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# Research on Drilling Well Control Risk Evaluation Method Based on AHP - Entropy Weight Method

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## Abstract

**In order to improve the accuracy and reliability of drilling well control risk evaluation, the study proposes a comprehensive evaluation model based on hierarchical analysis method (AHP) and entropy weight method. By integrating subjective experience and objective data, an index system covering five major criteria layers, namely, environment, human, equipment, management and technology, is constructed, 23 specific indexes are refined, and quantitative grading standards are formulated. AHP is used to determine the subjective weights of each index, entropy weighting method is used to calculate the objective weights, and linear combination method is used to integrate the subjective and objective weights, and finally fuzzy comprehensive evaluation method is used to quantify the risk level. Example analysis shows that formation stability index (0.1345), key equipment failure rate (0.1060) and formation pore pressure change rate (0.1040) are the top three core risk factors, and the results of well control safety evaluation of a drilling project belongs to the "comparatively safe" level. The study shows that this method can effectively balance the subjective and objective factors, clarify the key risk control points, provide theoretical basis and practical guidance for the scientific management of well control risk in drilling projects, and suggests focusing on the monitoring of formation stability, equipment maintenance, and pore pressure dynamic analysis to reduce the probability of well control accidents.**

## Keywords

**AHP-entropy Weighting Method; Drilling Well Control; Risk Evaluation; Combination Assignment.**

## 1. Introduction

With the continuous development of the petroleum industry, the operation scope of drilling engineering is expanding and the difficulty is increasing, and the drilling risk becomes more prominent. Drilling well control risk is one of the issues that need to be focused on in drilling engineering, and accurate evaluation of well control risk is crucial to ensure drilling safety [1]. Hierarchical analysis method (AHP) and entropy weight method are two commonly used risk evaluation methods, and the combination of the two can improve the accuracy and reliability of risk evaluation. The purpose of this paper is to study the well control risk evaluation method of drilling wells based on AHP-entropy weight method, which provides reference for risk prevention and control of drilling projects. [2]

## 2. Establishment of Drilling Well Control Risk Evaluation Index System

In drilling operation, well control operation mainly controls the wellhead operation after opening the oil and gas formation, including drilling, casing, logging, cementing, removing and

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installing the wellhead, removing and installing the blowout preventer, shutting down the well, weighting the well and removing and installing the overflow preventer, fender umbrella, outlet pipe, and blowout line, and so on [3]. According to the principles of scientific, systematic, operability and independence in the selection of indicators, a multi-level indicator system is constructed, such as personnel quality, equipment condition, geological environment, management level, etc., as the guideline layer, which is further subdivided into specific indicator layers, such as the training experience of the personnel, the failure rate of the equipment, the formation pressure coefficient, the degree of perfection of the safety management system and so on. [4]

## 2.1. Indicator System Framework Design

According to the characteristics and actual situation of drilling well control risk, based on the basic parameters of the accidental wells in the field, combined with the experience of experts to establish the drilling well control risk evaluation index system, and determine the specific evaluation indexes. For example, human factors can include indicators such as operator skill level and safety awareness; equipment factors can include indicators such as drilling equipment performance and maintenance; environmental factors can include indicators such as geological and climatic conditions; and management factors can include indicators such as safety management system and emergency plan [5]. Analyzing and comparing many risk factors, the evaluation indexes of drilling well control risk factors are finally determined as shown in Table 1.

**Table 1.** Indicators for evaluating well control risk in drilling

| target level | standardized layer | indicator layer |
|---|---|---|
| Drilling Well Control Risk Evaluation System A | Environmental factor B1 | Stratigraphic stability index C1 |
| | | Rate of change of formation pore pressure C2 |
| | | Formation fluid toxicity class C3 |
| | | Stratigraphic flow corrosivity class C4 |
| | | Extreme weather impact level C5 |
| | Human factor B2 | Operator specialty level C6 |
| | | Actual operational error rate C7 |
| | | Emergency Operations Proficiency C8 |
| | | Score on security knowledge test C9 |
| | Equipment factor B3 | Degree of equipment automation and intelligence C10 |
| | | Critical equipment failure rate C11 |
| | | Overloading of equipment C12 |
| | | Completion rate of scheduled maintenance plan C13 |
| | Management factor B4 | Comprehensiveness of the security management system C14 |
| | | HSE Management System C15 |
| | | Security Education and Training C16 |
| | | Emergency Preparedness Improvement C17 |
| | | Emergency Resource Mobilization Capacity C18 |
| | Technical factor B5 | Drilling fluid density design rationalization C19 |
| | | Pressure shut-in well technology refinement C20 |
| | | Degree of optimization of drilling parameters C21 |
| | | Well blowout runaway treatment technology C22 |
| | | Fire Fighting Technology C23 |

## 2.2. Quantitative Guidelines for Well Control Risk Evaluation Indicators for Well Drilling

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**Table 2.** Table of quantitative guidelines for drilling well control risk evaluation indicators

| serial number | assessment criteria | Evaluation classification | | | | |
|---|---|---|---|---|---|---|
| | | surety | safer | general | more dangerous | distress |
| 1 | Stratigraphic Stability Index (SSI) | [80, 100] | [60, 80] | [40, 60] | [20, 40] | [0, 20] |
| 2 | Rate of change of formation pore pressure | [0, 5%] | [5%, 10%] | [10%, 20%] | [20%, 30%] | [30%, 1] |
| 3 | Stratigraphic Fluid Toxicity Rating Score | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 4 | Stratigraphic Flow Corrosivity Rating Score | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 5 | Extreme weather impact score | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 6 | Operator Professional Rating Score | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 7 | Actual operational error rate | [0, 0.1%] | [0.1%, 0.5%] | [0.5%, 1%] | [1%, 3%] | [3%, 1] |
| 8 | Emergency Operations Proficiency Score | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 9 | Score on the safety knowledge test | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 10 | Equipment Automation and Intelligence Score | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 11 | Failure rate of critical equipment | [0, 1%] | [1%, 3%] | [3%, 5%] | [5%, 8%] | [8%, 1] |
| 12 | Score for equipment overloading | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 13 | Completion rate of the scheduled maintenance plan | [95%, 1] | [85%, 95%] | [70%, 85%] | [50%, 70%] | [0, 50%] |
| 14 | Score for comprehensiveness of safety management system | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 15 | HSE Management System Score | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 16 | Safety Education and Training Score | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 17 | Emergency Planning Completeness Score | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 18 | Emergency Resource Mobilization Capacity Score | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 19 | Drilling Fluid Density Design Rationality Score | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 20 | Pressure shut-in well technology refinement score | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 21 | Score for degree of optimization of drilling parameters | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 22 | Score for technology to deal with uncontrolled well blowouts | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |
| 23 | Fire Fighting Technology Score | [90, 100] | [80, 90] | [70, 80] | [60, 70] | [0, 60] |

According to the summary of the risk evaluation index system to analyze the quantitative assessment criteria of the indicators one by one, combined with the relevant literature, statistical data collection, quantitative evaluation of the indicators that can be quantified with specific data intuitively, on the indicators that are not easy to obtain intuitive data for

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evaluation, the quantitative evaluation of the assessment score evaluation, the quantitative evaluation of the indicators, the quantitative quasi see Table 2. according to the evaluation score of each factor or the quantitative evaluation of the data directly. According to the evaluation score of each factor or the quantitative evaluation of direct data, the evaluation results are categorized into five levels: safe, relatively safe, general, relatively dangerous and dangerous. [6]

# 3. Establishment of Drilling Well Control Risk Evaluation Model Based on AHP - Entropy Weight Method

## 3.1. AHP-Based Subjective Weight Determination

AHP is a method that decomposes a complex problem into multiple levels and determines the relative importance of each factor through two-by-two comparison [7]. It decomposes the decision-making problem into objective, criterion and program levels, and calculates the weights of the factors at each level by constructing a judgment matrix. Hierarchical analysis is a method that breaks down the elements that are always related to decision-making into levels such as objectives, guidelines and programs, and carries out qualitative and quantitative analysis on this basis.

According to the determined safety evaluation index system, a questionnaire is issued to experts in the drilling field, and a judgment matrix is constructed based on a two-by-two comparison of the factors at each level in the evaluation index system in accordance with the 1-9 scale method, in which the meanings of the 1-9 scales are shown in Table 3. The eigenvector method is applied to compute the eigenvector of the judgment matrix, and to determine the relative weights of the indicators with respect to the factors of the previous level. Then conduct consistency test, see equation (1) (2), if the consistency ratio CR is less than 0.1, the judgment matrix is accepted, otherwise the judgment matrix is adjusted and optimized until it meets the consistency requirements, and finally get the subjective weight vector of each indicator. [8]

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

$$CR = \frac{CI}{RI} \tag{2}$$

Where CR is the consistency ratio; CI is the consistency index, λmax is the largest characteristic root of the judgment matrix; n is the number of pairwise comparison factors; RI is the random consistency index, which can be determined by looking up the table.

**Table 3.** Meaning of scales 1-9

| scale | hidden meaning |
|---|---|
| 1 | Indicates that two factors are of equal importance compared to each other |
| 3 | Indicates that the former is slightly more important than the latter when comparing the two factors |
| 5 | Indicates that the former is significantly more important than the latter when comparing the two factors |
| 7 | Indicates that the former is more strongly important than the latter when comparing the two factors |
| 9 | Indicates the extreme importance of the former over the latter when comparing the two factors |
| 2, 4, 6, 8 | denotes the intermediate value of the above neighboring judgments |
| from the bottom (lines on a page) | If the ratio of the importance of factor i to factor j is $a_{ij}$, then the ratio of the importance of factor j to factor i is $1/a_{ij}$ |

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## 3.2. Determination of Objective Weights Based on the Entropy Weight Method

The concept of entropy was originally derived from thermodynamics to describe the degree of disorder in a system. In information theory, information entropy is a measure of uncertainty. For a random variable, the greater its information entropy, the greater the uncertainty of the variable, and the richer the amount of information it contains. This paper collects the relevant data of drilling well control risk evaluation indexes, standardizes the data, and makes the data of each index comparable [8]. According to the formula of entropy weight method, the information entropy value of each index is calculated, and then the entropy weight vector of each index is determined, the specific steps are as follows.

The basic steps for calculating the weights of the indicators in the evaluation set established by m objects and n evaluation indicators using the entropy weight method are as follows:

1) Convert measured data to standardized data after calibration.

2) Calculate the information entropy of the jth indicator.

$$E_j = -(\ln m)^{-1} \sum_{i=1}^{m} P_{ij} \ln P_{ij} \tag{3}$$

Where: j=1,2,...,n,$P_{ij} = \frac{d_{ij}}{\sum_{i=1}^{m} d_{ij}}$ , where $P_{ij}$ is the weight of the indicator value of the ith item under the jth indicator, and $d_{ij}$ is the indicator value of the ith item under the jth indicator.

3) Calculate the weight of each indicator.

$$w_j = \frac{1 - E_j}{n - \sum_{j=1}^{n} E_j} \tag{4}$$

where n is the number of indicators.

## 3.3. Composite Weight Calculation

AHP-entropy weight method is a comprehensive evaluation method that combines hierarchical analysis method and entropy weight method. It takes into account both the subjective judgment of the decision maker and the objective information of the indicator data, which can improve the accuracy and reliability of the evaluation results. [9]

The specific method is to determine the subjective weights by hierarchical analysis, then determine the objective weights by entropy weighting method, and finally synthesize the subjective weights and objective weights through equation (5) to get the comprehensive weights W of each index.

$$W = \alpha w_{AHP} + (1-\alpha) w_{熵} \tag{5}$$

Where α is the weight balance coefficient (0≤ α≤ 1), the larger α is, the greater the influence of the weights determined by AHP on the comprehensive weights is indicated; conversely, it indicates that the weights determined by the entropy weight method have a great influence on the comprehensive weights. The change of α is used to adapt to the needs of different evaluation occasions, so that the AHP-entropy weight method determines the weight method with good adaptability.

## 3.4. Fuzzy Integrated Evaluation

The fuzzy comprehensive evaluation method is a comprehensive evaluation method that uses the affiliation degree theory of fuzzy mathematics to quantify the indicators according to certain judging criteria. For complex, fuzzy, difficult to quantify the problem, there is a better applicability. [10]

Fuzzy integrated evaluation step

(i)Determine the set of factors U = {C1, C2, C3, ... .C23}.

(ii)Create a rubric set V={Safe, Safer, Fair, More Hazardous, Dangerous} according to the purpose and requirements of the evaluation.

(iii)By reviewing the literature, specifications, etc., and using fuzzy statistical method and expert experience method, the affiliation function is determined and the affiliation matrix $R_{23\times 5}$ (evaluation matrix) is established.

(iv)Operate using the known weights $W_{1\times 23}$. The formula is as follows:

$$Z = W \cdot R \tag{6}$$

# 4. Example Analysis

## 4.1. Project Overview

Changqing Oilfield X block is one of the key development areas of the oilfield, located in the Loess Plateau geomorphological area, with complex topography and longitudinal gullies, the reservoir type of a well in this block is mainly a low permeability reservoir, with the reservoir lithology dominated by fine sandstones and siltstones, and the reservoir depth is 2800~3200 m. The reservoir depth is about 10.6% of the average porosity in the reservoir, and the average permeability is about 2.7 mD, and the well is deployed based on the fine reservoir description and numerical simulation results. The wells are deployed based on reservoir fine description and numerical simulation results. The wells are deployed according to the results of reservoir fine description and numerical simulation. A rectangular well network is adopted, with an average well spacing of about 200 meters.

The drilling rig is ZJ40/2250L with a maximum hook load of 2250kN and a drilling depth of 4000 m. The mud pumps are equipped with two F-1300 mud pumps with a rated power of 956kW and a maximum displacement of 58L/s. The geosteering equipment adopts the advanced Schlumberger MWD (Measurement While Drilling) and LWD (Logging While Drilling). The wellhead is equipped with 70MPa hydraulic blowout preventer packages, including annular blowout preventers and double-gate blowout preventers.

## 4.2. Determination of Subjective Weights

Based on the established safety evaluation indicator system, questionnaires were distributed to experts in the relevant field. The results of the ranking of the influence levels of indicators at each level were compared pairwise, and scores were assigned on a scale of 1 to 9 to evaluate the influence levels, thereby constructing a judgment matrix. Due to the large volume of data and the complexity of the calculation process, the comparison judgment matrices for each factor can be input sequentially into the YAAHP hierarchical analysis method software to calculate the weights of each risk factor. The AHP weight calculation results for each risk factor are shown in Tables 4-9, where $w_i$ represents the relative criterion layer weight and $w_u$ represents the relative objective layer weight.

**Table 4.** Comparative judgment matrix for the target layer

| A | B1 | B2 | B3 | B4 | B5 | $w_i$ |
|---|---|---|---|---|---|---|
| B1 | 1 | 3 | 2 | 5 | 7 | 0.4387 |
| B2 | 1/3 | 1 | 1/2 | 3 | 4 | 0.1730 |
| B3 | 1/2 | 2 | 1 | 3 | 5 | 0.2588 |
| B4 | 1/5 | 1/3 | 1/3 | 1 | 2 | 0.0808 |
| B5 | 1/7 | 1/4 | 1/5 | 1/2 | 1 | 0.0488 |

Note: $\lambda = 5.0767$, CR = 0.0171< 0.1

**Table 5.** Comparative judgment matrix for environmental factors

| B1 | C1 | C2 | C3 | C4 | C5 | $w_i$ | $w_u$ |
|---|---|---|---|---|---|---|---|
| C1 | 1 | 2 | 3 | 3 | 5 | 0.3924 | 0.1722 |
| C2 | 1/2 | 1 | 3 | 3 | 5 | 0.2974 | 0.1305 |
| C3 | 1/3 | 1/3 | 1 | 1 | 3 | 0.1281 | 0.0562 |
| C4 | 1/3 | 1/3 | 1 | 1 | 3 | 0.1281 | 0.0562 |
| C5 | 1/5 | 1/5 | 1/3 | 1/3 | 1 | 0.0540 | 0.0237 |

Note: $\lambda = 5.1140$, CR = 0.0328< 0.1

**Table 6.** Comparative judgment matrix for human factors

| B2 | C6 | C7 | C8 | C9 | $w_i$ | $w_u$ |
|---|---|---|---|---|---|---|
| C6 | 1 | 1/5 | 1/3 | 2 | 0.1103 | 0.0191 |
| C7 | 1/5 | 1 | 3 | 6 | 0.5622 | 0.0972 |
| C8 | 1/3 | 1/3 | 1 | 4 | 0.2581 | 0.0446 |
| C9 | 1/3 | 1/6 | 1/4 | 1 | 0.0693 | 0.0120 |

Note: $\lambda = 4.0787$, CR = 0.0295< 0.1

**Table 7.** Comparative judgment matrix for equipment factors

| B3 | C10 | C11 | C12 | C13 | $w_i$ | $w_u$ |
|---|---|---|---|---|---|---|
| C10 | 1 | 1/7 | 1/5 | 1/3 | 0.0565 | 0.0146 |
| C11 | 7 | 1 | 2 | 5 | 0.5232 | 0.1354 |
| C12 | 5 | 1/2 | 1 | 3 | 0.2993 | 0.0775 |
| C13 | 3 | 1/5 | 1/3 | 1 | 0.1210 | 0.0313 |

Note: $\lambda = 4.0684$, CR = 0.0256< 0.1

**Table 8.** Comparative judgment matrix of management factors

| B4 | C14 | C15 | C16 | C17 | C18 | $w_i$ | $w_u$ |
|---|---|---|---|---|---|---|---|
| C14 | 1 | 2 | 3 | 5 | 7 | 0.4227 | 0.0341 |
| C15 | 1/2 | 1 | 3 | 4 | 6 | 0.2970 | 0.0240 |
| C16 | 1/3 | 1/3 | 1 | 3 | 5 | 0.1607 | 0.0130 |
| C17 | 1/5 | 1/4 | 1/3 | 1 | 3 | 0.0797 | 0.0064 |
| C18 | 1/7 | 1/6 | 1/5 | 1/3 | 1 | 0.0400 | 0.0032 |

Note: $\lambda = 5.1955$, CR = 0.0436< 0.1

**Table 9.** Comparative judgment matrix for technical factors

| B4 | C19 | C20 | C21 | C22 | C23 | $w_i$ | $w_u$ |
|---|---|---|---|---|---|---|---|
| C19 | 1 | 3 | 2 | 5 | 6 | 0.4268 | 0.0208 |
| C20 | 1/3 | 1 | 1/3 | 3 | 4 | 0.1600 | 0.0078 |
| C21 | 1/2 | 1/3 | 1 | 3 | 5 | 0.2816 | 0.0137 |
| C22 | 1/5 | 1/3 | 1/3 | 1 | 2 | 0.0811 | 0.0040 |
| C23 | 1/6 | 1/4 | 1/5 | 1/2 | 1 | 0.0505 | 0.0025 |

Note: $\lambda = 5.1636$, CR = 0.0365< 0.1

### 4.3. Determination of Objective Weights

Invite five risk evaluation team consisting of risk evaluators, technical managers, operators and technicians or experts of different specialties (process, equipment, instrumentation, etc.), etc., according to the actual data of the project, apply the quantitative guideline table of drilling well control risk evaluation indexes given in this paper to score each index of the drilling well control risk, and finally construct the evaluation matrix, standardize each index, and process it with the help of matlab and excel software to determine the objective weights.

## 4.4. Determination of Portfolio Assignment

Through the linear combination method, using formula (5), the weights calculated by hierarchical analysis method and entropy weighting method are combined and operated, in which α is taken as 0.7, and finally the combined weights of each index in the index system are obtained, and the specific calculation results are shown in Table 10.

**Table 10.** Combined weighting table

| target level | standardized layer | AHP | entropy weight | Guideline layer portfolio weights | indicator layer | AHP | entropy weight | portfolio weighting | arrange in order |
|---|---|---|---|---|---|---|---|---|---|
| A | B1 | 0.4387 | 0.2181 | 0.3725 | C1 | 0.1722 | 0.0466 | 0.1345 | 1 |
| | | | | | C2 | 0.1305 | 0.0421 | 0.1040 | 3 |
| | | | | | C3 | 0.0562 | 0.0336 | 0.0494 | 7 |
| | | | | | C4 | 0.0562 | 0.0494 | 0.0542 | 6 |
| | | | | | C5 | 0.0237 | 0.0464 | 0.0305 | 11 |
| | B2 | 0.1730 | 0.1689 | 0.1718 | C6 | 0.0191 | 0.0425 | 0.0261 | 14 |
| | | | | | C7 | 0.0972 | 0.0372 | 0.0792 | 4 |
| | | | | | C8 | 0.0446 | 0.0455 | 0.0449 | 8 |
| | | | | | C9 | 0.0120 | 0.0437 | 0.0215 | 17 |
| | B3 | 0.2588 | 0.6415 | 0.3736 | C10 | 0.0146 | 0.0511 | 0.0256 | 15 |
| | | | | | C11 | 0.1354 | 0.0372 | 0.1060 | 2 |
| | | | | | C12 | 0.0775 | 0.0421 | 0.0669 | 5 |
| | | | | | C13 | 0.0313 | 0.0512 | 0.0373 | 10 |
| | B4 | 0.0808 | 0.2286 | 0.1251 | C14 | 0.0341 | 0.0504 | 0.0390 | 9 |
| | | | | | C15 | 0.0240 | 0.0396 | 0.0287 | 12 |
| | | | | | C16 | 0.0130 | 0.0352 | 0.0197 | 18 |
| | | | | | C17 | 0.0064 | 0.0503 | 0.0196 | 19 |
| | | | | | C18 | 0.0032 | 0.0363 | 0.0131 | 23 |
| | B5 | 0.0488 | 0.0191 | 0.0399 | C19 | 0.0208 | 0.0398 | 0.0265 | 13 |
| | | | | | C20 | 0.0078 | 0.0466 | 0.0194 | 20 |
| | | | | | C21 | 0.0137 | 0.0456 | 0.0233 | 16 |
| | | | | | C22 | 0.0040 | 0.0402 | 0.0149 | 22 |
| | | | | | C23 | 0.0025 | 0.0469 | 0.0158 | 21 |

According to the above table it is known that the weight matrix W= (0.1345, 0.1040, 0.0494, 0.0542, 0.0305, 0.0261, 0.0792, 0.0449, 0.0215, 0.0256, 0.1060, 0.0669, 0.0373, 0.0390, 0.0287, 0.0197 0.0196, 0.0131, 0.0265, 0.0194, 0.0233, 0.0149, 0.0158).

## 4.5. Application of Fuzzy Evaluation

Based on the provisions of the Drilling Well Control Safety Regulations and reviewing the literature and consulting experts, the affiliation function was determined and the affiliation matrix R was constructed, as shown in Table 11.

According to Eq. (6), the well control safety evaluation vector of this drilling project is obtained: Z=(0.1009, 0.5110, 0.3882, 0, 0), and the maximum degree of affiliation of the well control safety evaluation vector of this project is 0.5110, and according to the principle of the maximum degree of affiliation, the well control safety level of this drilling project is assessed as relatively safe.

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**Table 11.** Matrix of affiliation of secondary indicators

| evaluation factor | Affiliation degree Ⅰ | Degree of affiliation II | Degree of affiliation III | Degree of affiliation IV | Affiliation V |
|---|---|---|---|---|---|
| C1 | 0.25 | 0.75 | 0 | 0 | 0 |
| C2 | 0 | 0.4 | 0.6 | 0 | 0 |
| C3 | 0 | 0.7 | 0.3 | 0 | 0 |
| C4 | 0 | 0.1 | 0.9 | 0 | 0 |
| C5 | 0 | 0.5 | 0.5 | 0 | 0 |
| C6 | 0 | 0.5 | 0.5 | 0 | 0 |
| C7 | 0.85 | 0.15 | 0 | 0 | 0 |
| C8 | 0 | 0.65 | 0.35 | 0 | 0 |
| C9 | 0 | 0.5 | 0.5 | 0 | 0 |
| C10 | 0 | 0.35 | 0.65 | 0 | 0 |
| C11 | 0 | 0.5 | 0.5 | 0 | 0 |
| C12 | 0 | 0.5 | 0.5 | 0 | 0 |
| C13 | 0 | 0.7 | 0.3 | 0 | 0 |
| C14 | 0 | 0.8 | 0.2 | 0 | 0 |
| C15 | 0 | 0.6 | 0.4 | 0 | 0 |
| C16 | 0 | 0.5 | 0.5 | 0 | 0 |
| C17 | 0 | 0.75 | 0.25 | 0 | 0 |
| C18 | 0 | 0.65 | 0.35 | 0 | 0 |
| C19 | 0 | 0.1 | 0.9 | 0 | 0 |
| C20 | 0 | 0.5 | 0.5 | 0 | 0 |
| C21 | 0 | 0.6 | 0.4 | 0 | 0 |
| C22 | 0 | 0.75 | 0.25 | 0 | 0 |
| C23 | 0 | 0.5 | 0.5 | 0 | 0 |

## 5. Conclusion

(1) This paper constructs a guideline layer from environmental, human, equipment, management and technology aspects, and subdivided into specific index layers, such as formation stability index, operator professional grade and other 23 indexes, which cover all key areas of well control risks and provide a basic framework for comprehensive evaluation.

(2) According to the comprehensive weighting table, it can be seen that the formation stability index (C1) has a weighting of 0.1345, the failure rate of key equipment (C11) has a weighting of 0.1060, and the pore pressure change rate of the formation (C2) has a weighting of 0.1040, and these three items are in the top three, so in the well control operation, it is necessary to pay attention to the formation stability and the pore pressure rate, choose the best key equipment, and at the same time, real-time monitoring of key equipment operation, strengthen the maintenance and management of equipment, and reduce the failure rate of key equipment.

(3) The drilling program was scored by expert questionnaires and actual data, combined with the subjective and objective and combined weights of each index, constructed an affiliation matrix evaluation, and determined that the safety of well control was relatively safe according to the principle of maximum affiliation.

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