires.

The factors in this study explain 23% of the variance in the suggestions for improvement to fire evacuation routes by all residents. It is a modest effect by all accounts, but the figure is statistically significant and therefore scientifically relevant ($p < 0.0001$). These results would indicate that non-physical barriers (panic, for example) and the fear of risk on the part of residents do shape the input they provide. On the other hand, 77% of the factors that influence the suggestions of residents lie beyond the scope of this study. These external factors include the financial condition of families; the specific layout of the home; previous experiences with fire and the strength of neighborly relationships. This substantial residual suggests that densely populated areas pose complex problems in terms of escape. The panicked action of the residents during the time of emergency depends upon many factors, such as the environmental condition prevailing at that time, the actions of their neighbors, and the rules and regulations made at the local level. The planners of the evacuation should not only emphasize the physical improvements, for example, road widening, but they should also take into account the social structure of the community, which plays an important role in decision-making by the residents.

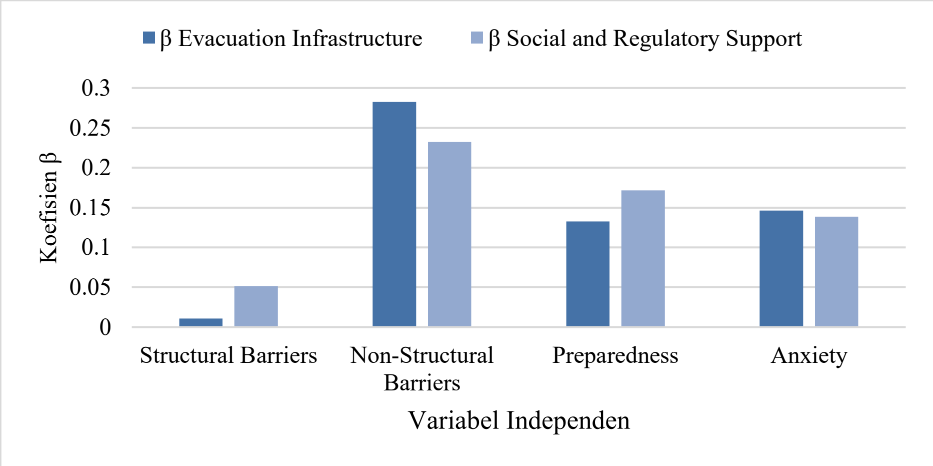

Fig. 2. Comparison diagram of the β coefficients of each variable
(Source: Authors)

These results support Protection Motivation Theory (PMT) (Rogers, 1975, 1983) in which protective behavior is described as the interaction between the assessment of a threat and available countermeasures. Non-structural barriers, e.g. panic, congestion, and confusion, can undermine assessments of countermeasures and therefore increase the requirement for behavioral training and institutional support. Accordingly, the Protective Action Decision Model (PADM) (Lindell & Perry, 2012) would note that protective actions are based on perceived threats, the effectiveness of the action, and trust in authority.

It can be observed in Fig. 3 that only Non-Structural Barriers, Readiness, and Anxiety have a significant influence on citizen suggestions, while Structural Barriers do not. This again proves that, for decision-making on evacuation in dense settlements, the role of psychological and social factors is more important than that of the physical conditions of buildings. In path analysis, a solid line represents a significant relationship ($p < 0.05$) and a dotted line represents an insignificant relationship, with a standard coefficient (β) indicating the strength and direction of influence between variables. This design further places non-structural and psychological factors at the forefront in determining the community's intention to propose improvements to evacuation routes and fire safety systems.

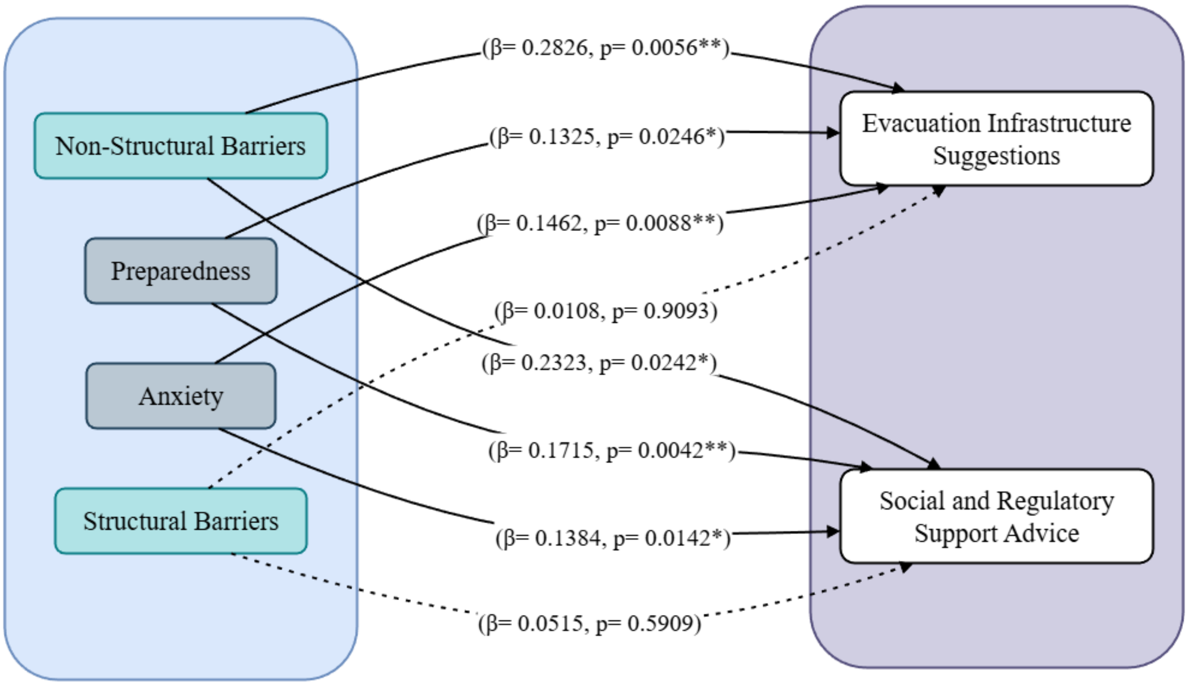

Fig. 3. Path diagram of the relationship between barriers, preparedness, and concerns regarding community suggestions
(Source: Authors)

The study has some limitations. The majority of respondents (89.2%) fell in the age range of 17–25 years. Therefore, the study reflects the perceptions of a tech-savvy younger generation with easy access to disaster information and different psychological responses from older age groups. The use of non-random sampling techniques (snowball and purposive) also potentially introduces selection bias and limits the generalizability of the findings. Young people tend to focus more on mental issues like anxiety and their own preparedness when it comes to a disaster. Older adults, in contrast, were more concerned with physical problems because they couldn't move as quickly. Future researchers should randomly recruit participants from different age groups to clearly identify differences in how each generation perceives danger and takes steps to protect themselves.

The findings further reveal that structural barriers, like narrow alleys and winding roads, do not show much effect on the suggestions of the residents ($p > 0.05$). This result is contrary to most common studies, which highlight physical optimization as the best strategy. On the other hand, non-structural barriers, such as panic and the wish to save belongings, have a significant effect ($\beta = 0.2826$). It therefore illustrates that people in densely populated areas have been used to narrow streets but still panic and get confused when an emergency happens. Just because somebody knows every corner of their neighborhood does not mean that they will be able to get out safely. More than physical improvements are needed to protect people from fire hazards. Social capacity building, panic management training, risk communication, and regular evacuation drills are much more essential.

Psychological perspectives further support these findings. Slovic (1987) risk perception involves both cognitive assessments and affective responses; thus, the fear that can be expected to drive people toward supporting regulation and routine evacuation training. Emotional factors have been reported to be significant determinants of protective behavior in densely populated settlements. Social and behavioral factors have been found to have impacts that are often more than just physical. Bali (2022), Osman et al. (2022), and Fauzi et al. (2023) all stress that communication among residents, collective awareness, and the quality of social relationships are very important. In highly bonded communities, where access is limited, strong social ties actually worsen psychological barriers such as normalcy bias (Fischer et al., 2022; Omer & Alon, 1994). Abunyewah et al. (2023), Sadri et al. (2021), and Chen et al. (2024) emphasize that social cohesion, interpersonal communication, and collective efficacy are three main factors that contribute to building community preparedness. Densely populated settlement residents give more priority to social capacity and regulatory support than to physical improvements. Institutions should be more proactive in providing integrated support.

These results have immediate implications for fire prevention and mitigation policies. An optimal approach should not only focus on the improvement of infrastructure but also include training based on participation, community-level practice of evacuations, and a reporting and early warning system that can mobilize the residents, supported by simple technology like smoke sensors and notifications on mobile phones. It confirms what other scholars in the country have found (Oktavian & Rahdriawan, 2023; Raniasta, 2023; Seni et al., 2024) that, in this case, social and regulatory factors proved more dominant than purely structural ones. Mitigation policies go beyond physical interventions. They propose citizen empowerment through improved governance, regular practice, and capacity building programs — all of which can counter normalcy bias and push for collective action.

The width of the road should not be the main concern; it is the level of panic among the residents. This will, therefore, change the design concept for highly populated areas. Planners should not only focus on road expansion but also on creating environments that can comfort people in times of crisis. This can be actualized, for instance, by putting up directional signs on the walls of houses, installing automatic emergency lights to avoid bumping into each other in the darkness, and making open spaces along alleys for temporary shelter. The last thing to do is to place the benches or rather the small gathering points for sitting or standing. This will help to memorize the routes and also show the direction in which the route was issued. In the end, planning for high-density areas should involve not only physical changes but also spaces that can boost collective safety. Residents should think fast, panic should be kept away, and the whole community should move out in an orderly fashion during any emergency — with the best example being fire.

CONCLUSION

This paper presents the association between barriers to evacuation, risk perception, and community proposals on enhancing fire evacuation paths in highly populated areas. It was found that non-structural and psychological aspects have a greater influence than physical conditions. Non-structural barriers, preparedness, and fear were significant predictors of citizen advice both for Evacuation Infrastructure and Social Support and Regulation, while structural barriers had no actual influence. This proves that the community-based improvement on the exit system will be effective through the imposition of more behavioral constraints and cognitive and affective evaluations of the risk of fire.

The preponderance of non-structural and perceptual variables in the model provides a sound theoretical basis for the PPM and PAD models in which threat appraisal, the evaluation of countermeasures, and trust as determinants of protective action are emphasized. It also relates with studies done in built-up areas that found citizen preparedness, collective efficacy, and social cohesion to matter in fire mitigation.

This study adds to that fact that planning for structural evacuation cannot only be based on building repairs; equally important is the strengthening of public knowledge, institutional capacity, and practice of preparedness activities. This reiterates the call for proper organization by the policymakers and local government units on community fire drills and risk communication and warning systems to ensure readiness of the people to respond. Thus, spatial design should be integrated with social and behavioral strategies for safety in congested areas The spatial design should, therefore, integrate social and behavioral strategies pertaining to the safety of crowded places.

A longitudinal study could focus on the readiness of the communities over time, the effectiveness of participatory mitigation programs, and how technology can be added with evacuation infrastructure to enhance fire resilience in complex urban settings.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The authors used ChatGPT and Copilot only to enhance language clarity and script readability during the drafting process. The use of AI is restricted to editorial and linguistic aid, with no role in data analysis, result interpretation, or scientific content development. All AI-assisted sections have been thoroughly reviewed and edited by the authors, who take full responsibility for the accuracy, originality, and integrity of the manuscript.

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