Forecast of Fire Protection Situation in High-Rise Buildings Based on Multi-Sensor Information Fusion

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Abstract. With the continuous development of modern science and technology and the increase in the amount of multi-sensor information, the prediction of the fire protection situation of high-rise buildings has gradually become a challenge. This paper establishes a prediction system for the fire protection situation of high-rise buildings and uses multi-sensor information fusion technology for high-rise buildings. The building fire protection situation index weight is weighted, and the original sensors are optimized to verify the prediction effect of the high-rise building fire protection situation. The experimental analysis results show that this method can reduce the initiative of the weight of the fire protection index of high-rise buildings and improve the accuracy of prediction.

Keywords: Fire Fighting Situation, High-Rise Buildings, Multi-Sensor Information Fusion, Safety Prediction

1. Introduction
With the progress of society in recent decades, the continuous development of the national economy and the rapid development of real estate development, the endless emergence of super high-rise buildings brings us economic and social benefits at the same time [1, 2], but it also brings us Here comes a new issue of fire safety. Regarding the important issue of how to pay attention to fire safety, especially the fire safety of super high-rise buildings [3, 4], the current incidence of fire in super high-rise buildings is relatively high, and there is a gradual upward trend, which gives the building structure and the people The safety of life and property constitutes a huge threat [5]. Because there are some characteristics that are not available on low floors, such as high floors, dense population, limited evacuation channels, and a wide range of impacts, it is easy to cause major disasters and accidents, which not only lays dangerous hidden dangers to the safety of people’s lives and properties, but also It also brings a serious threat to the prevention of fire safety [6]. How to prevent and control fires in super high-rise buildings is the focus and difficulty of our fire protection work. Therefore, the study of fire safety preventive measures for super high-rise buildings is of great significance.

According to relevant national standards and specifications, expert experience and improved fuzzy analytic hierarchy forecasting methods, the weights and prediction methods of related influencing factors such as the water supply system of fire hydrants, automatic sprinkler systems, and fire
extinguishing control in the building are correlated and analyzed to improve the high-rise building itself. The fire situation has important practical significance.

2. High-rise building fire protection situation prediction system

High-rise building fire protection situation prediction index system is the basis for forecasting high-rise building fire protection situation. The selection of predictive indicators should not only consider the building itself and the state of fire-fighting facilities, but also reflect the changes of important factors that have a potential impact on the fire-fighting situation, the impact of human activities and the availability of indicator data. Based on the safety prediction research results of related scholars, combined with the actual characteristics of my country's high-rise building fire protection situation, the author uses the principles of objectivity and ease of operation, and establishes a multi-layer factor set according to the principle of predictive index correlation. Based on comprehensive analysis and investigation and research, a high-rise building fire protection situation prediction system is proposed, as shown in Table 1.

| Level  | Second floor | The third floor | Fourth floor |
|--------|--------------|-----------------|--------------|
| one    | B1           | C1              | Fire detection and alarm system C11 |
|        |              |                 | Automatic sprinkler system C12 |
|        |              |                 | Smoke prevention system C13 |
|        |              |                 | Fire hydrant system C14 |
|        |              | C2              | The latest fire brigade response time C21 |
|        |              |                 | Fire brigade fire fighting and rescue capability C22 |
|        |              |                 | Fire separation distance and fire load C31 |
| A      | Passive fire protection | C3              | Building structure C32 |
|        | B2           |                 | Fire separation C33 |
|        |              |                 | Fire evacuation and safety exit C34 |
|        |              |                 | Fire resistance of building components C41 |
|        |              |                 | Fire resistance of decoration materials C42 |
|        |              |                 | Fire resistance of public goods C43 |
|        |              |                 | Aging degree of building circuit C44 |
|        |              |                 | Personnel density C51 |
|        |              |                 | Age composition C52 |
|        |              |                 | The quality of firefighters C53 |
|        |              | C4              | Fire Management Regulation C61 |
|        |              |                 | Full-time duty C62 |
|        |              | C5 inside the building | Amateur Fire Force C63 |
|        |              |                 | Management level C6 |

3. Multi-sensor information fusion algorithm

One of the main features of the improved fuzzy analytic hierarchy process is the fuzzy consistency matrix, which can meet the consistency conditions without the need for consistency testing. It can not only reduce the number of iterations, but also converge faster than the traditional priority judgment matrix. It can meet the requirements of calculation accuracy. Proceed as follows:

(1) Establish a priority judgment matrix \( F=f_{ij} \), this matrix is a fuzzy complementary matrix, and the values in the matrix adopt the two-element scaling method, which is represented by a scale of 0.1 to 0.9. This method can accurately describe any two The relative importance of each factor regarding a
criterion.

(2) Find the row sum \( r_i = \sum_{j=1}^{n} f_{ij} \), and use the conversion formula \( r_i = \frac{r_i - r_{\text{min}}}{2n} + 0.5 \) to transform the fuzzy judgment matrix \( F \) into a fuzzy consistency judgment matrix \( R = \{r_{ij}\}_{n \times n} \).

(3) The square root method finds the ranking vector, as shown in formula (1).

\[
W^{(0)} = \{\omega_1, \omega_2, \ldots, \omega_n\}^T = \left[ \frac{\sqrt{\prod_{j=1}^{n} e_{ij}}}{\sqrt{\prod_{j=1}^{n} e_{jj}}} \right]_{i=1}^{n}, \ldots, \left[ \frac{\sqrt{\prod_{j=1}^{n} e_{ij}}}{\sqrt{\prod_{j=1}^{n} e_{jj}}} \right]_{i=1}^{n}
\]

(4) Use the conversion formula \( e_{ij} = \frac{r_{ij}}{r_{ji}} \) to transform the complementary judgment matrix \( R = \{r_{ij}\}_{n \times n} \) into a reciprocal matrix \( E = \{e_{ij}\}_{n \times n} \).

(5) Taking the ranking vector \( W^{(0)} \) as the initial value \( V \) of the iteration of the eigenvalue method, find the ranking vector \( W^{(k)} \) with higher accuracy. \( V_0 = V(\omega_1, \omega_2, \ldots, \omega_n)^T \) is the initial value of the iteration \( V_k \), use the iteration formula \( V_{k+1} = EV_k \) to find the eigenvector \( V_{k+1} \), and find the infinite norm of \( \|V_{k+1}||V_k|| \equiv \varepsilon \), then \( \|V_{k+1}\|_{\infty} \) is the maximum eigenvalue \( \lambda_{\text{max}} \), and \( V_{k+1} \) is normalized, as shown in equation (2) Show.

\[
V_{k+1} = \left[ \frac{v_{k+1,1}}{\sqrt{\sum_{j=1}^{n} v_{k+1,j}^2}}, \frac{v_{k+1,2}}{\sqrt{\sum_{j=1}^{n} v_{k+1,j}^2}}, \ldots, \frac{v_{k+1,n}}{\sqrt{\sum_{j=1}^{n} v_{k+1,j}^2}} \right]^T
\]

The resultant vector \( W^{(k)} = V_{k+1} \) is the solution ranking vector, and the iteration ends. Otherwise, take \( V_k = \frac{V_{k+1}}{\|V_{k+1}\|_{\infty}} \) as the new initial value and iterate again.

4. Index weights and selection of factor sets

4.1. Evaluation index

The selection method of high-rise building fire situation assessment index set usually refers to ordinary high-rise safety predictions. According to the reliability of fire-fighting facilities and building design specifications, and the actual situation of fire-fighting engineering, the safety of high-rise buildings is usually divided into the following 4 levels: safety, relatively safe, unsafe, and very unsafe, see Table 2.

| Security Level | Safety | Safer | Not safe | Very insecure |
|----------------|--------|-------|----------|---------------|
| Predictive value | 0.9~1 0.7~0.9 0.5~0.7 <0.5 |

4.2. High-rise building safety prediction results

Analyze the combined weights of the fire-fighting situation prediction indicators for high-rise buildings, combine the field investigation results of the fire-fighting situation and the expert scoring method, obtain the predicted value \( \hat{F}_i \) of each indicator in the safety prediction index system, and use
\[ Q = \frac{\sum_{i=1}^{n} F_i N_i}{100} \] to calculate the final safety prediction value. Among them, \( F_i \) is the predicted value of the predictive index, and \( N_i \) is the index combination weight. According to the high-rise building's fire-fighting situation level setting, the building is classified.

5. Application examples

In a high-rise building, the tower has 2 floors underground and 32 floors above ground, with a total height of 145m. Among them, the underground part mainly includes garages, office spaces and equipment rooms, and the above-ground part mainly includes shopping centers, restaurants, residences and office spaces. The entire building adopts a frame structure, with a large roof on the ground floor with a height of 20.5m and a fire resistance rating of Class I. According to the survey results of the fire protection situation of the high-rise building, the predicted value of each safety prediction index is obtained based on the multi-sensor information fusion, as shown in Table 3. According to the judgment of the relative importance of the predictive indicators in Table 1, calculate the priority judgment matrix of the index structure system of the high-rise building.

**Table 3. Predictive index values of fire protection situation.**

| Predictor | Predictive value | Predictor | Predictive value |
|-----------|------------------|-----------|------------------|
| C11       | 85               | C41       | 76               |
| C12       | 87               | C42       | 79               |
| C13       | 83               | C43       | 75               |
| C14       | 85               | C44       | 85               |
| C21       | 80               | C51       | 78               |
| C22       | 82               | C52       | 80               |
| C31       | 83               | C53       | 75               |
| C32       | 79               | C61       | 75               |
| C33       | 83               | C62       | 83               |
| C34       | 81               | C63       | 76               |

Take the \( F_{C4-C4i} \) priority judgment matrix as an example to calculate, and use the conversion formula to obtain the fuzzy consistency judgment matrix, as shown in equation (3).

\[
R = \{ r_{ij} \}_{5 \times 5} = \begin{bmatrix} 0.50 & 0.55 & 0.59 & 0.66 \\ 0.45 & 0.50 & 0.58 & 0.63 \\ 0.41 & 0.42 & 0.50 & 0.56 \\ 0.34 & 0.37 & 0.44 & 0.50 \end{bmatrix}
\]

Use the square root method to find the ranking vector \( W^{(0)} = (0.237, 0.229, 0.189, 0.165)^T \).

The judgment moment \( R = [r_{ij}]_{4 \times 4} \) is transformed into a reciprocal matrix \( E \) through the conversion formula, as shown in equation (4).

\[
E = \{ e_{ij} \}_{4 \times 4} = \begin{bmatrix} 1 & 1.235 & 1.356 & 1.823 \\ 0.812 & 1 & 1.302 & 1.743 \\ 0.756 & 0.812 & 1 & 1.295 \\ 0.435 & 0.673 & 0.785 & 1 \end{bmatrix}
\]

Iterative calculation accuracy \( \varepsilon = 0.0001 \), let \( V_0 = W^{(0)} = (0.237, 0.229, 0.189, 0.165)^T \) as the initial value of the iteration of the eigenvalue method, after 3 iterations, \( W^{(3)} = (0.312, 0.287, 0.212, 0.189)^T \), calculation accuracy \( ||x_3||_\infty - ||x_2||_\infty \leq 0.0001 \).

In the same way, the results of \( AB, B_1-C, B_2-C, B_3-C, C_1-C_{1i}, C_2-C_{2i}, C_3-C_{3i}, C_4-C_{4i}, C_5-C_{5i}, C_6-C_{6i} \) matrix are \( (0.286, 0.313, 0.401), (0.4, 0.6), (0.35, 0.65), (0.45, 0.55), (0.307, 0.296, 0.209, 0.188), (0.4, 0.6), (0.332 \ldots) \).
0.305, 0.203 0.156), (0.296 0.343 0.361), (0.318 0.247 0.435).

Combined with the calculation formula, \( Q = \sum_{i=1}^{n} F_i N_i / 100 = 0.775 \) is calculated from the value in the table.

For super high-rise buildings, fire-fighting equipment needs to be updated and a safe and reliable alarm system is activated, which can play the role of early warning, early detection, early evacuation, and early warning in the early stage of a fire. Prepare emergency plans in advance to avoid fire. There was chaos. Adopt a safe and reliable fire extinguishing system and set up reliable smoke prevention and exhaust measures. There are fixed indoor fire hydrants, reservoirs and automatic sprinkler systems in the building, and water supply vertical pipes from the bottom to the top are set up to solve the problem of difficult water supply, so as to avoid insufficient water in the fire rescue. Enlarge the hose to withstand the pressure. Fire hydrant connections must be provided on each floor. A water pump adapter is installed on the outdoor ground. A corresponding check valve is installed on each vertical pipe to ensure uninterrupted water supply when the internal facilities stop running.

6. Conclusion
High-rise buildings should be based on fire self-rescue, effectively study the safety and reliability of internal fire-fighting facilities, and effectively distinguish the weights and coupling relationships of different parts. On the basis of comprehensive analysis and investigation and research, a high-rise building fire protection situation prediction system is given, an improved fuzzy analytic hierarchy model is established, and the index weights are determined. Through examples, the importance and weight ratios of different influencing factors are analyzed, and the building is calculated and analyzed. The study finds that this method can effectively predict the influence factors and safety degree of the fire protection situation of high-rise buildings.

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