Original Article

FRAME-TOPSIS Methods as a Technique for Fire Risk Assessment and Prioritizing Preventive Measures: A Case Study in the Isfahan School of Health Library

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Abstract

Aims: This study aimed to fire risk assessment and prioritize the preventive measures using a FRAME-TOPSIS method in the Isfahan School of Health Library. **Methods:** This descriptive-analytical study was conducted in 2023. First, the FRAME method was used to calculate this risk score in three areas: individuals, buildings and their contents, and activities. Second, the Fuzzy Delphi method was used to identify the preventive measures. Finally, the TOPSIS method was applied to prioritize preventive measures. Excel 2019 was used for TOPSIS and Fuzzy Delphi, and FRAME was calculated by FRAME software. **Results:** The results of the FRAME method showed the risk levels of fire for the Isfahan School of Health Library were unacceptable in individuals ($R = 1.04$) and activities ($R = 1.32$). The TOPSIS method revealed that the most important control measures for reducing fire risk levels in the library are installing an automatic fire alarm (0.732), improving electrical safety (0.694), and use of fireproof partitions (0.660). **Conclusion:** The study library has identified a high level of risk, necessitating the thorough implementation of control measures. Moreover, the methodology presented in this study can be applied to other locations where fire safety is of paramount importance, including hospitals, buildings, and industries.

Keywords: Assessment, Delphi methods, fires, FRAME, libraries, risk, TOPSIS

Introduction

Fires seriously threaten industrial, administrative, commercial, and educational environments. The level of devastation inflicted varies depending on the cause and circumstances and can lead to substantial financial and human casualties.[1,2] The National Fire Protection Agency reported a staggering number of fires in the US in 2015 – a total of 1,345,500. These fires resulted in a devastating 3280 fatalities, 15,700 injuries, and billions of dollars in financial losses.[3]

Hazardous materials in educational institutions, mainly libraries, can potentially cause devastating fires. Multiple fire incidents have occurred in educational institutions and libraries. The devastating fire that tore through two Iranian universities resulted in the loss of a staggering 85,000 and 8000 books, respectively.[4] In addition, fire accidents worldwide, such as at the University of Strasbourg Library and the National Library of Iraq in April 2003.[5] These unfortunate events have caused significant financial and personal losses and destroyed valuable scientific and historical works. Therefore, discussing and implementing fire prevention measures in these locations are crucial to prevent further losses.[6]

Based on several studies, it has been suggested that the occurrence of fires can be predicted.[7,8] Fire risk assessment is a systematic and thorough process that involves identifying potential sources of fire hazards and evaluating them based on their significance level. The objective is to pinpoint and prioritize areas of concern accordingly, aiming to reduce

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the risk of fire outbreaks and ensure people's and property safety.[9]

Various methods are used for fire risk assessment, such as NFPA 101 and the fire safety assessment system. Each method has its advantages and limitations.[10] The fire risk assessment method for engineering (FRAME) is another approach researchers commonly employ to evaluate fire risk.[11] In 2019, Guo employed this method to perform a fire risk assessment in commercial buildings.[12] Hokmabadi *et al*. and Mirzaie Ali Abadi *et al*. used this method to assess the fire risk in a hospital and the Hamedan University of Medical Sciences laboratory complex, respectively.[13,14]

According to recent studies that have employed the FRAME method, its most significant benefit is its ability to assess fire risk in three distinct categories: buildings, individuals, and activities. By evaluating and determining the potential risks, the FRAME method can determine whether the protective measures available are sufficient and effective. Another advantage of this method is its quantitative and accurate output. Once the risk assessment is complete and the level of risk is determined, it becomes crucial to identify viable control measures and effective solutions that decrease the probability and intensity of the risk.[15,16] However, limited resources and budget constraints may not be feasible to implement all control measures. Therefore, control solutions need to be prioritized. If the goal is to choose a solution from a few existing solutions, it can be beneficial to use multi-criteria decision methods.[17] The similar option method to the ideal solution (TOPSIS) is one of the multi-criteria decision-making methods proposed by Hwang and Yon in 1981.[18] This method evaluates the M option to and by n criteria. This technique, therefore, is based on the concept that the chosen option should have the least distance from the ideal positive solution and the most distance from the negative solution.[19,20] The TOPSIS method has been used in various occupational safety and health fields. Mousavi *et al*. prioritized noise control solutions, Ahmadi *et al*. selected the optimal method in the analysis of the events of the oil industry, and Gul *et al*. also used the TOPSIS method for occupational risk assessment in manufacturing.[21-23]

Although fire risk assessment studies have been conducted in various possible ways, not much attention has been paid to these studies in libraries. Assessing and controlling the fire risk in libraries is essential to prevent the loss of valuable information and cultural resources in our community. This is especially important due to past incidents of fire that have occurred and caused damage. This research aims to utilize the FRAME-TOPSIS technique to evaluate the degree of fire risk and give importance to measures that can minimize the possibility and intensity of fire risk at the Isfahan Faculty of Health library.

Materials and Methods

This descriptive and analytical study was conducted in 2023 at the library of the Faculty of Health at the University of Medical Sciences in Isfahan. The study involved three main stages: fire risk assessment using the FRAME method, determining control solutions using the Fuzzy Delphi method, and prioritizing corrective solutions measure using the TOPSIS method. The details of the three stages of this study are as follows:

FRAME method

First, a field survey of the library under study was done, checking and monitoring the condition of the study site and equipment. Fire safety is paid, and the amount of facilities and fire load was investigated. To collect data, a monitoring questionnaire and checklist according to the information the requirements were compiled in the FRAME instruction. FRAME evaluates the risk of fire for three separate aspects: the risk to the building and its contents (R), the risk to individuals (R1), and the risk to activities carried out in the building (R2). This method assesses the risk of fire using complex, long-term calculations. The risk levels of the three aspects are separately calculated and mentioned through the relationship formula [Table 1]. The calculations for the FRAME method were conducted using specialized software that was coded into an Excel file.[11,14,24]

There are two modes for deciding risk levels. In the first case, if $R \leq 1$, protective measures and risk acceptance are higher than the potential risk and the risk is deemed acceptable. In the second case, if $R > 1$, the level of risk is unacceptable.[14]

Fuzzy Delphi method to determine control solutions measure

The primary control solutions were identified through semi-structured interviews with experts and a literature review. The final control solutions were obtained using the Fuzzy Delphi method. A questionnaire containing linguistic phrases from Table 2 was sent to 20 experts to evaluate the importance of each control method. The expert panel was chosen from the HSE Committee of Health College. Participation in the study was voluntary, and individuals who were not satisfied were excluded from the study.

After collecting the questionnaires, the results were combined. Then, an arithmetic average method was used to calculate the percentage of agreement for each solution. The final solutions were determined based on the solutions that reached a 70% agreement limit, as identified in this study.[25]

Prioritizing control solutions using the TOPSIS method

The steps of TOPSIS were summarized as follows:[20]

Step 1: A decision matrix is created in this step. The matrix includes a set of criteria and alternatives, with criteria in columns and alternatives in rows.

Step 2: Equation 1 is used to normalize the evaluation matrix.

$$r_{ij} = \frac{\text{xij}}{\sqrt{\sum_{i=1}^{m} a^2_{ij}}} \quad (1)$$

(xij) represents the initial score of the evaluation matrix, and (rij) presents its normalized score.

Table 1: Formulas for computing the fire risk engineering assessment method

Activities	individuals	Building and its contents	
$R=\frac{P}{A\times D}$	$R1=\frac{P1}{A1\times D1}$	$R=\frac{P2}{A2\times D2}$	Fire risk level
P= $q\times i\times g\times e\times v\times z$	P1= $q\times i\times g\times e\times v\times z$	P1= $q\times i\times g\times e\times v\times z$	Potential risk
A= $1.6-a-t-c$	A= $1.6-a-t-r$	A= $1.6-a-c-d$	Acceptable risk level
$D=W\times N\times S\times F$	$D1=N\times U$	$D2=W\times N\times S\times Y$	Protection level

In this formula - q: Fire load factor, t: Evacuation time factor, Y: Salvage factor, i: Spread factor, r: Environment factor, e: Level factor, d: Dependency factor, v: Venting factor, W: Water supply factor, z: Access factor, U: Escape factor, N: Normal protection factor, F: Fire resistance factor, S: Special protection factor,[11] Similar items in formulas were not repeated[13]

Table 2: Spectrum of importance score and linguistic expression

Linguistic expression	Spectrum of importance
Very low	1
Low	2
Medium	3
High	4
Very high	5

Step 3: The equations to calculate the shortest distance from the best alternative (di^+) and the longest distance from the worst alternative (di^-) were 2 and 3, respectively.

$$di^+ = \sqrt{\sum_{j=1}^{n}(V_{ij} - Vj^+)^2}\; i=1,2,....,m \quad (2)$$

$$di^- = \sqrt{\sum_{j=1}^{n}(V_{ij} - Vj^-)^2}\; i=1,2,...,m \quad (3)$$

Step 4: Equation 4 calculated the closeness to the ideal (CL) in the worst condition.

$$CL^* = \frac{di^-}{di^- + di^+} \quad (4)$$

Finally, any option that has a larger CL is selected as the best option, and other options are prioritized according to that option.[20]

Data analysis

Excel 2019 was used for TOPSIS and Fuzzy Delphi, and FRAME was calculated by FRAME software (coded in Microsoft office 2019).

Results

The results of the FRAME method indicated that the activities fire risk level (1.32) and individuals (1.04) were greater than the acceptable level. The finding also showed the fire risk level for buildings and their contents (0.16) that the risk level was within the acceptable range. The factors used for calculating fire risk level based on the FRAME method are shown in Table 3.

The results of the Fuzzy Delphi methods are shown in Table 4. In total, nine control solution measures are approved by gaining 70% of the agreement of experts.

Table 3: Calculated risk level based on the fire risk engineering assessment method

Fire risk level	Related subfactors	Value of subfactors	Calculated risk level
Activities (R)	P	3.13	1.32
	A	1.63	
	D	1.45	
Individuals (R1)	P1	3.01	1.04
	A1	1.36	
	D1	2.11	
Building and its contents (R2)	P2	7.36	0.16
	A2	7.23	
	D2	6.11	

The result of prioritization of control solution measures by the TOPSIS method revealed that the installation of an automatic fire alarm (0.732), improving the safety of electricity (0.694), and use of fireproof partitions (0.660) are the most important control measures that should be considered to reduce the fire risk level in the library. Furthermore, improvement of the natural ventilation situation (0.560), installation of safety signs in the library (0.574), and relocation of the library (0.593) are less important among control solution measures [Table 5].

Discussion

The study's main objective is prioritizing control solutions for fire risks in the Isfahan Faculty of Health library using FRAME-TOPSIS. According to the FRAME-TOPSIS findings, individuals and activities pose unsafe and undesirable risks ($R > 1$), which require immediate attention. The library faces an alarming risk due to severe overcrowding, inadequate space, substandard partitioning, and the consistent neglect of maintenance, equipment, and safety systems. A study conducted in 2020 by Parvin Sepehr and their team evaluated the fire risk of an educational complex using the FRAME method. The results showed that the library presented a high risk of fire in two dimensions: individuals and activities ($r > 1$), which is in line with the current study's finding.[20] According to the TOPSIS, installing an automatic fire alarm is the most crucial control measure (0.732) to mitigate the fire risk in the library. Experts have determined that the current fire safety system is

Table 4: Result of the Fuzzy Delphi methods

Control solutions measure	Spectrum of importance					Fuzzy value			Defuzzied value	Agreement	Status
	Very low	Low	Medium	High	Very High	L	M	U			
Installation of automatic fire alarm	-	-	-	2	20	4	4.27	5	4.385	0.90	Approve
Improving the safety of electricity	-	-	1	16	5	3	4.09	5	4.045	0.72	Approve
Change layout	-	-	3	16	3	3	4.00	5	4.00	0.72	Approve
Preparing an emergency exit	-	2	2	18	-	2	3.63	4	3.565	0.81	Approve
Staff fire drills	1	2	3	16	-	1	3.40	4	3.2	0.72	Approve
Use of fireproof partitions	-	-	-	17	5	4	4.22	5	4.36	0.77	Approve
Relocation of the library	-	-	1	20	1	4	4.00	5	4.25	0.90	Approve
Installation of safety signs in the library	-	-	16	2	4	3	3.45	5	3.725	0.72	Approve
Improvement of the natural ventilation situation	-	1	17	2	2	2	3.22	5	3.36	0.77	Approve

Table 5: Result of the TOPSIS method and priority of control solutions measures

Control solutions measure	di^+	di^-	CL
Installation of automatic fire alarm	0.019	0.052	0.732
Improving the safety of electricity	0.018	0.041	0.694
Use of fireproof partitions	0.017	0.033	0.660
Improvement of the natural ventilation situation	0.015	0.028	0.651
Staff fire drills	0.015	0.023	0.660
Preparing an emergency exit	0.014	0.023	0.621
Change layout	0.013	0.019	0.593
Installation of safety signs in the library	0.012	0.016	0.574
Relocation of the library	0.011	0.014	0.560

CL: Closeness to the Ideal

insufficient as it relies on personnel being present during office hours to handle a fire. However, the majority of fires occur when the library is unoccupied. Consequently, a new system must be implemented to alert and mobilize auxiliary forces promptly. The study conducted by Hassanain and Al Ashwal in a Saudi Arabian library found that implementing fire alarm and extinguishing systems are the most effective way to enhance library safety, which aligns with the findings of our present study.[26] The TOPSIS method ranked improving electricity safety as the second-most important control measure (0.694). It has been observed that some electric heaters used by library staff may pose a potential fire hazard. To mitigate this risk, it is recommended that the library consider implementing a safe and appropriate heating system while also emphasizing electrical safety measures.[27] Fireproof partitions with a score of 0.660 were designated as the third priority. Although they cannot prevent fire, they effectively reduce fire transmission to the surroundings. These partitions are an expert-determined solution to reduce fire intensity. Financial constraints strictly restrict the installation of these partitions.[28] Improvement of the natural ventilation situation) 0.560) was designated as four priorities. The library under study must be equipped with proper natural ventilation to avoid a potential backdraft in the event of a slowly starting fire within a closed environment, causing the temperature of flammable materials to rise. Failure to improve the ventilation system could result in catastrophic consequences.[29] Therefore, taking swift action to address this issue is of utmost importance. When selecting control measures, several factors come into play. Mousavi *et al*. have identified safety, enforceability, and cost as the three main priorities to consider.[21] Relocation of the library to a different location is not viable as it is costly, and experts believe it is not feasible to implement. Hence, it is considered the least important priority for control measures. The limitation of the current study is that it did not account for the internal relationship between the selection of control measures. To address this, it may be beneficial to utilize the ANP method in future studies, which allows for consideration of the internal relationships between criteria and options.

Conclusion

Libraries are important spaces that must prioritize safety due to the potential damage caused by fire. To ensure safety, it is mandatory to adhere to international standards and analyze potential threats. This study presents a quantitative method for assessing fire risk in a payment library, considering three dimensions: the building and its contents, individuals, and activities. The findings indicated a high level of fire risk in the library and suggested specific solutions based on criteria such as feasibility and enforceability. The study revealed that the installation of automatic fire alarms, improving the safety of electricity, and using fireproof partitions were the most effective solutions to reduce fire risk. This scientific method can also be applied to other industries where fire safety is important.

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Ethics code

The Medical Ethics Committee of Isfahan University of

Medical Sciences approved the study protocol under the ethical code IR.MUI.RESEARCH.REC.1402.071.

Conflicts of interest

There are no conflicts of interest.

Authors' contributions

Ehsanollah Habibi: Study design; Seyed Mahdi Mousavi: Data analysis and Interpretation; Motjaba Nakaeipour: Data collection and Writing; Hossien Ebrahimi: Data collection and Writing.

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