Hidden hazard weight analysis and safety assessment of fire protection in residential areas

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Abstract. To evaluate the current situation of fire safety in domestic high-rise residential communities, the community, which integrates high-rise residential buildings, office buildings, and shops, was deliberately selected as an example to conduct fire safety assessment. Combined with the current domestic and foreign fire safety assessment methods and practical application of the review, the establishment of the community at all levels of the evaluation index system, the use of analytic hierarchy process (AHP) for fire safety assessment of the community. Results showed that the fire hydrant system and automatic fire alarm linkage system played a decisive role in the fire safety of the community. To perfect community fire safety assessment, and reduce the plot to fire safety risk, enhance the level of community comprehensively, can not only enhance residents on fire control safety knowledge, and the exact analysis of problems existing in the community fire and handled in time, but also strengthen fire safety management, enhanced the safety awareness of the people.

1 Introduction

Fire safety was directly related to people's life and property safety, and community fire safety was the focus and basic interest of everyone's concern. Accordingly, it was necessary to strictly carry out community fire safety assessment and check hidden dangers, in order to minimize the risk of community fire and ensure that people can live happily and stably. At present, a large number of foreign countries had invested resources to carry out performance design research [1], and there were more than a dozen fire models used internationally. The most common of which were regional models, field models, and combustible combustion sub-models. There were a variety of fire safety assessment methods abroad [2], such as "CFD, FLAME (enterprise fire risk assessment method)", and the organizations engaged in fire risk assessment standardization at the international level mainly include the International Organization for Standardization (ISO), the Alliance for Telecommunications Industry Solutions (ATISS), Specification of Semiconductor Equipment and Materials (SMI).

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According to the current relevant building fire protection code, checked whether the fire protection design content of the building meets the specifications and whether the design and construction are synchronized. Applicants can also use the logical analysis method, analyze the various situations and possible results of the fire with the help of the accident tree method, and use the Boolean logic gate to form an arborization with a logical system to form a whole and deduce layer by layer to obtain an interrelated logic diagram [3]. The comprehensive evaluation analysis method can also be used to establish an evaluation index model based on the relationship between various levels based on data analysis, and finally determine the weight coefficient of each index to process the evaluation index.

The population of Community studied was 10,000 residents, the per resident fire safety awareness of the community was weak. It was necessary to strictly carry out the fire safety assessment of the community, in order to deal with fire hazards in a timely manner. The key to prevention was to improve the comprehensive quality of fire protection and fire safety awareness of the entire community, and, at the same time, strictly stipulate the quality of fire protection facilities construction and installation, and ensure the fire safety management of property and inspection and maintenance units in the later stage. Fire safety assessment is to prevent hidden dangers process in fire safety, through the overall internal and external buildings and sampling residential buildings fire safety assessment and hidden danger investigation, the appropriate assessment method was used to obtain the overall fire safety level of the community, through the comprehensive evaluation standard of fire safety level to evaluate the community.

To conclude, in order to ensure public safety, paying attention to fire prevention is crucial for every country. This paper used the analytic hierarchy method to evaluate the fire safety of high-rise residential communities, which ensured the effective implementation of fire protection system functions, solved the fire hazards of existing residential communities, and laid a solid foundation for future building fire safety research.

2 Establish an evaluation index system for analytic hierarchy

2.1. Conception

Fire safety assessment [4] was to inspect and analyze the building and evaluate whether the fire protection design of the system meets the relevant standards and specifications. This article used AHP to conduct fire safety assessment, refers to a decision-making method that decomposes the elements that were always related to decision-making into goals, guidelines, programs,, and conducts qualitative and quantitative analysis on this basis. AHP is a security assessment method, which first analyzes the basic content of the problem, and then refines the actual problem into several different index elements according to the goals and the requirements to be achieved, and arranges the elements in hierarchies to form a structural model of hierarchical multi-level analysis [5]. According to the actual analysis of the problem, the method of total ranking of the hierarchy was used to obtain the relativity of the underlying factors to the problem, determine the relative importance weight of the bottom relative to the highest layer, and arrange the relative order of advantages and disadvantages [6]. The main steps were as follows:

(1)Calculated the product of each row element of the judgment matrix, M_i

(2)Calculated the nth power root of M_i,

$$\overline{W_i} = \sqrt[n]{M_i} \quad (1)$$

(3)Normalized vectors $\overline{W_i}$:

$$W_i = \frac{\overline{W_i}}{\sum_{i=1}^{n} \overline{W_i}} \quad (2)$$

The resulting matrix was the feature vector of the judgment matrix.

(4)Conducted a consistency check: Found the maximum eigenvalue

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i} \quad (3)$$

Determined the consistency metric value：

$$CI = \frac{(\lambda_{\max} - n)}{(\mathrm{n}-1)} \quad (4)$$

To measure the size of the consistency CI, the random consistency index RI was introduced，

$$CR = \frac{CI}{RI} \quad (5)$$

When

$$CR < 0.10$$

Through the consistency test, it means that the judgment matrix is consistent.

2.2. Hidden danger analysis

The main fire hazards of the community were divided into three parts, the first part was from the building materials market shops outside the community. A large number of vehicles transport goods, and in the event of a fire, there were large obstacles in evacuation and rescue. Second, there was illegal electricity use by market merchants, many merchants privately pulled cables to charge non-motor vehicles, and the internal wiring of the store was aging and chaotic, and therefore, short circuits were prone to fire. Third, there were building materials with different combustion performance grades in the market. According to the analysis of combustion performance, combustion products and fire resistance of building materials were listed as Table 1.

Table 1. Building materials market analysis table.

Serial number	Location	Content analysis	References	Combustion performance analysis
1	Building materials market	Semi-rigid PVC plastic flooring	GB8624-2012: "Classification of Combustion performance of building materials and products"	Toxic chemicals such as PVC additives and plasticizes were present in the material [7].
		Polypropylene carpets, pure wool carpets	Analysis of the combustion performance of several commonly used carpet materials [8]	The fire safety performance was low, polypropylene belongs to FH-3, FV-0, pure wool belongs to FH-1, FV-0.
		Natural wood	Wood combustion performance test analysis and flame retardant method research	Natural wood had strong flammability.
		Wood-based panels	Study on the influence of different decorations on the combustion performance of wood-based panels	Wood-based panels were influenced by different finishing materials and are directly proportional to the

two.

The second part was the apartment office building, which was a special type of building. Its overall structure was complex, densely staffed, and there were plenty types of places inside. The office building of this project was equipped with tutoring institutions, tenant offices, hotels, apartments, and other crowded places. The main fire hazards were divided into four categories, the first was the hidden dangers of things. The second was the hidden danger of people. The third was the inadequacy of property management personnel. The fourth was the hidden dangers in the environment. According to the fire code of building design, combustion products, and fire resistance analysis was shown in the Table 2.

Table 2. Analysis of apartment office buildings.

Serial number	*Location*	Content analysis	References	Hidden danger analysis
2	Office Building	Thing	GB50016: "Code for Fire Protection Design of Buildings"	The merchants in the building were strictly enforced, but it was not excluded that the staff forgot the power outage.
		People	XF654 2006: "Fire Safety Management Of Assembly Occupancies "	Internal fire safety responsibility was not clear.
		Property managers	Fire protection files	Fire extinguishing emergency plan was not perfect.
		Environment	GB50016: "Code for Fire Protection Design of Buildings"	The building were all separated by fire and the floors were different, but there still had a hidden danger

The third part was high-rise residential buildings, which were built into residential areas and met various relevant specifications with complete infrastructure and had been put into use. High-rise residential areas were easy to cause fires. After the fire, it was difficult to fight and rescue it, causing more casualties and property damage than ordinary buildings [9]. Its key part was also the most convenient place for fire to spread, which was the elevator shaft and power shaft of high-rise buildings [10], so strict fire blocking protection measures must be carried out on such passages to avoid further deepening of the disaster as much as possible. According to the fire code of building design, combustion products, fire resistance analysis is listed in Table 3.

Table 3. Analysis table of high-rise residential buildings.

Serial number	Location	Content analysis	References	Hidden danger analysis
3	High-rise residenti	Design and construction comply with fire codes	GB50096 2011: "Design Code For Residential Buildings"	There were no fire valves in the ventilation ducts of cable wells, pipe wells in residential buildings.

al complex	Fire fighting facilities were missing or damaged	GB50098 2009: "Code for Fire Protection of Civil Air Defense Engineering Design"	There were damage to fire hydrants, installation of emergency systems, abnormal operation of smoke and temperature detectors, and zero pressure of test fire hydrants.
	Blocked fire escapes	XF654 2006: "Fire Safety Management of Assembly Occupancies"	Private cars were parked in the special fire passage and climbing rescue surface area.
	Residents' safety awareness was weak.	XF654 2006: "Fire Safety Management of Assembly Occupancies"	The self-defense and self-rescue ability was poor.
	Property supervision was not in place	GB50016 2018: "Code for Fire Protection Design of Buildings"	There was a lack of full-time fire protection personnel, the fire supervision system was not in place.

2.3. Establish on an evaluation index system

Combined with the fire protection code of building design and expert suggestions, took community fire safety (A) as the first-level index, the safety factors were divided into five types of second-level indicators, fire management system (B_1), fireproofing installation (B_2), power consumption of machine room (B_3), fire hydrant water supplying system (B_4), and automatic fire warning system (B_5). Each index was divided into several third-level indicators, and 21 third-level indicators can be obtained comprehensively, and a safety assessment index system was established, was showed in Table 4.

Table 4. Safety assessment index system.

First indicators	Secondary indicators	Tertiary indicators
	Fire management system (B_1)	Formulate a fire safety management system and clarify fire protection responsibilities (C_1)
		Establish volunteer fire brigades (C_2)
		Organize regular drills (C_3)
		Regularly carry out fire protection publicity, education, and training activities (C_4)
		Fire safety patrols, inspection records and fire hazard rectification records (C_5)
	Fireproofing installation (B_2)	Specification setting of fireproof zones and smoke-proof zones (C_6)
		Fire safety passages, safety exits kept open (C_7)
		The evacuation door opens directly(C_8)

Community fire safety (A)		There is no debris under the fire shutter (C_9)
		Fire fighting facilities are in sound condition (C_{10})
		The machine room is equipped with carbon dioxide fire extinguishers, no obstruction(C_{11})
	Power consumption of machine room (B_3)	There is no loosening of the circuit joints of the machine room, no rust of the pipeline (C_{12})
		The terminal block plugs in the electrical appliances are not overloaded (C_{13})
		Selflessly pull the power supply (C_{14})
		The fire pump is operating normally (C_{15})
	Fire hydrant water supplying system (B_4)	The outdoor hydrant is intact (C_{16})
		The fire pool has plenty of water (C_{17})
		The spray head is intact (C_{18})
		The fire fighting facilities are clean, no running, running, dripping, or leakage (C_{19})
	Automatic fire warning system (B_5)	The automatic fire alarm system is intact(C_{20})
		Personnel are certified to work (C_{21})

3 Construct a two-pair comparison matrix to calculate the values of each indicator

In the hierarchy, there were internal factors or influences between upper and lower layers of each indicator. Through the score comparison by experts, the upper element A had a constraint relationship with the next layer of elements $B_{1–5}$ to form a judgment matrix, and then divided the value of each factor by the sum of the column values, in order to map the score comparison results to the range from 0 to 1. Under the upper layer element A, $B_{1–5}$ was weighted according to relative importance, and the evaluation result was judged according to the size of the weight. The following table shows the scale of the relative proportion scale of the evaluation index [11].

Table 5. The relative proportion scale of the evaluation index.

Scale	Meaning
I=1	Both factors are equally important
I=3	The former factor is slightly more important than the latter
I=5	The former factor is clearly more important than the latter
I=7	The former factor is strongly more important than the latter
I=9	The former factor is extremely important than the latter
I=2,4,6,8	The middle of the above two adjacent judgments
I=1/3,1/5,1/7, and1/9	The latter factor is slightly more obvious, strong, and extremely important than the former

Table 6. Weights of secondary indicator Bi.

A	B_1	B_2	B_3	B_4	B_5	$\overline{W_i}$	W_i
B_1	1	1/5	5	3	1/7	0.844	0.128
B_2	5	1	5	1/3	1/7	1.035	0.157
B_3	1/5	1/5	1	1/5	1/5	0.313	0.048
B_4	1/3	3	5	1	1	1.380	0.210
B_5	7	7	5	1	1	3.005	0.457
$\sum\overline{W_i}$						6.577	
$\lambda_{max} = 6.8201\ CI = 0.0455$							

According to the calculation steps of the analytic hierarchy method, the weights of the second- and third-level indicators were found, as displayed in Tables 6—11.

Table 7. Weights of three-level indicators corresponding to B_1.

B_1	C_1	C_2	C_3	C_4	C_5	$\overline{W_i}$	W_i
C_1	1	1/5	1/3	3	1	0.725	0.110
C_2	5	1	9	5	1	2.954	0.487
C_3	3	1/9	1	1	1	0.803	0.132
C_4	1/3	1/5	1	1	1	0.582	0.096
C_5	1	1	1	1	1	1.000	0.165
$\sum\overline{W_i}$						6.064	
$\lambda_{max} = 5.9349\ \ CI = 0.0234$							

Table 8. Weights of three-level indicators corresponding to B_2.

B_2	C_6	C_7	C_8	C_9	C_{10}	$\overline{W_i}$	W_i
C_6	1	1	5	1	1	1.380	0.249
C_7	1	1	3	3	3	1.933	0.349
C_8	1/5	1/3	1	2	1	0.668	0.121
C_9	1	1/3	1/2	1	1/3	0.562	0.076
C_{10}	1	1/3	1	3	1	1.000	0.465
$\sum\overline{W_i}$						5.543	
$\lambda_{max} = 6.6118\ CI = 0.0403$							

Table 9. Weights of the corresponding three-level indicators in B_3.

B_3	C_{11}	C_{12}	C_{13}	C_{14}	$\overline{W_i}$	W_i
C_{11}	1	1/7	1/3	1/3	0.371	0.077
C_{12}	7	1	3	1	2.141	0.443
C_{13}	3	1/3	1	1	1.000	0.207
C_{14}	3	1	1	1	1.316	0.273
$\sum\overline{W_i}$					4.828	
$\lambda_{max} = 4.1275\ \ CI = 0.0425$						

Table 10. Weights of the three-level indicators corresponding to B_4.

B_4	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	$\overline{W_i}$	W_i
C_{15}	1	1	1/5	1	1	0.725	0.142
C_{16}	1	1	1	1	1	1.000	0.196
C_{17}	5	1	1	1	1	1.380	0.270

C_{18}	1	1	1	1	1	1.000	0.196
C_{19}	1	1	1	1	1	1.000	0.196
$\sum \overline{W_i}$						5.105	
$\lambda_{max} = 5.3269 \quad CI = 0.0817$							

Table 11. Weights of three-level indicators corresponding to B_5.

B_5	C_{20}	C_{21}	$\overline{W_i}$	W_i
C_{20}	1	1	1.000	0.500
C_{21}	1	1	1.000	0.500
$\sum \overline{W_i}$			2.000	
$\lambda_{max} = 2.000 \quad CI = 0.0000$				

4 Consistency check

The maximum characteristic values of the second and third level indicators were calculated, respectively λ_{max} [12,13], determined the consistency metric value. To measure the size of the consistency CI, the random consistency index RI (RI value correspondence table12.) was introduced.

When $CR < 0.10$ Through the consistency test, it means that the judgment matrix was consistent, that was, the judgment matrix was logically reasonable [14]. The specific calculation were illustrated as follows:

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \tag{6}$$

$$CR = \frac{CI}{RI} \tag{7}$$

Table 12. Correspondence table of RI values.

Order	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Table 6. Calculations on the secondary indicator B_i consistency ratio:

CR=CI/RI=0.0455/1.12=0.0406＜0.1

Table 7. Calculations on the consistency ratio of B_1 corresponding to the three levels of indicators:

CR=CI/RI=0.0234/1.12=0.0209＜0.1

Table 8. Calculations on the consistency ratio of B_2 corresponding to the three levels of indicators:

CR=CI/RI=0.0403/1.12=0.0.0360＜0.1

Table 9. Calculations on the consistency ratio of B_3 corresponding to the three levels of indicators:

CR=CI/RI=0.0425/0.9=0.0472＜0.1

Table 10. Calculations on the consistency ratio of B_4 corresponding to the three levels of indicators:

CR=CI/RI=0.0817/1.12=0.0729＜0.1

Table 11. Calculations on the consistency ratio of B_5 corresponding to the three levels of indicators:

CR=CI/RI=0.0000＜0.1

The results showed that the CR values of each judgment matrix were less than 0.1, indicating that the consistency test of each judgment matrix meets the requirements. When CR＜0.10, passing the consistency test indicates that the judgment matrix had satisfactory consistency. According to the analysis of the calculation results in the above table, it was found that in the secondary indicators, B_4, B_5. The weight value was the highest, among which C_{19}, C_{20}, C_{21}, which occupied a large proportion. The second was B_2. Among them, C_6, C_7, C_{10} larger weight. Next was B_1, B_3. Among them, C_3, C_5, the weight value was large. The fire safety assessment results were slightly inconsistent with the on-site inspection results and related specifications, so the community fire safety management should make decisions to actively eliminate fire hazards.

5 Relevant suggestions and countermeasures

Table 13. Relevant suggestions and countermeasures.

Project facilities	Hidden dangers	Rectification suggestions and countermeasures
Fire safety management	(1)Fire control room was unattended. (2)Corridors, stairwells, elevator anterooms park non-motor vehicles that affected evacuation. (3)The fire control room management personnel did not hold a certificate to work. (4)Property management personnel did not supervise the daily management of fire protection, and the training of fire safety knowledge and fire emergency drills for residents were not enough. (5) The fire emergency plan, fire safety management system were not perfect.	(1) Standardize the installation of fire fighting facilities within the market, including fire extinguishers, emergency lights, fire hoses, fire zones, fire doors, fire shutters and other devices. (2) Intelligent automatic fire alarm system and automatic sprinkler system can be installed if conditions permit. (3) It is strictly stipulated that vehicles transporting goods are prohibited from occupying the fire lane. (4) Evacuation passages in stairwells or corridors stipulate that merchants are prohibited from stacking goods and clearing evacuation barriers. (5) Establish a clear fire safety management system and strictly implement it. (6) Supplement the missing equipment in the fire control room, and train the staff to cancel the certificate of the operator of the prevention control room to ensure that the certificate is on duty and two people are on duty. (7) Communicate with the
Building fire protection facilities	(1) Many households installed double-layer security doors, which hindered evacuation and increased the fire load. (2) The normally closed fire door was open. (3) Individual automatic sprinkler, smoke and temperature detectors cannot work normally. Emergency lights, and safety exit evacuation instruction signs were damaged. (4) The number of fire extinguishers installed in the building was insufficient.	
Electricity consumption in the computer room	(1) The wiring in the electric well was messy with no fire prevention. (2)Cable peripherals were not fire	

	protected. (3) Some shops pulled cables to charge vehicles.	full-time fire brigade to conduct fire safety education and training for all units in the building, and carry out regular drills.
Hydrant water supply system	(1) The fire pump room had not been inspected daily, and the personnel can not operate the equipment and facilities, and some equipment was not proficient in operation. (2) The wet alarm valve was closed, and the pressure of the test hydrant was zero. (3) Fire pump lacked with lifting facilities. (4) High-rise residential buildings were recommended to be equipped with light fire hoses.	(8) It is recommended to add fire pump lifting facilities and repair facilities and equipment damaged by the fire linkage control system. (9) Strengthen residents' awareness of fire safety and ensure that fire emergency drills are carried out regularly. (10) Train property fire safety managers, and strengthen the work of property fire safety inspections and fire prevention inspections in accordance with the law.
Automatic fire alarm system	(1) The equipment failure of the alarm linkage system was not handled in time. (2) Insufficient fire safety knowledge of operation and maintenance personnel. (3) The power distribution cable was not fireproof and plugged through the wall.	

6 Conclusion

According to the results of index evaluation and analysis and the comparison of the actual situation, it was found that the main problems in the fire safety situation of the community lied in the following three points:

(1) Fire safety management, strengthening the training of fire control room and related staff fire safety knowledge and skills was the top priority. With the continuous improvement of China's national economic level, the urban population was much larger than the rural population. Therefore, the fire safety of high-rise building communities had also become the key that we must pay much attention to, and we must combined relevant standards to conduct standard and strict investigation and assessment of community fire safety, and accurately implement fire safety management.

(2) In the continuous development of fire science and technology, at the same time, the function of fire protection facilities was complex, the degree of intelligence was improved readily. The general staff can not use advanced fire control room equipment without training, or the alarm system due to the failure can not timely transmit the signal to each emergency system, can not smoothly carry out the initial rescue work, and which will lead to casualties or property losses. To ensure that the automatic fire alarm system can operate normally at all times, it can respond to various emergencies at any time.

(3) Building fire protection facilities, building fire prevention facilities were used as a basis for judging the rescue time in the event of a fire, so it was necessary

to design and build in strict regulations in accordance with the building fire protection code, and in the face of emergencies, it was a practical guarantee for the on-site rescue personnel and the victims.

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