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Research Article

Fuzzy Comprehensive Safety Evaluation of Pipeline Disaster in China-Russia Crude Oil Permafrost Region Based on Improved Analytic Hierarchy Process-Entropy Weight Method

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Considering the difficulty in evaluating pipeline safety in permafrost region, the pipeline disaster safety evaluation index system in permafrost region is analyzed and established. A comprehensive weight determination method based on improved fuzzy analytic hierarchy process, entropy weight method and Lagrange algorithm is proposed, and a fuzzy comprehensive evaluation model of permafrost pipeline safety is established. Taking the disaster safety evaluation of pipeline in the China-Russia crude oil permafrost region as an example, the proposed method is used to determine the comprehensive weight of disaster safety index of permafrost pipeline and carry out comprehensive safety evaluation. The rationality of the comprehensive weight determination method is verified by comparing with the performance of the traditional AHP evaluation method.

1. Introduction

The China-Russia crude oil pipeline is one of the four major energy strategic channels in China, which is of great significance to the construction of China Mongolia Russia economic corridor. The total length of China-Russia crude oil pipeline in China is 933.11 km. The pipeline enters China from Mohe in the northeast and reaches Daqing forest farm in the south. The route passes through a large number of continuous frozen soil, island frozen soil, sporadic frozen soil and seasonal frozen soil areas. Among them, the permafrost length is about 441 km, the seasonal permafrost region is about 512 km^2, and the permafrost region with high temperature and high ice content is about 119 km. The pipeline is laid in the traditional trench way. The normal temperature operation throughout the year leads to the continuous melting of the frozen soil around the pipeline, which further causes problems such as thawing settlement, hot thawing depression and hot thawing settlement along the pipeline. The annual precipitation along the pipeline is 460.8 mm, the groundwater level is high, and there are about 50 km^2 of swamp wetlands. The settlement area passes through a large paddy fields, the surface runoff system is developed, and the surface water in the settlement zone along the line gathers to form a thawing ditch. The thawing ditch is widely distributed in cold season, with the development of freezing and thawing, hot thawing and other disasters. However, research on the safety evaluation of such disasters is rarely reported [1–5]. Therefore, there is an urgent need for appropriate safety analysis and evaluation methods for pipeline disaster in permafrost regions.

Safety evaluation is a complex problem of multi-objective and multi-criteria combining qualitative and quantitative analysis. The commonly used evaluation methods include analytic hierarchy process, fuzzy theory evaluation method, entropy weight method and multi factor comprehensive evaluation method [6, 7]. For example, Yang et al. [8] improved the fuzzy comprehensive evaluation of water quality by using analytic hierarchy process and entropy weight method, and established a health risk evaluation model. Zeng et al. [9] constructed an urban gas pipeline risk evaluation index system including 105 evaluation factors. Combined with Analytic Hierarchy Process (AHP) and entropy weight method, the comprehensive weight of the evaluation index was determined, and then the fuzzy comprehensive evaluation method and risk analysis matrix were used to evaluate the risk level. Ba et al. [10] proposed a fuzzy comprehensive evaluation method based on improved AHP. Through calculation and analysis, the membership function of fuzzy comprehensive evaluation for corrosion risk evaluation was obtained, which improves the practicability of fuzzy comprehensive evaluation. Su et al. [11] proposed an evaluation method based on comprehensive weight. Firstly, the evaluation index system was established by selecting four evaluation indexes: detection accuracy, technical reliability, economic rationality and data richness. Then, based on analytic hierarchy process and entropy weight method, combined with sensitive and objective data, the geophysical selection area was comprehensively evaluated by fuzzy evaluation method. Wang et al. [12] et al. determined the index weights of disaster reduction capability index, disaster resistance capability index and disaster relief capability index through analytic hierarchy process (AHP). BP neural network was used to test the index weight. Finally, the fuzzy comprehensive evaluation model was used to evaluate the disaster response ability. Based on the idea of group decision-making, Yang et al. [13] calculated and weighted the weight interval of indicators; combined with the fuzzy comprehensive evaluation method, a fuzzy comprehensive evaluation model based on uncertainty AHP method was established. In order to reasonably select the evaluation method of soil heavy metal pollution, Xu et al. [14] et al. improved the analytic hierarchy process by using the three-scale method combined with the maximum entropy fuzzy evaluation model; based on the soil heavy metal pollution in Bayi irrigation area of Shenyang, a new method for soil heavy metal pollution evaluation was established. Wang et al. [15] et al. introduced analytic hierarchy process to determine the weight of bleaching, white water recycling and end wastewater treatment indicators in the process of pulp and paper production, then carried out fuzzy mathematical evaluation through matrix calculation, and finally calculated the comprehensive score to comprehensively evaluate and optimize the papermaking water pollution control technology. Liu et al. [16] et al. proposed an AHP fuzzy comprehensive performance evaluation and feedback method for complex equipment. AHP method was used to determine the weight of each evaluation index of complex equipment, and a fuzzy comprehensive evaluation method was used to comprehensively evaluate each performance index. Xu et al. [17] determined the weight of index systems at different levels by comprehensively using analytic hierarchy process (AHP) and fuzzy comprehensive evaluation method (FCE), and conducted multiple fuzzy evaluations at different levels to obtain the final comprehensive evaluation results, which provided constructive guidance for decision-makers to establish and evaluate the weapon equipment test index system.

However, the index weight determined by the above methods is highly subjective and can not objectively reflect the impact of various index factors in the system. Therefore, a more scientific, objective and accurate method is needed to determine the index weight.

There are many safety factors involved in the evaluation of pipeline disasters in permafrost region[18, 19]. It is difficult to determine the weight of each index factor in the process of safety evaluation. When AHP is used, the weight of each evaluation index is mainly selected by human operation, which may cause information loss. The entropy weight method can solve the problem of excessive information loss and fully retain the information of the original data, but some indicators may be neutralized in the calculation process. In view of the above problems, this paper uses the improved AHP and entropy weight method to determine the comprehensive weight, and then uses the fuzzy comprehensive evaluation method to evaluate the safety of pipeline disasters in permafrost region.

2. Establishment of Safety Analysis and Risk Evaluation Index System

Through investigation, literature review and consultation with experts [20, 21], it can be determined that the safety evaluation index system is constructed from three levels: target layer, criterion layer and index layer. Among them, the target layer is the pipeline disaster safety evaluation index system in permafrost region, which is recorded as A; the criterion layer includes four risk factors for pipeline disaster safety evaluation in permafrost region: frozen soil characteristics, natural environment, pipeline parameters and engineering measures, which are recorded as $A_1 \sim A_4$ respectively. The safety analysis of each risk factor is carried out below. The complete safety evaluation system is shown in Figure 1.

The factors affecting disasters in permafrost region under engineering thermal disturbance can be generally divided into three categories: external environment, permafrost characteristics and corresponding engineering measures [22]. Considering the characteristics of China-Russia oil pipeline engineering in permafrost region, the factors affecting the hydrothermal stability of pipelines can be generally divided into four categories: permafrost characteristics, natural environment, pipeline parameters and engineering measures [23].

The characteristics of frozen soil include average annual ground temperature, frozen soil types, water content, thickness and upper limit of frozen soil, frost heaving rate, coefficient of thaw-subsidence, surface pond and other factors [24, 25]. The ground temperature of frozen soil will significantly affect its strength, so the average annual ground temperature is recorded as one of the safety evaluation indexes, denoted as A_{11}, and different types of frozen soil represent different ice contents. It is also recorded as one of the safety evaluation indexes, denoted as A_{12}, and in addition, the amount of water content should also be recorded

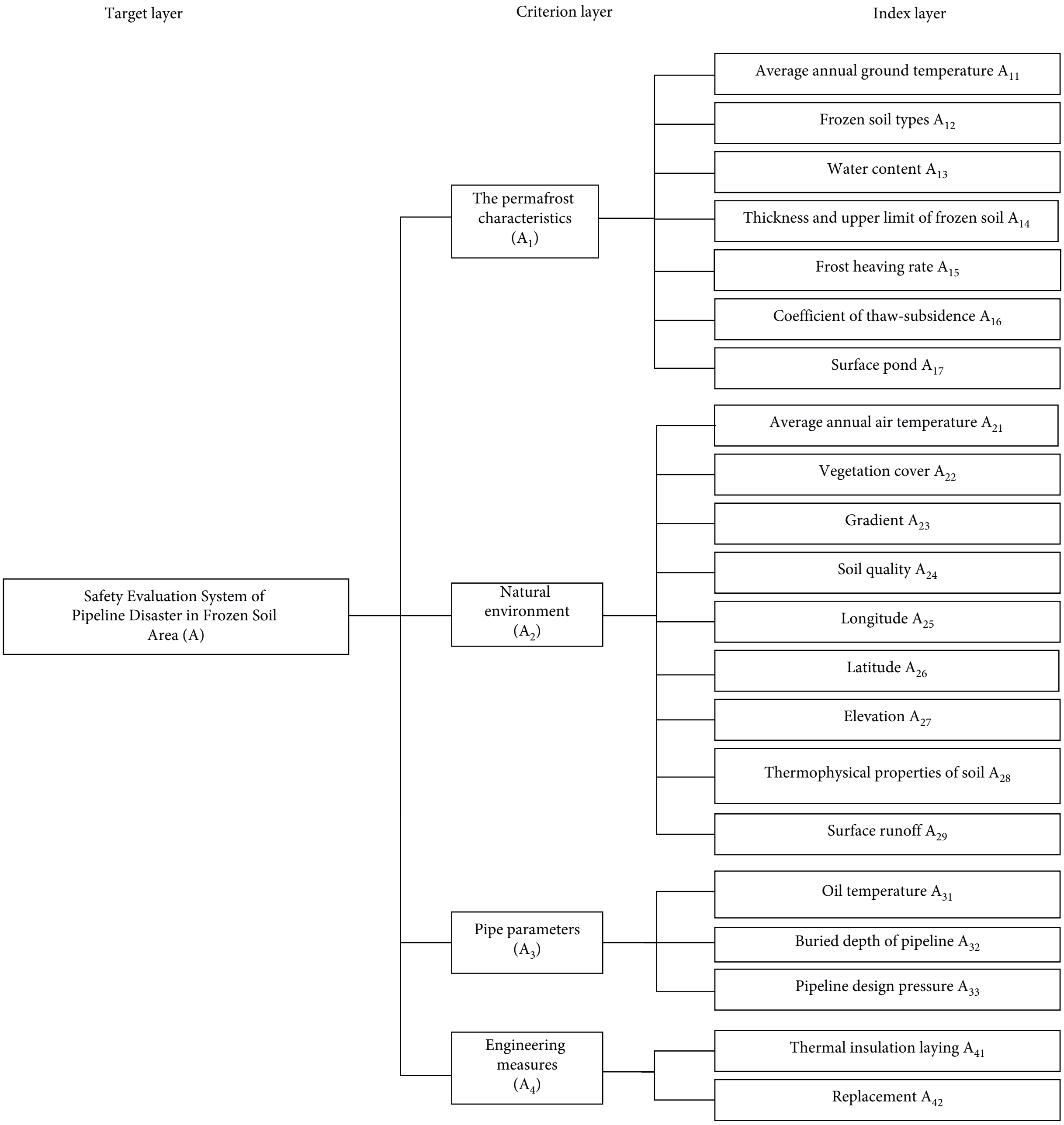

Figure 1: Structure of pipeline disaster safety evaluation index system in China-Russia crude oil permafrost region.

as one of the evaluation indexes, denoted as A_{13}; the thickness of active layer in permafrost region reflects the degree of land-atmosphere heat exchange. The increase of active layer thickness would enlarge the temperature difference between warm and cold seasons, which is harmful to the thermal stability of foundation soil around pipelines. Therefore, the thickness and upper limit of the frozen soil layer are recorded as A_{14}; frost heaving rate refers to the phenomenon of frost heaving classification of seasonal fusion layer, denoted as A_{15}; the thawing settlement coefficient refers to the thawing settlement grade of frozen soil, denoted as A_{16}; surface pond is the precipitation in the area, denoted as A_{17}.

The natural environment mainly includes annual average temperature, vegetation cover, gradient, soil quality, longitude, latitude, elevation, soil thermophysical properties, surface runoff, etc., which are recorded as A_{21}~A_{29} respectively [26]. Pipeline parameters mainly include oil temperature, buried depth of pipeline, pipeline design pressure, etc., which are recorded as A_{31}~A_{33} respectively. Human activities disturb the permafrost, which is the external inducing factor affecting the pipeline disaster safety in the permafrost region. The engineering measures are to maintain the thermal stability of the pipeline in the permafrost regions to protect the stability of the pipeline. Specific behaviors include thermal insulation laying and replacement, which are recorded as A_{41}~A_{42}.

3. Determine the Comprehensive Weight

There are many risk factors for pipeline disaster safety in permafrost region. Accurate simulation of the impact of various risks on disaster safety depends on the scientific and objective determination of the size of each index. However, due to the subjectivity and one-sidedness of human judgment, the traditional analytic hierarchy process is slightly insufficient, which affects the objectivity of judgment results. When using entropy weight method for analysis, some particularly dangerous evaluation indicators are likely to be offset by other indicators with low risk index, which reduces the risk of overall evaluation and loses impartiality. To solve these two problems, the improved analytic hierarchy process is applied to determine the grade weight of the index; then the entropy weight method is used to determine the attribute weight of the index; finally, Lagrange operator is used to combine the two to determine the comprehensive weight.

3.1. Determination of Weight by Improved AHP Method. When constructing the judgment matrix, the traditional AHP method needs to compare all the factors at the same level. If there are N factors to be compared in this level, the expert group needs to make N (N-1)/2 judgments to construct the judgment matrix [27, 28]. This method is complicated, and experts are prone to boredom, so the decision is not objective. In order to solve this problem, an improved AHP method is proposed in this paper. The specific steps are as follows

Step 1. Score the index. According to the importance of the index, the index is scored with a score of 1–9. The extremely important index is 9 points, the extremely unimportant index is 1 point, and other indexes are scored according to Table 1.

Step 2. Construct an improved judgment matrix. The judgment matrix B is determined by calculating the index score. Let c_i and c_j be the scores of two index factors in a certain level, then the element B in b_{ij} can be expressed as:

$$b_{ij} = \begin{cases} c_i - c_j + 1, & c_i > c_j, \\ 1, & c_i = c_j, \\ \dfrac{1}{\left|c_i - c_j\right| + 1}, & c_i < c_j. \end{cases} \tag{1}$$

The constructed judgment matrix B can be expressed as:

$$B = \left(b_{ij}\right)_{n\times n} \tag{2}$$

Step 3. Calculate the weight.

Table 1: Index.

Score	Level of importance
1	Extremely unimportant
3	Unimportance
5	Moderately important
7	Importance
9	Extremely important
2,4,6,8	Between the above two adjacent score scales

The maximum eigenvalue of matrix B is calculated according to the formula $\lambda_{\max}$ and the maximum eigenvector w_i',

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{\left(Bw'\right)_i}{nw_i'} \ (i = 1, 2, \ldots, n), \tag{3}$$

$$w_i' = \frac{\sqrt[n]{\prod_{j=1}^{n} b_{ij}}}{\sum_{i=1}^{n} \sqrt[n]{\prod_{j=1}^{n} b_{ij}}}. \tag{4}$$

The maximum eigenvector w_i' is the hierarchy weight of the index.

3.2. Determination of Weight by Entropy Weight Method. The solving process of entropy weight method can be transformed into a multi-object and multi-index evaluation problem [29, 30]. There are M evaluation indexes and N evaluation objects to form an evaluation matrix $P = \left(p_{ij}\right)_{m\times n}$:

$$P = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ p_{m1} & p_{m2} & \cdots & p_{mn} \end{bmatrix}, \tag{5}$$

where p_{ij} is the evaluation value of the j-th project under the i-th index. For this kind of evaluation problem, the process of calculating the entropy weight of each index is as follows.

(i) Step 1: Calculate the proportion q_{ij} of the j-th object under the i-th comment,

$$q_{ij} = \frac{p_{ij}}{\sum_{j=1}^{n} p_{ij}}. \tag{6}$$

(ii) Step 2: Calculate the entropy e_i of the i-th index,

$$e_i = -\frac{1}{\ln n} \sum_{j=1}^{n} q_{ij} \cdot \ln q_{ij}. \tag{7}$$

(iii) Step 3: Calculate the entropy weight w_i'' of the i-th index,

$$w_i'' \frac{1 - e_i}{m - \sum_{i=1}^{m} e_i}. \tag{8}$$

After the above calculation, the attribute weight of each index can be determined.

3.3. Comprehensive Determination of Weight. The above methods use the improved AHP and entropy weight method to calculate the hierarchical weight and attribute weight of each index respectively, and the following method uses the Lagrange operator to calculate the comprehensive weight of each index [31, 32].

$$w_i = \frac{\sqrt{w_i' w_i''}}{\sum_{i=1}^{n} \sqrt{w_i' w_i''}} \ (i = 1, 2, \ldots, n), \tag{9}$$

where w_i' is the hierarchy weight of the index, w_i'' is the attribute weight of the index.

Through the above calculation, the comprehensive weight of the index can be obtained. The weight determined by Lagrange algorithm combines the analytic hierarchy process and entropy weight method to retain the information of the index itself to the greatest extent. At the same time, it avoids the subjectivity of analytic hierarchy process to determine the index and the neutralization of entropy weight method to risk indicators, making the weight of the index system more reasonable and scientific.

4. Fuzzy Comprehensive Evaluation Method

4.1. Determination of Various Sets. The first step of fuzzy comprehensive evaluation is to determine the index set, weight set and comment set [33]. The safety index evaluation system in this paper is shown in Figure 1, which can be divided into the main index set and sub index set; the weight set can be obtained by the above comprehensive weight method, and can also be divided into the main weight set and sub weight set. The specific representation method is shown in Table 2.

Table 2: Representation of factor set and weight set.

Various sets	Representation method
Main index set	$A = \{A_1, A_2, A_3, A_4\}$
Main weight set	$W = \{W_1, W_2, W_3, W_4\}$
Sub index set	$A_k = \{A_{k1}, A_{k2}, \ldots, A_{kn}\}$
Sub weight set	$W_k = \{W_{k1}, W_{k2}, \ldots, W_{kn}\}$

Comment set is the set of comments made by the judge on the evaluated object, which is usually represented by V, that is $V = \{v_1, v_2, \ldots, v_m\}$. According to the general rules of safety evaluation, m is taken as 4 in this paper, and the safety evaluation set V of pipeline disasters in permafrost region is divided into four levels, that is, v ={no risk, mild risk, moderate risk and high risk}.

4.2. Establish Fuzzy Risk Assessment Matrix. The second step of fuzzy comprehensive evaluation is to establish a fuzzy evaluation matrix. Firstly, the single index A_i ($i = 1, 2, \ldots, n$) in the index set is evaluated to determine its subordinate degree to the evaluation set v_j ($j = 1, 2, \ldots, m$) from the perspective of index u_i, and then the evaluation result $r_{i1} = (r_{i1}, r_{i2}, \ldots, r_{im}) \in [0, 1]^m$ is obtained. Finally, fuzzy evaluation is conducted on each factor set to obtain the fuzzy evaluation matrix R.

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{22} \\ \vdots & \vdots & \cdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}, \tag{10}$$

where r_{ij} =($i = 1, 2, \ldots, n$; $j = 1, 2, \ldots, m$) represents the membership of factor layer u_i to level j comment v_j.

4.3. Fuzzy Operation. The third step of fuzzy comprehensive evaluation is fuzzy operation. The fuzzy operator "∘" is used to fuzzy change the safety evaluation index weight set W and fuzzy evaluation matrix R to obtain the fuzzy comprehensive evaluation result B.

$$B = W \circ R. \tag{11}$$

For multi-level evaluation, the method from low level to high level is used to evaluate layer by layer, and the final evaluation result is obtained.

5. Example Calculation and Analysis

Taking the safety evaluation of pipeline disaster in China-Russia crude oil permafrost region as an example, this paper uses the above determined comprehensive weight and fuzzy comprehensive evaluation model to evaluate the safety of frozen soil disaster risk.

5.1. Determine the Comprehensive Weight

5.1.1. Improving AHP to Determine Weight

(i) Step 1: According to the workflow shown in Figure 2, the expert group scores each index. Due to space constraints, this paper only gives the calculation process of the index weight of the criterion layer. The scoring results of the criterion layer are 8, 6, 5 and 5 in the order of $A_1 \sim A_4$.

(ii) Step 2: According to the scoring results and the criteria determined in this paper, an improved judgment matrix B_A is constructed,

$$B_A = \begin{bmatrix} 1 & 3 & 4 & 4 \\ \frac{1}{3} & 1 & 2 & 2 \\ \frac{1}{4} & \frac{1}{2} & 1 & 1 \\ \frac{1}{4} & \frac{1}{2} & 1 & 1 \end{bmatrix}. \tag{12}$$

(iii) Step 3: calculate the hierarchical weight of the criterion layer.

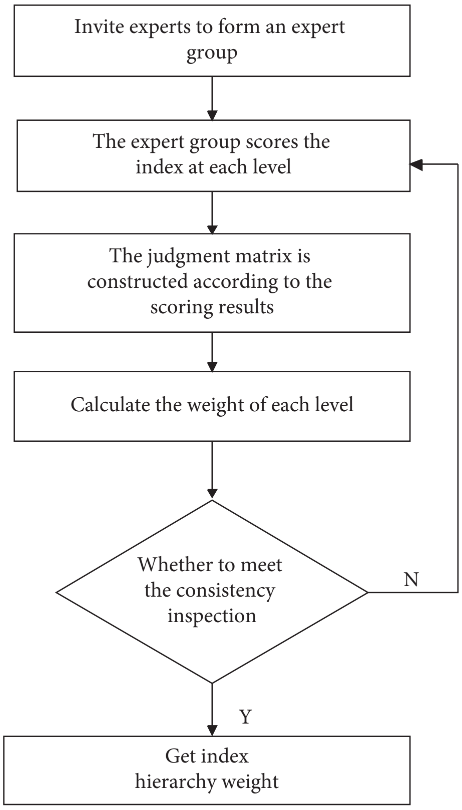

Figure 2: Flow chart of determining hierarchy weight by improved AHP.

The hierarchy weight of the criterion layer is calculated according to (3) and (4), and the following results are obtained:

$$w_i' = (0.4236, 0.2514, 0.1625, 0.1625). \tag{13}$$

The hierarchical weight of the criterion layer is calculated based on MATLAB and a schematic diagram is plotted in Figure 3. As can be seen from Figure 3, although the analytic hierarchy process has been improved, the weights determined by the analytic hierarchy process are very different from each other, and the results are not objective enough.

5.1.2. Entropy Weight Method to Determine Weight

(i) Step 1: According to the workflow shown in Figure 4, the expert group firstly evaluate each item in the index system according to the comment set determined in this paper, then the evaluation results are summarized and the final result is calculated according to the formula.

$$r_{ij} = \frac{x_n}{N}, \tag{14}$$

where x_n is the number of times a certain index u_{ij} is rated as v_n by the expert group, and N is the number of experts. The expert evaluation results are shown in Table 3. Due to space limit, this paper only lists the evaluation results of criteria layer index.

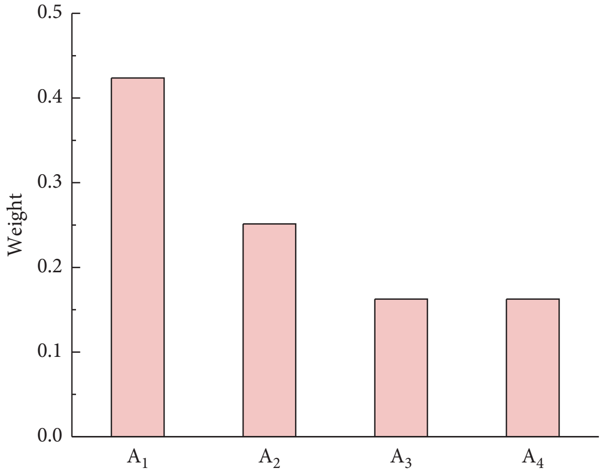

Figure 3: Schematic diagram of hierarchy weight of criterion layer.

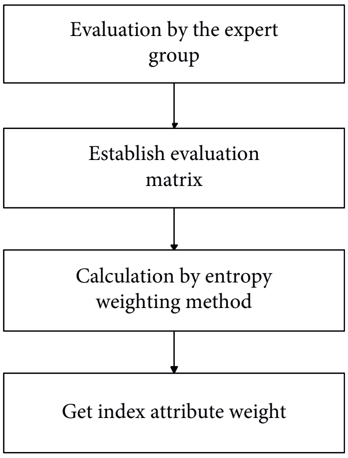

Figure 4: Flow chart of determining attribute weight by entropy weight method.

(ii) Step 2: Establish the evaluation matrix. According to the expert evaluation results, the evaluation matrix R is established R_A.

$$R_A = \begin{bmatrix} 34 & 35 & 36 & 31 \\ 40 & 44 & 40 & 43 \\ 15 & 13 & 14 & 13 \\ 6 & 9 & 5 & 8 \end{bmatrix}. \tag{15}$$

(iii) Step 3: Determine the weights.

According to the calculation principle of determining the weight by entropy weight method, the attribute weight of criterion layer is calculated by MATLAB software. The results are as follows:

$$w_i' = (0.3625, 0.4237, 0.1069, 0.1069). \tag{16}$$

Figure 5 shows the attribute weight of the criterion layer determined by the entropy weight method. It can be

Table 3: Expert evaluation results.

Criterion layer	No risk	Mild risk	Moderate risk	High risk
A_1	34	40	15	6
A_2	35	44	13	9
A_3	36	40	14	5
A_4	31	43	13	8

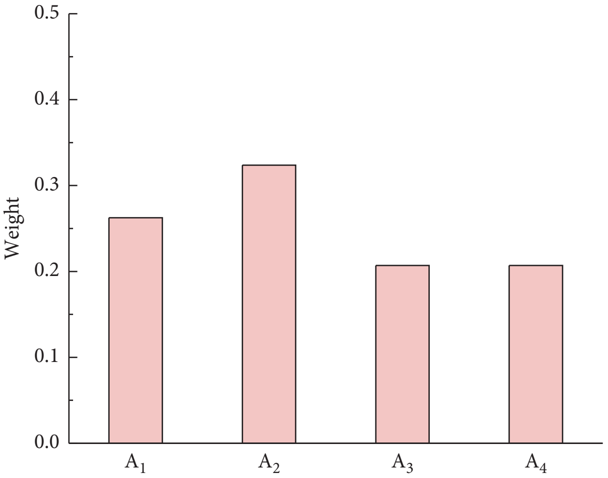

Figure 5: Schematic diagram of attribute weight of criterion layer.

seen that the weight determined by the entropy weight method can effectively reduce the impact of subjective factors, but some risk index may be neutralized. According to the above method, the weight of the index layer can be obtained, so as to obtain the overall attribute weight.

5.1.3. Comprehensive Determination of Weight. According to the Lagrange algorithm for calculating the comprehensive weight determined in this paper, the comprehensive weight of the criterion layer can be determined as follows according to (9):

$$w_i = (0.3625, 0.4237, 0.1069, 0.1069). \tag{17}$$

Figure 6 shows the comprehensive weight of the criterion layer. It can be seen that the comprehensive weight determined by the improved analytic hierarchy process and entropy weight method not only overcomes the subjectivity of analytic hierarchy process, but also avoids the neutralization of risk factors, which is more scientific Figure 7, effective and objective.

5.2. Fuzzy Comprehensive Evaluation

(i) Step 1: Evaluate the index layer. According to the evaluation process shown in , fuzzy comprehensive evaluation is firstly conducted on the index layer. Due to the space limit, this paper only gives the evaluation results of the index layer, as shown in Table 4.

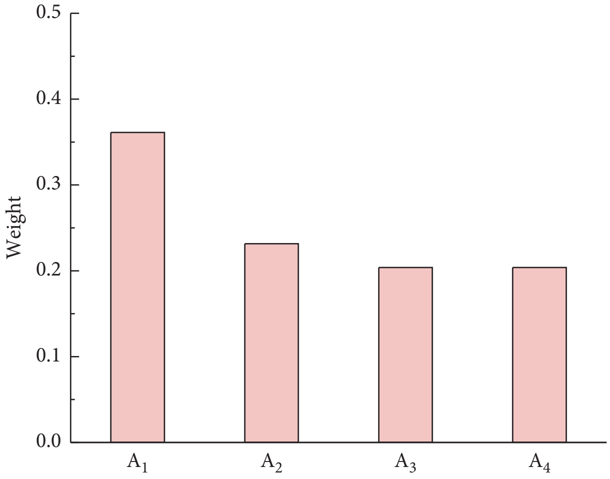

Figure 6: Schematic diagram of comprehensive weight of criterion layer.

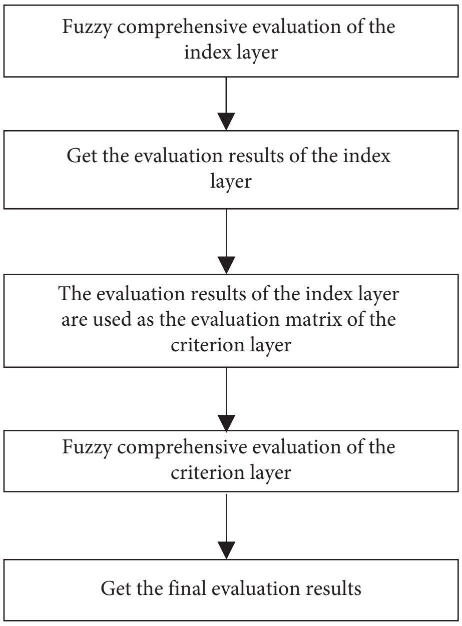

Figure 7: Flow chart of fuzzy comprehensive evaluation.

Table 4: Evaluation results of the index layer.

Index layer	No risk	Mild risk	Moderate risk	High risk
A_1	36.25	41.26	16.36	8.36
A_2	34.23	44.23	15.24	10.23
A_3	35.47	38.36	16.74	5.78
A_4	33.89	44.63	11.98	7.36

(ii) Step 2: Evaluate the criterion layer. Taking the fuzzy evaluation result of the index layer as the fuzzy evaluation matrix of the criterion layer, the fuzzy evaluation result of the criterion layer is obtained by using equation (13).

$$
\begin{aligned}
B &= W \circ R \\
&= (0.3625, 0.4237, 0.1069, 0.1069)\begin{bmatrix} 36.25 & 41.26 & 16.36 & 8.36 \\ 34.23 & 44.23 & 15.24 & 10.23 \\ 35.47 & 38.36 & 16.74 & 5.78 \\ 33.89 & 44.63 & 11.98 & 7.36 \end{bmatrix} \\
&= (35.06\,, 42.57\,, 15.46\,, 8.77).
\end{aligned}
\tag{18}
$$

Figure 8 shows the evaluation results obtained by using the method in this paper. According to the principle of maximum membership, the safety of pipeline disaster in China-Russia crude oil permafrost region is evaluated as mild risk in this paper.

5.3. Comparative Analysis. In order to better test the scientificity and rationality of the comprehensive evaluation method of improved FAHP and entropy weight method, the evaluation results obtained by traditional AHP method are compared with those obtained by the proposed method in this paper. Due to space limitation, the solution process of traditional AHP method is not described in detail.

Using the traditional AHP method, the weight of the criterion layer can be obtained as follows:

$$w = (0.5126, 0.3238, 0.0818, 0.0818). \tag{19}$$

The weight diagram of traditional AHP criterion layer is shown in Figure 9. By comparing Figure 6 and9, it can be found that the weights obtained by the traditional AHP method are highly subjective, the differences between factors are large, and the weights of individual factors are weakened. The comprehensive weight obtained by improved AHP method and entropy weight method can well solve the problem of large subjectivity of weight. The obtained weight overcomes subjective factors and retains the differences between weights, which is more scientific and objective.

The final evaluation results obtained by the traditional AHP method are shown in Figure 10.

According to the principle of maximum membership, the safety evaluation result obtained by the traditional AHP is also at mild risk, as shown in Figure 10. However, compared with Figure 8, the percentages of "no risk" and "mild risk" in the results obtained by the traditional AHP are close, the degree of discrimination is not enough, and the reliability of the results is not high. In the results obtained by the improved FAHP and entropy weight method, the proportion of "mild risk" is close to 50%, which is significantly different from that of other comments, and the results are more convincing.

To sum up, the improved FAHP and entropy weight comprehensive evaluation method can avoid the subjectivity of the traditional AHP method when determining the factor weight, and retain the natural attributes of the factors as much as possible, which is more scientific and objective. When solving the evaluation results, the evaluation results obtained by the comprehensive evaluation method have

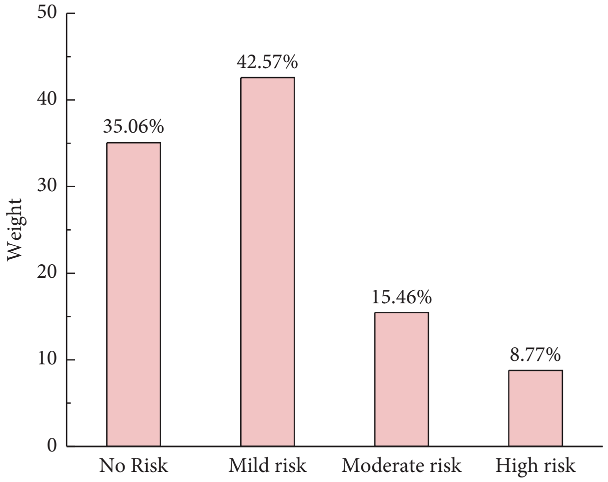

Figure 8: Safety assessment results of pipeline disaster in permafrost region of China-Russia crude oil.

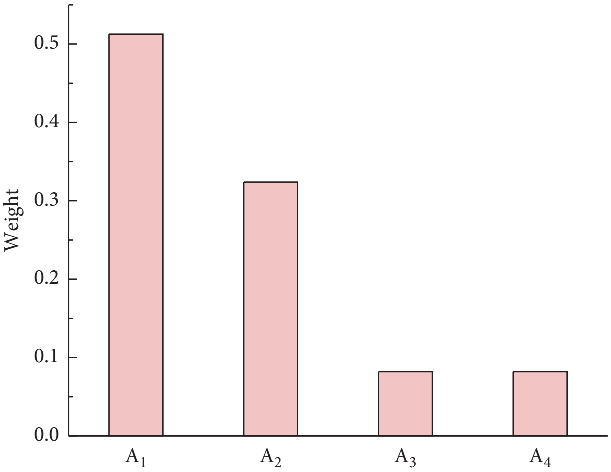

Figure 9: Schematic diagram of traditional AHP criterion layer weights.

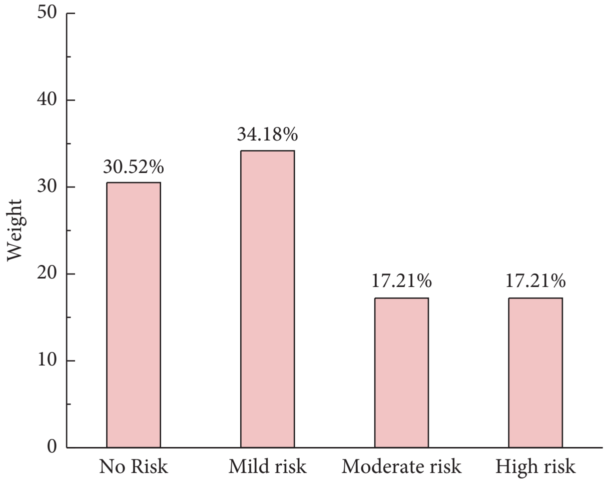

Figure 10: Safety evaluation results of traditional AHP.

high discrimination, strong credibility and more persuasive conclusions.

6. Conclusion

In this paper, four risk factors of pipeline disaster in China-Russia crude oil permafrost region are analyzed, and the safety evaluation system of frozen soil pipeline is constructed. A method to determine the comprehensive weight based on improved AHP and entropy weight method is proposed, and a fuzzy comprehensive evaluation model of frozen soil pipeline is constructed. The disaster safety of China-Russia crude oil frozen soil pipeline is evaluated, and the overall evaluation results and conclusions are obtained. The improved FAHP and entropy weight comprehensive evaluation method and traditional AHP evaluation method are compared and analyzed, and the advanced and reasonable method is verified. The method proposed in this paper provides a new idea for the safety analysis and evaluation of frozen soil pipeline.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors' Contributions

Conceptualisation, methodology, validation, data curation, visualisation, writing—original draft preparation, Y. S. and D. C.; data analysis were performed by M. Z.; theoretical analysis, T. Z.; formal analysis writing—review and editing, all authors. All authors have read and agreed to the published version of the manuscript.

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