The High-rise Building Fire Risk Assessment Based on Fuzzy Comprehensive Evaluation

Hanfeng Huang

School of Civil Engineering and Architecture, Southwest Petroleum University, Chengdu 610500, China

1405286409@qq.com

Abstract. The fire risk assessment is the basic means to reduce and control of high-rise building fire. At present, the high-rise building fire risk evaluation method are many, but few have combined probability method and fuzzy evaluation method of fire risk evaluation. The author based on the comprehensive analysis of high-rise building fire risk factors, the establishment of a high-rise building fire risk probability fuzzy comprehensive evaluation model, and with concrete project example, discusses the mathematical model for the application in the high-rise building fire risk assessment, aims to the research of high-rise building fire risk assessment method to provide a new try, to take reasonable fire prevention and control technology measures to provide helpful guidance in theory and method.

Keywords: High-rise Building, Fire Risk Assessment, Fuzzy Comprehensive Evaluation.

1. Introduction

In recent years, with the rapid development of economy in our country, high-rise buildings also rapid development at an alarming rate, followed by a fire problem is increasingly outstanding [1]. As a result of the high-rise building stack effect, high altitude wind speed accelerate and electrical fire, lead to fire spread so fast; Huge building functional diversification, the work is very complicated to put out a fire disaster prevention; Narrow saves level, narrow the evacuation passageway, and firefighters haphazard, and fighting and rescue work is very difficult; Persons and property of high concentration, make the loss caused by fire especially serious. Therefore, to reduce and control the happening of the high-rise building fire is an important issue in the field of fire safety engineering, and the first thing to risk of fire is studied, find out its regularity.

High-rise building fire risk research can be divided into disaster evaluation, prediction, control and protection and so on several parts, including the fire risk assessment is a basic link, the link of prediction and control of disaster prevention is only based on a correct evaluation on the fire risk is on the basis of the practical significance, and the validity and rationality of fire prevention and control technology and with the correct fire risk evaluation complement each other [2]. There are a lot of high-rise building fire risk assessment method, but as a result of which involves many factors, the relationship between the various factors, combined with management, and other human factors involved, the simple linear superposition can't fully reflect the high-rise building fire risk, and fuzzy analysis method has been gradually used widely at present.

2. The concept and steps of fuzzy comprehensive evaluation

Fuzzy Comprehensive Evaluation method is to point to in a Fuzzy environment, considering the influence of multiple risk factors, according to a certain risk for Comprehensive Evaluation method of risk source elements. The membership degree of fuzzy mathematics comprehensive evaluation method based on the theory of the qualitative evaluation into quantitative evaluation, which uses fuzzy mathematics to is restricted by various factors of things or object to make an overall evaluation. Fuzzy comprehensive assessment result is clear, system science, can well solve the problem of have the nature of fuzzy and hard to quantify, suitable for the results of various uncertainty problems [3-4].

High-rise building fire risk probability and fuzzy comprehensive evaluation process is shown in figure 1.

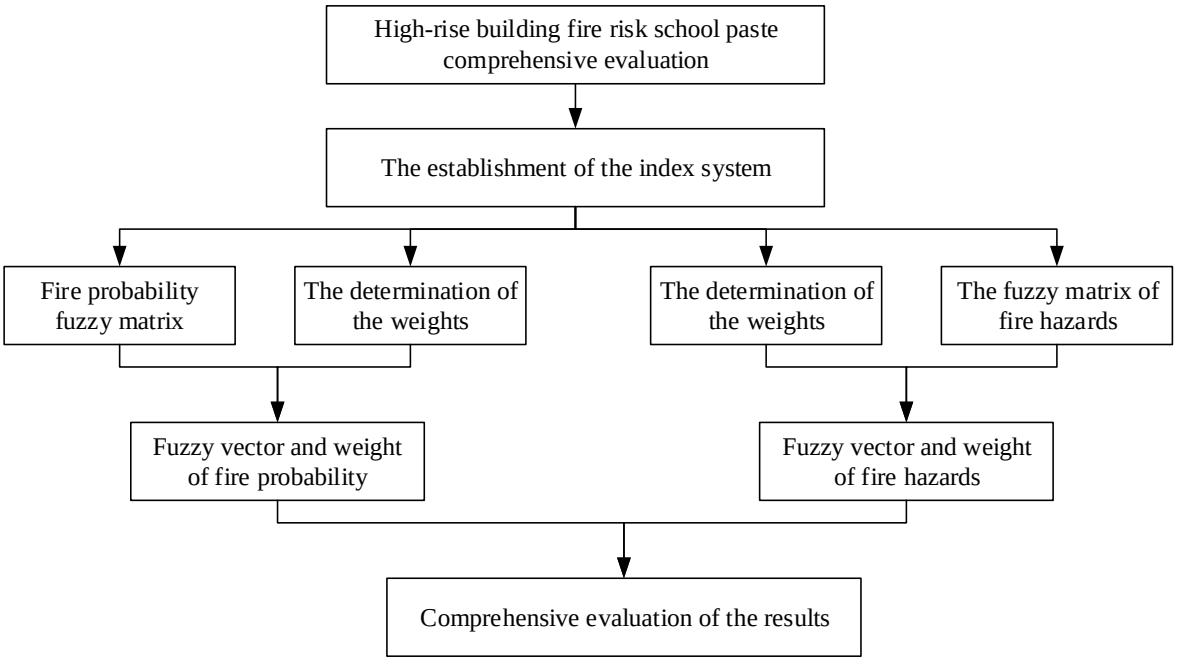

Figure 1. Fuzzy comprehensive evaluation process for high-rise building fire risk probability

Fuzzy mathematics comprehensive evaluation method of basic steps are as follows:

(1) Determine the evaluation factor set of objects $\mathbf{X} = \{\boldsymbol{x_1}, \boldsymbol{x_2}, \ldots \boldsymbol{x_n},\}$. the indicators of factor set refers to the object of study, used to describe the characteristics of the object of study. ForX_i, i= 1, 2,..., n is the evaluation factors, n is the number of single factor on the same level, the collection constitutes the evaluation framework. And the weight of each factor indexes can be determined by analytic hierarchy process is determined.

(2) The evaluation set is given $\mathbf{Y} = \{\boldsymbol{y_1}, \boldsymbol{y_2}, \ldots \boldsymbol{y_m},\}$. Among them$Y_j$, j = 1, 2,..., m is the evaluation results, m is the element number, which ranks number or evaluation class number. Decision set on the degree of evaluation indicators, the result set of elements can be either qualitative, can also be a quantitative score. According to the actual situation to determine the level of high-rise building fire risk evaluation theory domain Y = {very safe, comparing safe, safe, dangerous, very dangerous}.

(3) Determine the membership degree matrix, the single factor evaluation matrix$\mathbf{R} = \left(\boldsymbol{r_{ij}}\right)_{\boldsymbol{m*n}}$. R in general can be obtained by the method of expert scoring or market research, said the decision evaluation of each index. $\boldsymbol{r_{ij}}$ is the degree of factor xi with yj, if m elements for the comprehensive evaluation, the result is a m n columns of the matrix, called the membership degree matrix R.

(4) By means of fuzzy transformation $\mathbf{B} = \mathbf{W} \cdot \mathbf{R}$ of W to B and get a decision object set. W as an index of the weight vector. Fuzzy matrix multiplication and common matrix multiplication operation process, only to real Numbers. The fuzzy arithmetic by fuzzy arithmetic, defined as follows:

$$a \vee b = \max(a, b);$$

$$a \wedge b = \min(a, b).$$

(5) The multi-level fuzzy comprehensive evaluation. There are many factors in the research question, if the distribution of the weight is average, due to the importance of the weight$\sum a_i = 1$, while the number of factors more than 10, the weight of most of these factors will be less than 0.1.

3. High-rise building fire risk evaluation index system

High-rise building fire risk evaluation index system, is the foundation of high-rise building fire risk evaluation. Select index is comprehensive, objective, the index standard to determine whether accurate, practical, are related to the correctness and practicability of the evaluation results. High-rise building fire risk evaluation index system is connected to each other, and mutual restriction involving

fire danger factors constitute an organic whole. According to the systematic principle, scientific principle, the principle of evaluation index of particularity and universality, quantifiable principles of evaluation index, application system security analysis method, through designing fire scenario, on the basis of many building fires the cause of the accident investigation, and with reference to the high-rise building fire prevention design specifications, high-rise building fire risk evaluation index system is established, the application of the combination of qualitative and quantitative analytic hierarchy process, the weight of each index was determined[5]. High-rise building fire risk evaluation index system and weight distribution as shown in table 1. From the selected evaluation index can know, high-rise building fire risk evaluation set is a multi-factor, multi-level evaluation system.

Table1. The evaluation factor set and the evaluation result for single factors for fire safety of high-rise buildings

Target layer	Rule layer	Scheme layer		Factor set and the evaluation result				
				1	2	3	4	5
High-rise building fire safety	Positiv fireproofing u	Fire fighting equipment u1	Fire detection system u11	0.63	0.09	0.17	0.11	0
			Automatic sprinkler system	0.07	0.33	0.4	0.14	0.06
			Alarm system u13	0	0.52	0.15	0.18	0.15
			Fire radio guidance system u14	0.9	0.06	0	0.04	0
			Smoke control system u15	0.06	0.16	0.68	0.1	0
			Fire hydrant system u16	0.13	0.47	0.12	0.2	0.08
		Fire brigade u2		0.71	0.08	0.14	0.07	0
	Passive fireproofing v	Fire separation v1		0.52	0.2	0.06	0.18	0.04
		Building structure v2		0.26	0.21	0.3	0.02	0.21
		Floor fire load v3		0	0.48	0.36	0.16	0
		Horizontal fireproof partition v4		0.7	0.1	0.06	0.14	0
		Vertical fire compartmentation		0.4	0.52	0.08	0	0
		Fire elevator v6		0.78	0.15	0.07	0	0
		Horizontal evacuation distance		0.62	0.32	0.06	0	0
		Security exit v8		0.7	0.1	0.23	0.07	0
	Fire safety management w	Building internal personnel w1	Personnel density w11	0.61	0.19	0.2	0	0
			Age w12	0.19	0.22	0.19	0.4	0
		Management level w2	Fire training situation w13	0	0	0.28	0.66	0.06
			Regulations for the fire w21	0.58	0.26	0.06	0.1	0
			Staff on duty w22	0	0.22	0.37	0.37	0.04
			Amateur fire organization w23	0	0.68	0.26	0.06	0
		Building usage patterns w3		0.38	0.57	0.05	0	0

Positive fireproofing. It is directly limit the fire occurrence and development of technology, divided into firefighting equipment and fire department, firefighting equipment is divided into fire detection system, automatic sprinkler system, alarm system, fire radio guidance system, smoke control system and fire hydrant system.

Passive fireproofing. It is to improve or enhance the capacity of building components or materials under fire destroyed technology, mainly include the fire separation, the structure of the building, floor, fire load level fire partition, vertical fire compartmentation, fire elevator, horizontal distance and safe evacuation exit.

Fire safety management. It is one of the important indicators, building fire safety assessment can be divided into building internal personnel status, management level and building model. Building into personnel density, age, status, and the fire protection training. The management level is divided into fire management regulations, professional and amateur fire organization on duty.

4. Case analysis

High-rise building fire risk assessment is a multi-factor and multi-level fuzzy comprehensive evaluation. In a 25 comprehensive office building as an example, the evaluation is divided into five levels, namely the evaluation sets is safe, relatively safe, generally safe, not safe, is very unsafe. The fire control, security, fire safety of construction experts group according to the evaluation sets, each factor score of table 1, after the normalization of the factors can be the high-rise buildings in a single factor evaluation results.

Based on multiple factors of multistage fuzzy comprehensive evaluation method, comprehensive evaluation of high-rise building fire risk, can get various factors of evaluation result:

$$u1 = (0.242, 0.331, 0.220, 0.142, 0.065),$$
$$u = (0.359, 0.268, 0.200, 0.124, 0.049),$$
$$v = (0.463, 0.249, 0.167, 0.085, 0.036),$$
$$w1 = (0.314, 0.151, 0.218, 0.302, 0.015),$$
$$w2 = (0.116, 0.412, 0.264, 0.192, 0.016),$$
$$w = (0.281, 0.321, 0.187, 0.199, 0.012).$$

By u, v, w constitute a total fuzzy comprehensive evaluation matrix in high-rise building:

$$R = (u, v, w)^T = \begin{matrix} 0.359 & 0.268 & 0.200 & 0.124 & 0.049 \\ 0.463 & 0.249 & 0.167 & 0.085 & 0.036 \\ 0.281 & 0.321 & 0.187 & 0.199 & 0.012 \end{matrix}$$

Total factor fuzzy evaluation results as follows:

$$B = A \cdot R = 0.385, 0.271, 0.184, 0.123, 0.036$$

Therefore, can judge the high-rise building fire risk assessment results is very safe.

5. Conclusion

In this paper, in view of the high-rise building fire risk are presented with the actual method of fuzzy comprehensive evaluation, including the establishment of evaluation index system, the mathematical model of evaluation, evaluation procedure and concrete steps, for high-rise building fire risk evaluation method provides a new attempt. Fuzzy comprehensive evaluation method of high-rise building fire risk is fire safety engineering evaluation method in the application of building fire risk assessment. It can provide reliable basis for fire protection design of buildings, the building fire prevention and control countermeasures and measures more scientific, reasonable and effective. With the development of fire safety engineering in our country continuously and improvement of fuzzy comprehensive evaluation method of high-rise building fire risk will constantly improve in the fire engineering, and will play a more important role increasingly.

References

[1] S.M. Lo: Fire Technology, Vol.35 (1999) No.2, p. 131.

[2] W. Wei-jun: Fire Science and Technology, Vol.7 (2008), p. 4.

[3] M.Liu, S.M. Lo, B.Q. Hu: Neural Computing and Applications, Vol.18 (2009) No.6, p. 643.

[4] Y. Guang-wang, and Q. Hua-li: Procedia Engineering, Vol.11 (2011), p. 620.

[5] S.M. Lo, B.Q. Hu, M. Liu: Fire technology, Vol.41 (2005) No.4, p. 255.