ISSN: 2664-9640

Quantitative research and evaluation of fire alarm system

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Abstract

This paper conducts quantitative research on the problem of fire alarm system. First, the enumeration method is used to establish a mathematical model to obtain real fire data. Then, an evaluation model based on the analytic hierarchy process and entropy weight method is established to evaluate each component. Finally, according to the calculation results, a comprehensive evaluation model is established to evaluate the fire brigade and give suggestions for improvement.

Keywords

Fire alarm system; Enumeration method; Analytic Hierarchy Process; Entropy weight method.

1. Introduction

Since the 1990s, the industrialization of fire detection and alarm in my country has developed very rapidly. There are more than 100 enterprises engaged in the production of fire detection and alarm products, with an annual output value of several billion yuan. It has become an integral part of my country's high-tech industry. Products have also entered the Chinese market in large numbers. About 2 million fire detectors are newly installed in buildings in my country every year[1].

This paper uses a combination of qualitative and quantitative methods to screen indicators, and uses a combination of subjective and objective methods to process data and statistically analyze indicators, and then make a comprehensive score for various types of components of each team in a certain place, so as to analyze each component more scientifically and intuitively Brigade components suggest improvement issues and draw scientifically accurate conclusions. This has important theoretical and practical significance for the government to formulate the management and maintenance of each component of the regional fire alarm system. The main work of this paper is as follows:

First, combined with the data to determine the number of real fires in the city in a given time period, establish a comprehensive evaluation model for various types of components, and help the government select reliable fire detector types with the help of the two indicators of reliability and failure rate.

Secondly, select appropriate evaluation indicators and establish an intelligent judgment model for different types of components in each region, so that when each team issues an alarm for a certain type of component in their respective jurisdictions, it can judge whether the alarm signal is a false alarm, which can be more accurately judged its authenticity. On this basis, the true probabilities of alarms issued by different component types in each team are obtained.

Finally, after analyzing the results, evaluate the comprehensive management level of each team, quantify the main indicators of the three teams with the worst management level, and give a reasonable improvement plan.

2. Establishment and solution of scoring model and authenticity model

2.1. Comprehensive evaluation model based on analytic hierarchy process and entropy weight method

According to the known data, determine the real number of fires in the city from June 1 to June 18, establish a comprehensive evaluation model, and select reliable fire detector types with reliability and failure rate as indicators. Specifically, it can be divided into the following two aspects[2].

Using the enumeration method, it is known that the real alarm is the alarm situation of the same machine number in the same loop in the same project. Traverse the number of false alarms and the alarms that belong to the conditions of a real fire. The sum of the three alarm times is the real number of fires, and the real number of fires in the city from June 1 to June 18 can be solved.

The analytic hierarchy process(AHP) and the entropy weight method are used to carry out the subjective and objective comprehensive analysis. Take the alarm rate, the number of times of use, the fire alarm accuracy rate, and the failure rate as indicators. First, according to the references, the entropy weight method is used to obtain the weight of each index, and then, combined with the AHP model, the score of each fire detector is obtained, and finally, the government is recommended according to the subjective and objective comprehensive score. AHP is to decompose the decision-making problem into different hierarchical structures in the order of the overall objective, sub-objectives, evaluation criteria, and alternatives, and then use the method of solving the eigenvectors of the judgment matrix to obtain the pairs of elements at each level. The priority weight of an element in the upper level, and finally the weighted sum method is to recursively merge the final weight of each alternative to the total goal, and the one with the largest final weight is the optimal plan. The flow chart of AHP is shown in Figure 1.

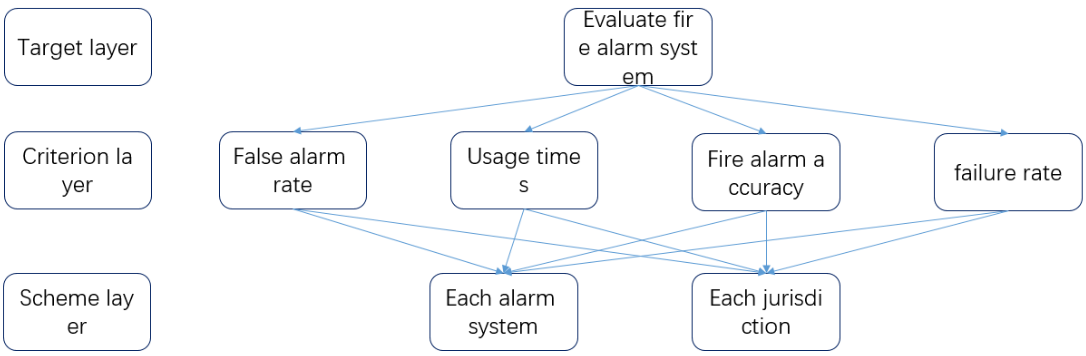

Figure 1 The flow chart of the analysis hierarchy of fire alarm system

2.1.1 Entropy weight method to determine weight

For the criterion layer in Figure 1, according to the principle of combining qualitative and quantitative, first normalize the data to obtain the relevant index judgment matrix:

$$R=\begin{bmatrix} a_{11} & \cdots & a_{im} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nm} \end{bmatrix}$$

The judgment matrix R is standardized, and the standardized matrix $B=(b_{ij})_{n*m}$ is obtained, where $b_{ij}\in[0,1]$, there are three processing methods.

When a_{ij} is a positive indicator, that is, the larger the indicator, the better the state:

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$$b_{ij} = \frac{a_{ij-}a_{\min}}{a_{\max} - a_{\min}} \tag{1}$$

When a_{ij} is a reverse indicator, that is, the smaller the indicator, the better the state:

$$b_{ij} = \frac{a_{\max -}a_{ij}}{a_{\max} - a_{\min}} \tag{2}$$

When a_{ij} is a moderate index, assuming that [q, w] is the optimal moderate interval, there are:

$$b_{ij} = \begin{cases} 1 - \dfrac{\max(q - a_{ij,} a_{ij} - w)}{\max(q - a_{\min}, a_{\max} - w)} \\ 1 \end{cases} \tag{3}$$

interval $a_{ij} \not\subset (q, w)$.

Among them, $a_{\max}$, and $a_{\min}$ are the best or worst among different objects under the same evaluation index.

The entropy weight is determined below.

Define the entropy of the jth evaluation index as:

$$H_j = -\frac{\sum_1^m f_{ij} * Lnf_{ij}}{L_{nm}}, i = 1,2,3,\ldots,n \tag{4}$$

In the above formula, $f_{ij} = \frac{b_{ij}}{\sum_i^m b_{ij}}$, when $f_{ij} = 0$, Lnf_{ij} is meaningless, so the calculation of f_{ij} is modified and defined as $f_{ij} = \frac{1 + b_{ij}}{\sum_i^m (1 + b_{ij})}$.

Calculate the entropy value of each evaluation index $W = (w_i)1 * n$, where.

$$w_i = \frac{1 - H_i}{n - \sum_1^n H_i} \tag{5}$$

And satisfying $\sum_1^n w_i = 1$, four index weights can be obtained, as shown in the following Table 1.

Table 1 Weights of four indicators

Index	Alarm rate	Usage count	Fire alarm accuracy	Failure rate
Weights	0.223	0.251	0.424	0.12

2.1.2 Based on the establishment of comprehensive evaluation model

First, data preprocessing is performed, model screening of components and comprehensive evaluation and analysis are performed.

Then, the filtered data is obtained, further data processing is performed, and the number of fire alarms is processed to obtain an approximate distribution map of the number of fire alarms, and the data that does not conform to the general development law is eliminated to reduce the adverse effects of a few cases on the final result. The frequency chart is shown in Figure 2.

ISSN: 2664-9640

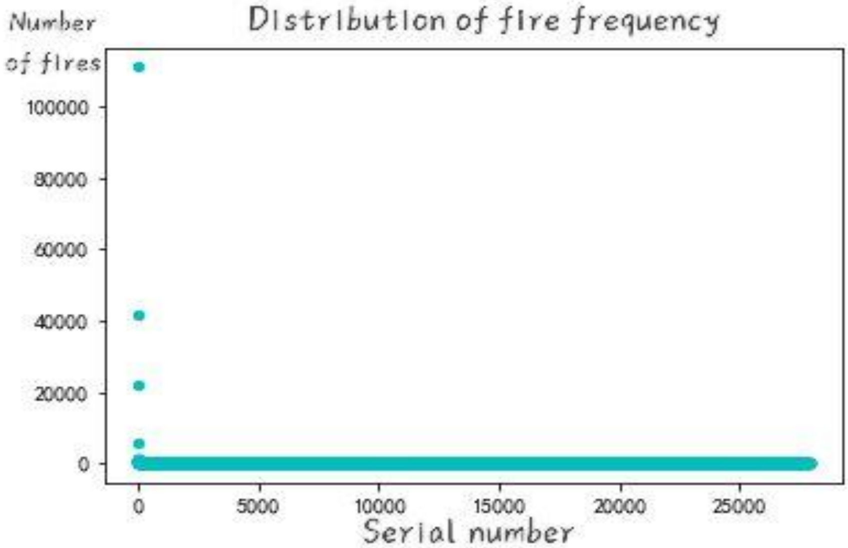

Figure 2 Distribution of the number of fire alarms

As can be seen from the above figure, the number of fire alarms in the first four groups of data is too many, the highest is 111093, and the average alarm is 4.28 times per minute.

The component evaluation problem is decomposed into three levels, the uppermost layer is the target layer M, that is, the fire alarm system of the city is evaluated; the lowest layer is the scheme layer, that is, the evaluation target is each alarm system and each jurisdiction; the middle layer is the criterion layer. C, including the alarm rate C1, the number of times of use C2, the fire accuracy rate C3 and the failure rate C4 four indicators.

Build a judgment matrix and compare the indicators in the criterion layer pairwise to obtain a paired contrast matrix, and check the consistency of the matrix.

First, calculate the consistency index:

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

Then, calculate the consistency ratio:

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

The weight of the four indicators is obtained by the entropy weight method, and it is obtained that CR=0.0743 <0.1, which passed the consistency test.

2.1.3 Solving the analytic hierarchy process model

The entropy weight method is used to obtain the weights of the four indicators, which are brought into the AHP to obtain the comprehensive scores of the components, as shown in Table 2.

Table 2 Comprehensive score table of the top six components

Part Type	False alarm rate	Usage count	Fire alarm accuracy	Failure rate	Score
Point smoke detector	6162.489	18487	0.005818	1.09E-05	100
Point type smoke	2314.815	6	0	3.84E-07	92.492 14
Flame detector	3472.222	4	0	3.84E-07	90.953 51

Manual call point	6430.48	2342	0.009138	9.48E-06	85.81437
Point type temperature smoke	2314.815	1	0	3.45E-06	83.42574
Signal valve	2314.815	6	0	4.32E-06	80.88492

As can be seen from the above table, according to reliability and failure rate, AHP and entropy weight method are established to conduct subjective and objective evaluation models for various types of components in Annex 1, and finally determine that the component with the highest score is the point-type smoke detector. Therefore, the most recommended detector type for the government is the point-type smoke detector.

2.1.4 Analytic hierarchy process model results and analysis

Some results of the model are shown in Table 3.

Table 3 Top six component ratings

Part Type	Score
Point smoke detector	100
Point type smoke	92.49214
Flame detector	90.95351
Manual call point	85.81437
Point type temperature smoke	83.42574
Signal valve	80.88492

The entropy weight method is used to calculate the weight, which reduces the subjectivity of the AHP and makes the results more objective and convincing. Obviously, the components in the table have higher scores for point-type smoke detectors and point-type smoke lighting, so it can be concluded that the reliability of point-type smoke detectors and point-type smoke lighting is relatively high when alarming a fire, the government can choose it for fire alarm.

2.2. Model establishment and solution based on AHP

Referring to the above results, select the appropriate parameters, and use the failure rate, accuracy rate, and false alarm rate as indicators, attach weights to the corresponding indicators, establish an AHP model, and obtain the weight indicators of the reliability of each component and the false alarm rate in turn. , to further judge whether it is a false alarm, the true alarm rate of each component of Brigade A~I can be obtained[3].

2.2.1 Data preprocessing

Relying on the traditional analytic hierarchy process, the traditional analytic hierarchy process uses a numerical value to represent the relative importance of each factor by introducing an appropriate scale, so as to determine its weight. The judgment matrix is constructed. The larger the value, the greater the relative importance of the two. The scale of the judgment matrix and its meaning are shown in Table 4. The criterion layer in this paper mainly includes false alarm rate, fire alarm accuracy rate, and failure rate.

2.2.2 The establishment of the model based on the analytic hierarchy process

The component evaluation problem is decomposed into three levels, the uppermost layer is the target layer M, that is, the fire alarm system of the city is evaluated; the lowest layer is the scheme layer, that is, the evaluation target is each alarm system and each jurisdiction; the middle layer is the criterion layer. C, including three indicators of false alarm rate C1, fire alarm accuracy rate C2, and failure rate C3. Build a judgment matrix and compare the indicators in the

ISSN: 2664-9640

criterion layer pairwise to obtain a paired contrast matrix, and check the consistency of the matrix.According to the relevant literature[4], the weights of the three indicators are 0.45, 0.45, and 0.1, respectively, and it is concluded that CR=0.0613 <0.1, which passed the consistency test.

2.2.3 Solving the model based on Analytic hierarchy process

The establishment of AHP can obtain whether the alarm signal of each component can better represent the false alarm. Table 4 shows the probability of real fire of some brigade alarm signals.

Table 4 Partial results of authenticity evaluation

Affiliated to the fire department	Affiliated to the fire department	Failure rate	Accuracy of the evaluation of each team
Fire brigade A	Point temperature detector	8.42685 E-06	2.73571E-05
Fire brigade A	Point type smoke detector	1.09399 E-05	2.94302E-05
Fire brigade A	manual alarm button	9.47534 E-06	5.07723E-05
Fire brigade A	Smart photoelectric probe	1.41507 E-05	8.87845E-05
Fire brigade A	Composite detector	8.75364 E-06	1.42556E-05
Fire brigade B	Point type smoke detector	1.09399 E-05	1.88248E-05
Fire brigade B	Point temperature detector	8.42685 E-06	3.60665E-05
Fire brigade B	Smart photoelectric probe	1.41507 E-05	2.85076E-05
Fire brigade B	manual alarm button	9.47534 E-06	3.53058E-05
Fire brigade B	Beam smoke		
Fire brigade B	Linear Beam Smoke Detector	7.72313 E-06	0.010248028

3. Establishment and solution of analytical model based on comprehensive evaluation

Based on which team lacks which detector, according to the specific index values obtained, quantify the number of fires, component failure rate, and false alarm rate as indicators, establish a comprehensive evaluation model, and obtain the scores of each team.

3.1. The establishment of a weighted sum model

Define constants A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R. Eighteen teams.

Decision variable: Number of fires - cs.X is the weight of component failure rate; Y false alarm rate weight; Z is the weight of the number of fires.

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First, use data fitting to perform data fitting on component failure rate, false alarm rate, and number of fires, perform weighted summation of each decision variable, and add parameter estimation, and discard or interpolate data with no or excessive deviation. operate.

SUM (risk score) = component failure rate * X + false alarm rate * Y + number of fires * Z, which is:

$$SUM = fa * X + n_j * Y + cs * Z \tag{8}$$

3.2. 3.2 Solution of the model

The types of fire detectors not installed in some brigades are shown in Table 5 below.

Table 5 Types of fire detectors not installed in some brigades

	Omponent name
Fire brigade A	Intelligent temperature sensing, Point type smoke, Hydrant, Pressure switch, Gas detector, Intelligent photoelectric detector, Point type temperature smoke, Linear beam smoke detector, Light beam smoke, Signal valve, Flame detector
Fire brigade B	Intelligent temperature sensing, Point type smoke, Multiple-sensor, Hydrant, Pressure switch, Gas detector, Intelligent photoelectric detector, Point type temperature smoke, Light beam smoke, Flame detector
Fire brigade C	Intelligent temperature sensing, Point type smoke, Multiple-sensor, Hydrant, Pressure switch, Gas detector, Intelligent photoelectric detector, Point type temperature smoke, Light beam smoke, Flame detecto
Fire brigade D	Intelligent temperature sensing, Point type smoke, Multiple-sensor, Hydrant, Pressure switch, Gas detector, Intelligent photoelectric detector, Point type temperature smoke, Linear beam smoke detector, Flame detector
Fire brigade E	Intelligent temperature sensing, Point type smoke, Multiple-sensor, Hydrant, Gas detector, Point type temperature smoke, Linear beam smoke detector, Light beam smoke, Signal valve, Flame detector

The number of fires in each team is shown in Table 6.

Table 6 Number of fires in some brigades

Fire brigade	Number of fires
Fire brigade A	22
Fire brigade B	15
Fire brigade C	30
Fire brigade D	10
Fire brigade E	5
Fire brigade F	12
Fire brigade G	50
Fire brigade H	9
Fire brigade I	8
Fire brigade J	21
Fire brigade K	12
Fire brigade L	14
Fire brigade M	44
Fire brigade N	32
Fire brigade O	6
Fire brigade P	22
Fire brigade Q	21
Fire brigade R	10

ISSN: 2664-9640

3.3. Model results and analysis

The number of fires, false alarm rate, and component failure rate in the three brigades are shown in Table 7.

Table 7 Indicators

Fire brigade	Number of fires	Component failure rate	False alarm rate
Fire brigade M	44	0.000089469562732023	0.312882449897636
Fire brigade N	32	0.0000429927930529516	0.358270584373258
Fire brigade G	50	0.0000551587838154418	6.21417578925685

Suggestion for improvement: The G team has a lot of fires, so it is necessary to train and improve the fire handling ability and reaction speed after the alarm. The reliability of the components of the N brigade is low, and it is necessary to consider replacing the fire alarm components with high reliability. The failure rate of components in the M brigade is relatively high, and it is necessary to consider replacing components with a lower failure rate.

4. Conclusion

In view of the problems in fire alarm, this paper uses quantitative analysis method to establish a model to analyze the use and improvement of fire protection components, which has important theoretical and practical significance for the government to formulate the management and maintenance of each component of the regional fire alarm system. The results show that using the entropy weight method[5] and the analytic hierarchy process for comprehensive processing, compared with the traditional analytic hierarchy process, the objectivity is more prominent, and the subjective and objective comprehensive evaluation makes the results more objective and convincing. Moreover, AHP has three advantages: systematic, practical and concise. Due to the limitations of AHP, the optimal solution can only be selected from the original law, and the optimal solution needs to be discussed separately.

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