

Novel Hybrid Decision Model for Electrical Fire Risk Evaluation of High-Rise Buildings based on Asymmetric Proximity

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Abstract

This paper investigates the risk assessment method of electrical fires of high-rise buildings based on hybrid decision models considering asymmetric proximity. Based on the occurrence mechanism of electrical fires in high-rise buildings, a four-level evaluation index system considering the disaster causing body, fire site environment, affected body, and fire driving factors is established based on FP growth mining association rules, and the risk grade is divided further. An improved DEMATEL+ANP index weight assignment method for balancing the interaction relationship between indexes is proposed, and a hybrid decision model for electrical fire risk assessment in high-rise buildings, taking further account of asymmetric proximity and improved evidence cloud theory. Combined with specific examples, the effectiveness of the proposed building electrical fire risk assessment method is verified. This method can better balance each risk evaluation index, fully considering the fuzziness and randomness in the electrical fire risk assessment of high-rise buildings, and improve the accuracy and applicability of electrical fire risk assessment.

Keywords: high-rise building; electrical fire; association rules; cloud theory; asymmetric closeness; hybrid decision

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1. Introduction

As the direct evidence of the rapid development of the national economy and the continuous increase of social electricity consumption, high-rise buildings with dense population have sprung up like mushrooms in the past two decades in China [1-4], which, however, lay huge hidden fire dangers year by year. At the end of 2020, 68.9% of the fire accidents were caused by electrical factors such as short circuit, line overload, poor contact, etc., 26.2% by equipment problems such as malfunction or improper operation, and 4.9% by other reasons, as reported by the China Fire Yearbook Statistic [5]. Just in 2020, there were 109,000 residential fires caused by electrical reasons, accounting for 43.4% of the total number of fire accidents. Therefore, it is of great practical significance to carry out risk assessment of electrical fire in high-rise building to pragmatically guarantee the development of the national economy and the safety of people's lives and property.

The occurrence of electrical fire in high-rise buildings is caused by a variety of factors, and these factors intersect and influence each other. However, current analysis indicators in the process of the electrical fire risk assessment of high-rise buildings are relatively single. Reference [6] studied a fire risk analysis method of high-rise student apartment based on analytic hierarchy process (AHP), which determined the weights of each index at each level, and deduced that fire safety education and training are the most important factors in its index system. Reference [7] proposed a method to determine the weight of each fire risk influence factor by using analytic hierarchy process, and analyzed the fire risk assessment of high-rise buildings based on the connection degree model of set pair analysis, and finally gave the safety level. These studies adopt the method of AHP with strong subjectivity in the weighting analysis of risk assessment indicators, which not only brought difficulties to the comprehensive analysis of the impact of high-rise building electrical fire cause, but also increased the difficulty in risk assessment of electrical fire in high-rise buildings.

Currently, there is a significant number of research and applications of risk assessment technology in the field of wind power [8-12], but relatively few research on the risk assessment technology of electrical fire in high-rise buildings, and the

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few assessment methods are still qualitative analysis based on traditional expert experience. In Reference [13], the fault tree model, analytic hierarchy process and grey relation analysis were adopted to conduct qualitative and quantitative analysis of the causes of high-rise building fire, but the influence of indexes on each other was ignored, and the evaluation methods were relatively single. Reference [14] used the grey relation analysis to construct the grey relation evaluation model of high-rise building fire system and analyzes the system risk level. However, the randomness of fire risk assessment was not taken into account, so the results would deviate from the actual situation. Reference [15] proposed a fire safety evaluation method for high-rise buildings based on improved CUOWGA operator, which simplified the calculation process, but this method ignored the randomness existing among the boundaries of the five evaluation grades. Reference [16] presented a fire risk assessment method for super high-rise intelligent buildings based on the unascertained theory, which transformed the uncertainty problem into the relative certainty of clustering results by introducing the cluster analysis in the unascertained theory. At present, the research on the electrical fire risk assessment of high-rise buildings does not consider the ambiguity and randomness of the boundary of each assessment state, and the assessment index is relatively single.

This paper proposes a FP-Growth mining-improved DEMATEL+ANP-improved evidence cloud theory hybrid decision model considering asymmetric closeness for electrical fire risk assessment in high-rise buildings. Considering the causes of electrical fires in high-rise buildings, a four-level assessment index system based on the FP-Growth mining correlation rule is established, taking into account the causative agent, the fire environment, the affected body, and the fire driving factors. 18 factors are selected as evaluation indexes and a risk classification is made. An improved DEMATEL+ANP indicator weighting method with balanced consideration of the interactions between indicators is designed, and a hybrid decision model for electrical fire risk assessment in high-rise buildings is developed, considering asymmetric proximity and improved evidence cloud theory. The correctness and general applicability of the proposed method is verified by combining specific examples.

2. Construction of Electrical Fire Risk Assessment Index System for High-Rise Buildings

2.1. Association Rules and FP-Growth Algorithm

Considering the comprehensiveness, non-overlapping and accessibility, while referring to relevant regulations, existing research results and the experience of experts in the relevant fields, 38 electrical fire risk assessment indicators are chosen preliminarily, of which the correlations are explored using association rules and the system structure is optimized with the aim to simplify the complexity in following evaluation process.

Association rule, which is adept in uncovering the implicit relations between different things is usually expressed as a logical implication $X \Rightarrow Y$, where X and Y are respectively the forerunner and successor of the association rule, and $X \cap Y = \Phi$. Support degree, credibility degree, and effect degree are the three indexes that are commonly used to describe the attributes of an association rule.

- 1) Support degree. The probability of the simultaneous occurrence of X and Y in an association rule, as shown in Equation (1):

$$\text{Support}(X \Rightarrow Y) = P(XY) \quad (1)$$

- 2) Credibility degree. The probability of the occurrence of Y derived from the association rule $X \Rightarrow Y$, taking the occurrence of X as the precondition, as shown in Equation (2):

$$\text{Confidence}(X \Rightarrow Y) = \frac{P(XY)}{P(X)} \quad (2)$$

- 3) Effect degree. The degree that the increase of the occurrence probability of event Y due to the occurrence of event X , as shown in Equation (3).

$$\text{Lift}(X \Rightarrow Y) = \frac{P(XY)}{P(X)P(Y)} \quad (3)$$

Effective strong association rule - An association rule $X \Rightarrow Y$ is effectively strong when:

$$\begin{cases} \text{Support}(X \Rightarrow Y) \geq \text{Sup}_{\min} \\ \text{Confidence}(X \Rightarrow Y) \geq \text{Conf}_{\min} \\ \text{Lift}(X \Rightarrow Y) \geq \text{Lift}_{\min} > 1 \end{cases} \quad (4)$$

As shown in Equation (4), where Sup_{\min} , Conf_{\min} and Lift_{\min} are the thresholds of support, credibility, and effect degree, respectively.

This study employs the FP-Growth algorithm to reveal the strong association rules from raw data, and its implementation is schematically presented in Figure 1 [17].

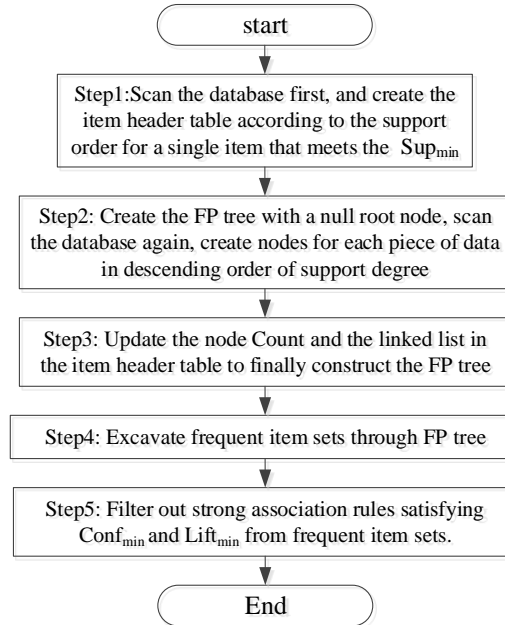


Figure 1. The flow chart of the FP-growth algorithm

2.2. Electrical Fire Risk Assessment Index System

Taking the electrical fire data of the high-rise buildings in a city from 2016 to 2020 as an example, and respectively setting the value of Sup_{\min} , Conf_{\min} , and Lift_{\min} in FP-Growth algorithm as 2%, 62%, and 2%, 18 strong association rules are obtained and part of them are extracted in Table 1.

Table 1. Part of the strong association rules				
	Strong association rule	Support (%)	Confidence (%)	Lift
1	line and equipment abnormality \Rightarrow conduction state	3.32	62.03	2.76
2	line overcurrent \Rightarrow current flow state	3.56	65.18	7.95
3	fuse abnormality \Rightarrow protection device state	4.24	73.85	9.79
4	fire extinguisher abnormality \Rightarrow fire fighting equipment state	3.03	63.27	8.97

Based on the comprehensive analysis of the strong association rules, an electrical fire risk assessment index system of high-rise buildings that consists of 4 second-level indicators and 18 third-level indicators is finally established, taking into account of the factors of disaster-causing object, fire site environment, disaster-affected object and fire driving, as shown structurally in Figure 2.

It can be learned from the analysis on the above indexes utilizing tools such as ISM (Interpretative Structural Modeling) [18] that these indicators mutually influence each other. For example, excessive currents may cause the insulating material to fuse or the contact surface between the conductors determines the state of discharge.

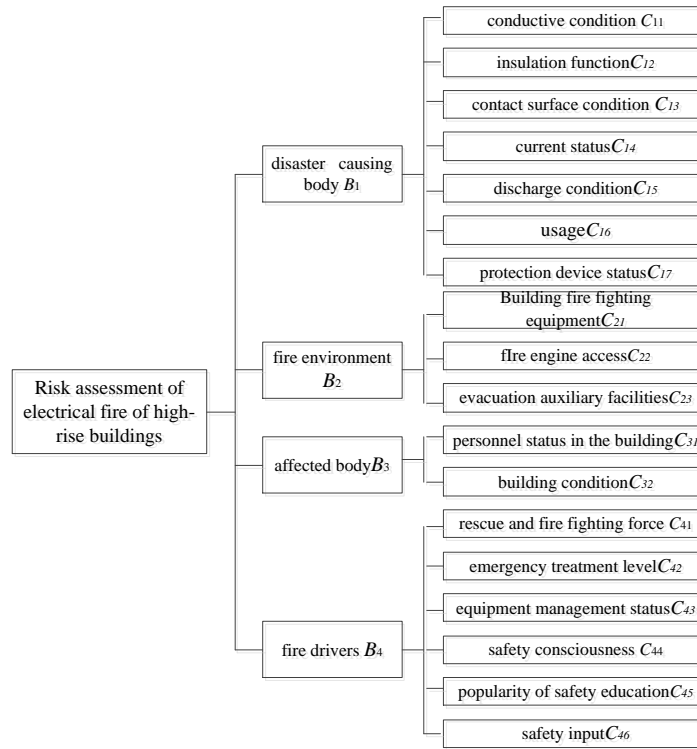


Figure 2. Index system of the electrical fire risk assessment

2.3. Risk Levels Grading

Currently, no world-wide recognized standard is available to the electrical fire risk grading of high-rise buildings. Referring to the fire risk grade standard [19] and the experience of the experts, this paper divides the electrical fire risk of high-rise buildings into 4 levels with the corresponding comment set $N=[n_1, n_2, n_3, n_4]$. Table 2 provides the value range of each risk level and the corresponding countermeasures.

Table 2. Risk level grading and countermeasures

Risk level	Value range	Countermeasure
low risk n_1	[0.6, 1]	Inspecting normally
medium risk n_2	[0.4, 0.6]	Inspecting more frequently
high risk n_3	[0.2, 0.4]	Inspecting with higher priority
serious high risk n_4	[0, 0.2]	Examining immediately

3. Weighting Method based on Improved DEMATEL+ANP

Currently, the popular methods for weighting the evaluation indexes are mainly categorized as the subjective weighting method (e.g. the AHP method) and the objective weighting method, such as the entropy weighting method. The evaluation accuracy of the subjective weighting method tends to be easily influenced by human subjectivity, whereas its counterpart is usually of larger deviation in the weights, partly due to the large deviation of the raw data itself. Moreover, the mutual influence among the final indicators as analyzed in Section 1.2 should be considered effectively. Bearing these in mind, this paper proposes an improved DEMATEL+ANP technology to tackle the weights assignment problem, which will comprehensively consider the mutual influence of indexes and integrate subjective and objective factors. The specific implementation process of this method is as follows:

- 1) Constructing the comprehensive influence relation matrix R based on DEMATEL method.

The direct influence matrix M between the criterion layers is defined as shown in Equation (5):

$$M = [m_{ij}]_{r \times r} \quad (5)$$

where, m_{ij} is the coefficient given by experts representing the influence of criterion layer i on criterion layer j , and $m_{ij}=0$; r is the number of criterion layers in the evaluation system.

Calculating the comprehensive influence relation matrix R as shown in Equation (6):

$$R = N(I - N)^{-1} \quad (6)$$

where N is the standardized direct relation matrix, that is shown in Equation (7):

$$N = \frac{M}{\lambda} \quad (7)$$

where:

$$\lambda = \max_{1 \leq i \leq r} \left(\sum_{j=1}^r m_{ij} \right)$$

- 2) Simplify the network structure of the criterion layer according to the correlation thresholds set by the comprehensive influence relation matrix R , use triangular fuzzy number to construct the fuzzy judgment matrix, and then construct the unweighted super matrix W on the basis of the eigenvectors of the defuzzification version of the fuzzy judgment matrix after the consistency test, as shown in Equation (8).

$$W = \begin{matrix} & \begin{matrix} e_{11} & C_1 & C_2 & \dots & C_p \end{matrix} \\ \begin{matrix} C_1 \\ e_{11} \\ e_{12} \\ \vdots \\ e_{1q_1} \end{matrix} & \begin{bmatrix} e_{11}e_{12} \dots e_{1q_1} & e_{21}e_{22} \dots e_{2q_2} & \dots & e_{p1}e_{p2} \dots e_{pq_p} \\ W_{11} & W_{12} & \dots & W_{1p} \\ W_{21} & W_{22} & \dots & W_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ W_{p1} & W_{p2} & \dots & W_{pp} \end{bmatrix} \end{matrix} \quad (8)$$

where, C_p is the element group p in the network layer, and e_{pi} is the i -th index in the group p ($i=1, 2, \dots, q_p$, q_p is the number of the elements in the); W_{ij} is the pairwise comparison eigenvector of the elements in C_j and C_i .

3) W is multiplied by the eigenvector of the pairwise comparison matrix under the criterion layer to obtain the weighted super matrix W , and the weighting value w_j , $j=1, 2, \dots, e$ (e is the number of the indicators) of each evaluation index is finally obtained by finding the limit of W .

4. Electrical Fire Risk Assessment Methods for High-Rise Building

4.1. Risk Assessment Methodology Study

In the assessment of risk levels, there is often a tendency to use uncertainty language to make judgements, resulting in an inability to give intuitive quantitative results. On the contrary, the cloud theory can provide an uncertainty transformation mechanism between qualification and quantitation, thus well integrating the fuzziness and randomness to form a two-way mapping. A cloud model is usually numerically characterized by the expected value E_x , entropy E_n , and super-entropy H_e , denoted as $K(E_x, E_n, H_e)$. A general fuzzy evaluation method relies on the specialist experiences to obtain the membership degree between the index and the evaluation level, whereas the cloud theory can accurately reflect the fuzziness and randomness of the data, thus improving the accuracy and applicability of risk assessment.

The values of the digital characteristic parameters of a cloud theory model can be determined as shown in Equation (9) [20]:

$$\begin{cases} E_x = \frac{(k_{\min} + k_{\max})}{2} \\ E_n = \frac{(k_{\max} - k_{\min})}{2.355} \\ H_e = \frac{E_n}{100} \end{cases} \quad (9)$$

where k_{\max} and k_{\min} are respectively the upper and lower limits of a certain risk level.

The electrical fire risk assessment indicators are quantified by utilizing cloud theoretical model, and the calculations of the model characteristic parameters of each indicator can be referred to Table 3.

Table 3. Calculation the of digital characteristic parameters			
Index characteristic interval	Digital characteristic parameter		
	E_x	E_n	H_e
$[k_4, k_5]$	$(k_4 + k_5)/2$	$(k_5 - k_4)/2.355$	$E_n/100$
$[k_3, k_4]$	$(k_3 + k_4)/2$	$(k_4 - k_3)/2.355$	$E_n/100$
$[k_2, k_3]$	$(k_2 + k_3)/2$	$(k_3 - k_2)/2.355$	$E_n/100$
$[k_1, k_2]$	$(k_1 + k_2)/2$	$(k_2 - k_1)/2.355$	$E_n/100$

Figure 3 depicts the cloud theoretical model corresponding to the electrical fire risk level grading.

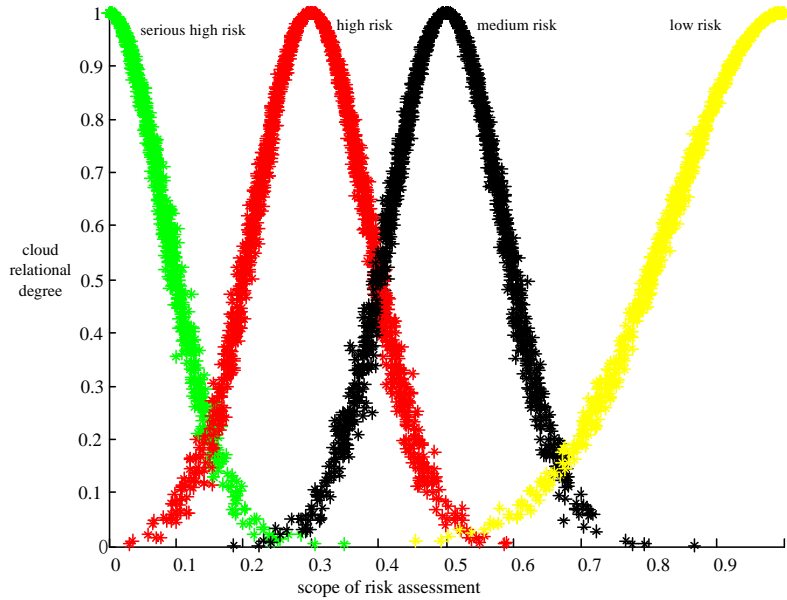


Figure 3. Cloud model of the risk level evaluation

Calculating the cloud relational degree γ between the index to be evaluated and the risk assessment level, as shown in Equation (10):

$$\gamma = e^{-\frac{(k-E_x)^2}{2(E_n')^2}} \quad (10)$$

where, k is the quantitative value of the index to be evaluated, and E_n' is the random variable of a normal distribution with the expectation of E_n and the standard deviation of H_e .

The risk assessment matrix G is then constructed by combining the cloud relational degrees of each index value as shown in Equation (11):

$$G = \begin{bmatrix} \gamma_{11} & \gamma_{12} & \cdots & \gamma_{1t} \\ \gamma_{21} & \gamma_{22} & \cdots & \gamma_{2t} \\ \vdots & \vdots & \ddots & \vdots \\ \gamma_{s1} & \gamma_{s2} & \cdots & \gamma_{st} \end{bmatrix} \quad (11)$$

where, s is the number of risk assessment indicators, and γ_{st} is the cloud relational degree of index s to risk level t .

Evidence theory is a method of reasoning and dealing with uncertainty, relying on the accumulation of data, and reducing conflicts between data and effectively fusing information from multiple data sources and different structures. This paper defines four state levels n_1 to n_4 of the electrical fire risk rating for high-rise buildings as elements of the identification framework, as shown in Equation (12).

$$\Theta = \{n_1, n_2, n_3, n_4\} \quad (12)$$

Assuming that there are s pieces of evidence independent of each other, the correlations of the indicators are used as the basic probability assignments (BPA) of the evidence theory when a risk stratum assessment is made, and the correlations of the risk stratum are used as the BPA of the evidence theory when the overall assessment is made. The synthesis rule for the D-S evidence theory is shown in Equation (13).

$$\{m_1 \oplus m_2 \oplus \dots \oplus m_s\}(\psi) = \begin{cases} \sum_{A_1 \cap A_2 \cap \dots \cap A_s = \psi} \frac{m_1(A_1)m_2(A_2)\dots m_s(A_s)}{1-Q}, & \psi \neq \phi \\ 0, & \psi = \phi \end{cases} \quad (13)$$

where: $Q = \sum_{A_1 \cap A_2 \cap \dots \cap A_s = \phi} m_1(A_1)m_2(A_2)\dots m_s(A_s)$, A_1, A_2, A_s are subsets of the recognition frame Θ , Ψ is a non-empty subset

of the intersection of subsets of the recognition frame Θ , and $m(\Psi)$ is the underlying probability assignment.

Considering the different relative importance of different sub-bodies of evidence, a confidence factor is introduced to correct the underlying probability assignment before the evidence is synthesized

$$\begin{cases} m'(A) = \beta m(A) \\ \beta = u \frac{w_j}{w_{\max}} \\ w_{\max} = \max\{w_1, w_2, \dots, w_j\} \\ m'(\Theta) = 1 - \beta \end{cases} \quad (14)$$

where $m'(A)$ is the value of the modified confidence function, u is the preferred feasibility coefficient, set to 0.9 in the text, $m'(\Theta)$ is the uncertainty of the evidence, and w_j is the weight of the j^{th} sub-evidence.

4.2. Asymmetric closeness analysis

Generally speaking, larger deviation is unavoidable for an electrical fire risk assessment method that only considers the maximum membership principle. In this paper, we further perform the asymmetric closeness decision analysis on the comprehensive evaluation value, so as to make full use of each evaluation factor and increase the evaluation accuracy.

The asymmetric closeness is defined as:

$$N(J, K) = 1 - \frac{1}{n} \sum_l^n |\gamma_J(\chi_l) - \gamma_K(\chi_l)|^l \quad (15)$$

Where, γ_J and γ_K are cloud relational degrees of fuzzy subsets J and K , respectively, and χ_l are comments of the risk level l .

4.3. Electrical fire risk assessment process

Considering the asymmetric closeness, this paper synthesizes a comprehensive evaluation method based on the hybrid decision-making model utilizing the technology of FP-Growth mining, improved DEMATEL+ANP, and improved evidence cloud theory. Its implement flow is specified in Figure 4.

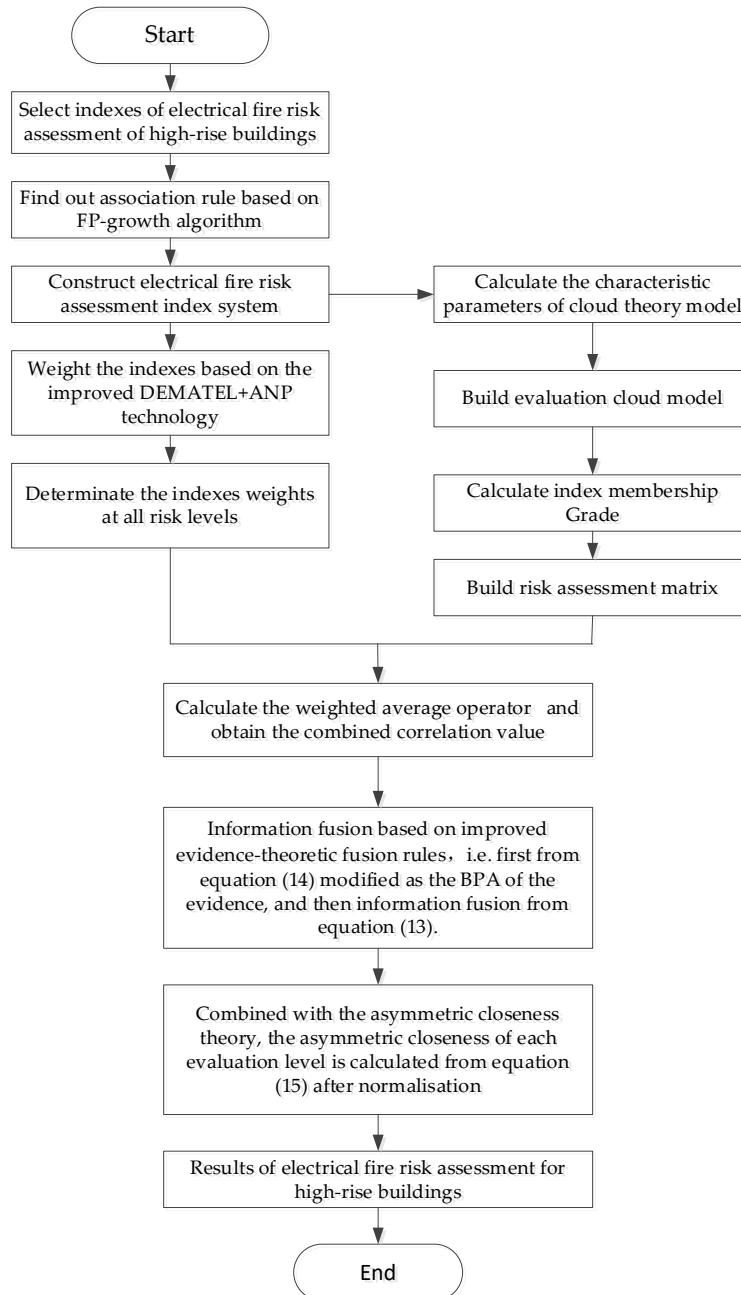


Figure 4. Risk assessment process of the electrical fire

- 1) Constructing the original evaluation index system on the basis of relevant regulations, existing research results of electrical fire risk assessment of high-rise building, and the experience of relevant experts in this field.
- 2) Adopting the FP-Growth algorithm (Formula (1)-(4)) to find out the association rules of the raw data for the given set of thresholds, constructing the risk assessment index system and grading the risk levels of the electrical fire in high-rise building.
- 3) Utilizing the improved DEMATEL+ANP algorithm (Formula (5)-(8)) for weighting the evaluation indexes determined in Step 2.

- 4) Calculating all the digital characteristic parameters (E_x , E_n , H_e) of each indicator according to the proposed cloud theory method (Formula (9)) in Section 4.1, to determine the cloud model.
- 5) Calculating the cloud relational degree between each indicator and the grading cloud model (Formula (10)) on the basis of the index level cloud model determined in Step 4, and obtaining the risk evaluation matrix (Formula (11)) after the normalization.
- 6) The weighted average operator is used to obtain the combined correlation value, on the basis of the index weight given by Step 3 and the risk assessment matrix of cloud relational degree among evaluation grades calculated in Step 5.
- 7) Perform information fusion according to the improved evidence theory fusion rules based on the combined correlation values obtained in Step 6, the first from Equation (14) modified as the BPA of the evidence, and then information fusion from Equation (13).
- 8) Based on the fusion values of each risk level obtained in step 7), in combination with the asymmetric closeness theory, the asymmetric closeness of each evaluation level is calculated by Equation (15) to give the final result of the electrical fire risk assessment for high-rise building

5. Case Study

The electrical fire data of a high-rise building in a city of Hubei Province, China, is collected to verify the performance of our comprehensive evaluation method. This 230-meter building is located in the transportation hub zone with 36 floors above ground and 2 floors underground, among which floor 1 to 5 are shopping malls, and floors 6 to 32 are luxury apartments and class A office building. The high-rise building is provided with sufficient fire-fighting equipment, and at the same time the whole building is equipped with an advanced supervising system that can provide sufficient qualified data required to perform the fire risk evaluation.

Table 4 lists the two sets of index values collected from the supervising system of the target high-rise building. The digital characteristic parameter values of the cloud model of the corresponding risk level are calculated utilizing the cloud theory algorithm, and the results are provided in Table 5. The criterion levels and the relationship between indicators are determined by eight experts in the field of building electrical fire fighting, and the evaluation index weights given by the improved DEMATEL+ANP method and the traditional AHP method are compared in Figure 5.

Table 4. Data of electrical fire index of high-rise buildings

	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{21}	C_{22}	C_{23}	C_{31}	C_{32}	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}	C_{46}
1	0.3	86	2.80%	7	6%	0.53	0.68	0.55	0.63	0.73	0.62	0.45	0.47	0.73	0.7	0.82	0.79	0.69
2	0.6	129	4.40%	14	9%	0.6	0.82	0.65	0.47	0.63	0.71	0.61	0.68	0.38	0.41	0.67	0.51	0.49

Table 5. Cloud theoretical parameter values of the assessment indexes

index	n_1	n_2	n_3	n_4
C_{11}	(0.1500,0.0849,0.0008)	(0.4250,0.1486,0.0015)	(0.7000,0.0849,0.0008)	(0.9000,0.0849,0.0008)
C_{12}	(25.0000,21.2314,0.2123)	(70.0000,16.9851,0.1699)	(110.0000,16.9851,0.1699)	(140.0000,8.4926,0.0849)
C_{13}	(0.0200,0.0085,0.0001)	(0.0450,0.0127,0.0001)	(0.0700,0.0085,0.0001)	(0.0900,0.0085,0.0001)
C_{14}	(2.5000,2.1231,0.0212)	(7.5000,2.1231,0.0212)	(12.5000,2.1231,0.0212)	(17.5000,2.1231,0.0212)
C_{15}	(0.0150,0.0085,0.0001)	(0.0400,0.0127,0.0001)	(0.0700,0.0127,0.0001)	(0.0925,0.0064,0.0001)
C_{16}	(0.9000,0.0849,0.0008)	(0.7250,0.0637,0.0006)	(0.4500,0.1274,0.0013)	(0.1500,0.1274,0.0013)
C_{17}	(0.8500,0.1274,0.0013)	(0.6000,0.0849,0.0008)	(0.4000,0.0849,0.0008)	(0.1500,0.1274,0.0013)
C_{21}	(0.8750,0.1062,0.0011)	(0.6250,0.1062,0.0011)	(0.3750,0.1062,0.0011)	(0.1250,0.1062,0.0011)
C_{22}	(0.8750,0.1062,0.0011)	(0.6250,0.1062,0.0011)	(0.3750,0.1062,0.0011)	(0.1250,0.1062,0.0011)
C_{23}	(0.9000,0.0849,0.0008)	(0.7000,0.0849,0.0008)	(0.4500,0.1274,0.0013)	(0.1500,0.1274,0.0013)
C_{31}	(0.8750,0.1062,0.0011)	(0.6500,0.0849,0.0008)	(0.4500,0.0849,0.0008)	(0.1750,0.1486,0.0015)
C_{32}	(0.8500,0.1274,0.0013)	(0.5500,0.1274,0.0013)	(0.3000,0.0849,0.0008)	(0.1000,0.0849,0.0008)
C_{41}	(0.8500,0.1274,0.0013)	(0.6000,0.0849,0.0008)	(0.4000,0.0849,0.0008)	(0.1500,0.1274,0.0013)
C_{42}	(0.8000,0.1699,0.0017)	(0.5000,0.0849,0.0008)	(0.3000,0.0849,0.0008)	(0.1000,0.0849,0.0008)
C_{43}	(0.8750,0.1062,0.0011)	(0.6500,0.0849,0.0008)	(0.4000,0.1274,0.0013)	(0.1250,0.1062,0.0011)
C_{44}	(0.9000,0.0849,0.0008)	(0.7000,0.0849,0.0008)	(0.4500,0.1274,0.0013)	(0.1500,0.1274,0.0013)
C_{45}	(0.9000,0.0849,0.0008)	(0.6500,0.1274,0.0013)	(0.4000,0.0849,0.0008)	(0.1500,0.1274,0.0013)
C_{46}	(0.8500,0.1274,0.0013)	(0.6250,0.0637,0.0006)	(0.4000,0.1274,0.0013)	(0.1250,0.1062,0.0011)

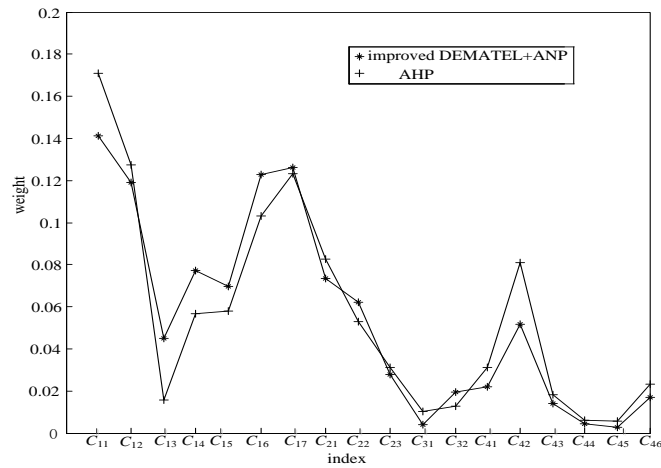


Figure 5. Comparison of the index weights

It can be learned from Figure 5 that AHP method pays more attention to the influence of the fire driving factors on electrical fire in high-rise building, while the improved DEMATEL+ANP method especially focuses on the effect of the disaster causing object. Specifically, the standard deviation of the weights of Method 1 is 0.0464, which is about 13.8% lower than the 0.0528 of Method 3. Therefore, the integration of improved DEMATEL+ANP technology provides our evaluation method the ability to weight the indexes in a more balance manner than the AHP method, thus benefiting to take into account the mutual influence between indicators.

The FP-Growth mining-improved DEMATEL+ANP-improved evidence cloud theory hybrid decision method (called Method 1), as highlighted in this paper, which considers asymmetric closeness, is compared with the improved DEMATEL+ANP-cloud theory (called Method 2), which takes into account the maximum affiliation principle, the AHP-cloud theory (called Method 3), and the fuzzy-DS-based theory (called Method 4). A comparison was made and the results are shown in Table 6.

Table 6. Performance comparison of the electrical fire risk assessment methods

Data set	Method	Risk level				Assessed result	Actual result
		n_1	n_2	n_3	n_4		
1	Method 1	0.8356	0.9761	0.8149	0.6185	medium risk	medium risk
	Method 2	0.1971	0.5724	0.2278	0.0027	medium risk	medium risk
	Method 3	0.3361	0.3905	0.2345	0.0389	medium risk	medium risk
	Method 4	0.2244	0.5363	0.2379	0.0014	medium risk	medium risk
2	Method 1	0.7817	0.9049	0.9158	0.7422	high risk	high risk
	Method 2	0.1302	0.3911	0.3897	0.089	medium risk	high risk
	Method 3	0.2828	0.2751	0.2764	0.1657	low risk	high risk
	Method 4	0.0954	0.4215	0.4021	0.081	medium risk	high risk

Table 6 reveals that the results given by different evaluation methods for the two sets of data are quite different. For data set 1, the evaluation results for Method 1 agree well with those of Method 2 that employs the maximum membership degree principle, when the maximum value of the assessment value is 19% larger than other values. When Method 1 was compared with Method 3, although the results were consistent, it was found that using only a single indicator assignment method such as the AHP could lead to blurred boundaries in the identification of risk assessment states due to the one-sided nature of its weight assessment. When Method 1 was compared with Method 4, it was found that the assessment judgements of both remained consistent

For the second group of data: when comparing Method 1 with Method 2, it was found that the assessment results using the principle of maximum affiliation had problems of validity when the difference between the maximum and the next largest value in the combined assessment did not exceed 1.5%, resulting in the assessment results not being consistent with the actual results. When comparing Method 1 with Method 3, it was found that the single-indicator assignment method could lead to assessment results that deviated from the actual results due to its one-sided nature. When Method 1 was compared with Method 4, it was found that Method 4 ignored the trend of change at the time of assessment, did not consider the randomness at the boundary of different status classes, and also ignored the different impact of each indicator in the actual assessment due to the existence of inconsistency, resulting in the final results not being consistent with the actual.

6. Conclusion

This paper proposes a FP-Growth mining-improved DEMATEL+ANP-improved evidence cloud theory hybrid decision model considering asymmetric closeness for electrical fire risk assessment in high-rise buildings, and the application of the method is carried out with actual data and the results of the calculations show that:

- 1) With the aid of FP-growth method to deeply mine the association rules, the final index system for the evaluation of electrical fire risk is minimal but can comprehensively cover the indexes from the aspects of disaster-causing body, fire scene environment, disaster-affected objects, and fire driving factors.
- 2) The integration of the DEMATEL+ANP method can effectively decrease the standard deviation of the indicator weights from the 0.0528 for the AHP method to 0.0464, which is about 13.8%, verifying that our method weights the indicators in a more balance manner to better explore the influence between indexes.
- 3) The proposed FP-Growth mining-improved DEMATEL+ANP-improved evidence cloud theory hybrid decision model considering asymmetric proximity can better balance each risk evaluation index, and has higher assessment accuracy than the single weight assignment combined with cloud theory, solving the problem of low validity when using only the maximum affiliation principle, further accounting for ambiguity and randomness in the assessment, and also improves the accuracy and applicability of the assessment of electrical fire risk in high-rise buildings.

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