Risk Assessment of Oil and Gas Drilling Engineering Cooperation Project Based on Fuzzy Comprehensive Evaluation

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Abstract This paper establishes the risk assessment index system according to characteristics of oil and gas drilling engineering cooperation project. After modularizing risk indexes of oil and gas drilling engineering cooperation project into eight clusters, risks are evaluated on the basis of multi-level fuzzy comprehensive evaluation method. The study is to construct risk assessment indexes system of oil and gas drilling in order to provide a guide to establishment of risk prevention mechanism, and to provide significant reference for decision-makers of oil & gas drilling engineering cooperation project.
Key words Risk assessment; Fuzzy comprehensive evaluation; Oil and gas drilling project; Cooperation project

1 Introduction

Oil and gas drilling engineering cooperation project is a basic work in oil and gas exploration and development. It is a systematic engineering that involves many investor and administration section, complicated techniques, lots of investments and large risks. While it is also a systematic engineering that involves several work categories and work procedures, grade separation and continuous operation. And it is a concealed underground engineering. The characteristics determine that there are many uncertainties in oil and gas drilling project, and there are great risks in every aspect of oil and gas drilling project. If effective measures can not be taken, it will easily lead to kinds of accidents which will threaten the safety of operating personnel and environment pollution even huge loss of government property [1].

Through summarizing the research on risk analysis of oil and gas drilling engineering cooperation project both in home and abroad, the results are as following:

Firstly, among research objects, the number of the study on risk analysis of general exploration and development project is much bigger than the number specifically for the risk of oil and gas drilling project. And from risk management aspects of oil and gas drilling project, there is more study on HSE risk management of drilling operation than that on integrated risk management of drilling cooperation project [2].The risk research caused by objective factors is much more than the research of risk caused by subjective factors, namely human behavior factors and how to avoid the risk of behavior [3].

Secondly, in the research ways, qualitative analysis is more effective than quantitative analysis, and single factor risk analysis is also more effective than multi-factor risk analysis.

2 Risk Assessment Indexes System of Oil and Gas Drilling Engineering Cooperation Project

2.1 Characteristics of risks in drilling cooperation project

From a broad perspective, the risks of oil and gas drilling engineering cooperation project mean the possibility of loss of investor which would come from every environment conditions or human activities having some connection with oil and gas drilling engineering cooperation project, and drilling organization and its stakeholders have difficult in accurately foreseeing or controlling the influenced factors[4].However, from a narrow perspective, risks of drilling engineering cooperation project refers to the occurring possibility of specific hazard events in the implementation process of drilling engineering project. In a word, the risk has the following main features: difference; seriousness; diversity; concealment; variability.

2.2 Establishing risk assessment indexes system of drilling engineering cooperation project

According to the characteristics of risks in oil and gas drilling engineering cooperation project and the goal to be achieved, the risks factor will be decomposed into different component elements, then it will be stratified, clustered and combined according to the interaction and membership relation between the factors, so that a delivered-hierarchy and order level indicator system is formed. Elements in first-level indexes dominate previous position [5].In this thesis risk evaluation indexes system of oil & gas drilling cooperation project is constructed which can be seen in Table 1:

Table 1 Risk Assessment Index System of Oil and Gas Drilling Engineering Cooperation Project

Risk assessment index system of oil and gas drilling engineering cooperation project U	Natural factor U_1	Geological factor U_{11} Sulfur gas U_{12}
	Technological factor U_2	Borehole stability U_{21} Drilling fluid property U_{22} Torque and friction U_{23} Cementing qualityU_{24}
	Management factor U_3	Management organization U_{31} Management policy and implementation U_{32} Management staff U_{33} Risk education and training U_{34}
	Economic factor U_4	Risk education and training fees and prize fund U_{41} Risk technical measures cost U_{42} Industrial hygiene technical measures cost U_{43} Labor insurance supplied fees U_{44}
	The frequency of accidents U_5	The frequency of equipment accidents U_{51} Personal accident frequency U_{52} The frequency of mine accidents U_{53} Environmental pollution severity U_{54}
	Distribution and loss of staff U_6	Operating personnel density U_{61} Operating personnel quality U_{62} Economic loss per capita U_{63}
	Relief capability U_7	The number of ambulance staff U_{71} Ambulance Equipment U_{72} The distance to the adjacent ambulance teams U_{73}
	Contract risk U_8	Objective risk U_{81} renege on agreements U_{82}

All risk indexes in the first layer of oil and gas drilling cooperation project is obtained by summarizing risk factors which refer to eight aspects. And then each factor index in the first layer is decomposed into several corresponding factor indexes in the second layer. This integrated process is achieved by using fuzzy comprehensive evaluation method, and the risk quantization of factor index in each base layer is generally given by the experts on drilling risk management on the basis of their experience and knowledge [6].

3 Risk Assessment Method and Process

Because the risks have many attributes and are easily influenced by various factors in risk evaluation of drilling engineering cooperation project, all relevant factors must be made comprehensive consideration and the general comment when we evaluate risk degrees of the project and make the decisions for the matter in order to provide the most realistic risk assessment results. The size of risk factors exist is usually beyond recognition. It is difficult to unify to get clearly vivid boundary line and not easy to accurately judge risk factors. Therefore, when we carry out risk assessment, it is necessary for us to use some quantitative methods to describe fuzzy concepts, so that fuzzy concepts become relatively sure. That is why we use fuzzy comprehensive evaluation method to judge and think it can be a more accurate result which is easier to implement in the real applications.

The basic idea of risk estimation and assessment using fuzzy comprehensive evaluation method is to consider synthetically the impact of all risk factors, to set the weight, to differentiate the importance degree of each factor, o describe the fuzzy boundary of various factors by the membership, and to construct fuzzy evaluation matrix. Through the multi-layer compound operation, we calculate various possibility degree of risk level in which a high probability degree is the ultimately determined value. Finally we determine the level of evaluation object. Concrete process is as follows.

3.1 Determining the factors and weight of risk

Risk factors set is presumably $U=\{U_1,U_2,\ldots\ldots,U_n\}$, $U_i(i=1,2,\ldots\ldots\ldots,n)$is the first *i* factor of the first level (the highest risk level)and it is also determined by some factors of risks in the second level, that is to say $U_i=\{U_{i1},U_{i2},\ldots\ldots,U_{im}\}$,among which, $U_{ij}(j=1,2,\ldots\ldots\ldots,m)$is risk factor of the second level.

AHP method is used to determine the indexes weight. Corresponding weight is given on the basis of the importance of various risk factors at each level. Weight set of risks in the first level is defined as $A=\{a_1,a_2,\ldots\ldots\ldots,a_n\}$and $a_i(i=1,2,\ldots\ldots\ldots,n)$is U_i in the proportion of U, among which, $\sum a_i=1(i=1,2,\ldots\ldots\ldots,n)$.Weight set of risks in the second level is defined as $W=\{w_{i1},w_{i2},\ldots\ldots\ldots,w_{im}\}$and $w_{ij}(j=1,2,\ldots\ldots\ldots,m)$ is the weight of the first *j* factor U_{ij} of the deciding factor U_i in the second level, among which, $\sum w_{ij}=1(j=1,2,\ldots\ldots,m)$.

3.2 Revising the weight of project risk indexes

After processing by AHP method, weight matrix is as follows, while A_{ij} is the weight and importance degree that are got out after the first *i* expert judges the first *j* index and uses AHP method to deal with. In following matrix *m* refers the number of experts and *n* is the number of indexes.

$$A=\begin{bmatrix} A_{11} & A_{12} & \ldots & A_{1n} \\ A_{21} & A_{22} & \ldots & A_{2n} \\ \ldots & \ldots & A_{ij} & \ldots \\ A_{m1} & A_{m2} & \ldots & A_{mn} \end{bmatrix}$$

In order to judge the dispersion degree of the matrix weight from the experts, it is necessary to calculate the similarity coefficient between weights, thus the similarity coefficient matrix is composed. Similarity coefficient and similarity matrix R are defined as:

$$R_{ij}=1-\sqrt{(1/n)\sum_{k=1}^{n}(A_{ik}-A_{jk})^2}$$

$$R_{ij}=\begin{bmatrix} R_{11} & R_{12} & \ldots & R_{1m} \\ R_{21} & R_{22} & \ldots & R_{2m} \\ \ldots & \ldots & R_{ij} & \ldots \\ R_{m1} & R_{m2} & \ldots & R_{mm} \end{bmatrix}$$

Where R_{ij} refers to similarity degree of weight results between the experts *i* and *j* on the evaluation of the first k item; Known by the above formula, the smaller R_{ij}, the smaller the similarity. Besides, *n* refers to the dimension of index weight, which is also the number of evaluation indexes.

3.3 Establishing the evaluation set

No matter how many the factor levels have, the evaluation set has only one. The evaluation set is applicable to risk factors and risk influenced factors. The evaluation benchmarks given by evaluating set can be expressed by $V=\{v_1,v_2,\ldots,v_p\}$, where $v_k(k=1, 2, \ldots, p)$ is the first *k* possible result of overall evaluation.

3.4 Establishing two-level fuzzy evaluation matrix

The risk assessment team composed of experts or executives evaluate the current risk state according to the given assessment benchmark. This evaluation is a fuzzy mapping. Even for the same evaluation project, the evaluation results can only be expressed by the size of possibility degree of the first *j* evaluation scale on the first *i* factor because different evaluators can be made for different assessments. This possibility degree is called the membership degree, denoted by r_{ij}. r_{ij} is defined as the number of experts making the first *j* evaluation scale on the first *i* factor / the total number of experts participating in the evaluation, thus the fuzzy evaluation matrix is defined as:

$$R_{ij}=\begin{bmatrix} r_{11} & r_{12} & \ldots & r_{1n} \\ r_{21} & r_{22} & \ldots & r_{2n} \\ \ldots & \ldots & rij & \ldots \\ r_{m1} & r_{m2} & \ldots & r_{mn} \end{bmatrix}$$

3.5 Fuzzy comprehensive evaluation

According to the fuzzy evaluation matrix, the set of fuzzy comprehensive evaluation is:

$$B = A * R_{ij} = (a_1, \ a_2, ..., \ a_n)\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & r_{ij} & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} = (b_1, \ b_2, ..., \ b_n)$$

The occurrence probability of project risks is:

$P_f = B * V^T = (b_1, b_2, ..., b_n)(V_1, V_2, ..., V_n)^T$. Among which, b_i(i=1，2，…，n) means the membership degree of the first *i* factor relative to evaluation set when we carry out comprehensive evaluation on evaluation objects composed of risk factors.

3.6 Determining the risk size by equal risk curve method

The identified risks are divided into low, medium, and high class on the basis of equal risk curve method. Generally thinking, low risk means there is only slight effect on the project target and the occurrence probability is also small (less than 0.3). Medium risk means that the occurrence probability is large (from 0.3 to 0.7) and the risk affects the achievement of the project object. High risk means that the occurrence probability is larger (0.7 and above) and it has a very negative impact on the achievement of the project objective [7].

4 Case Studies

We select one drilling cooperation project of the Great Wall Drilling Company and carry out risk assessment by using the above described multi-level fuzzy comprehensive evaluation.

4.1 Weight calculation

Applying experts' survey of risk factors, six risk management experience experts on oil and gas drilling cooperation project evaluate the relative importance of various factors that influence drilling cooperation project, they are required to count and calculate relative weight of eight risk factors in drilling cooperation projects by using EXCEL table [8]:

$A = (0.084, 0.146, 0.095, 0.104, 0.233, 0.115, 0.106, 0.117)$

At the same time, calculating single weight A_{ki}(i=1,2,…8) of sub-factors in the next layer relative to the upper layer A_k (k=1,2,3,…,8)are separately:

$A_1 = (0.5, 0.5)$

$A_2 = (0.3916, 0.1441, 0.1441, 0.3202)$

$A_3 = (0.4820, 0.2103, 0.0974, 0.2103)$

$A_4 = (0.2, 0.4941, 0.1643, 0.1416)$

$A_5 = (0.1698, 0.097, 0.4297, 0.3035)$

$A_6 = (0.3119, 0.4905, 0.1976)$

$A_7 = (0.429, 0.429, 0.142)$

$A_8 = (0.453, 0.547)$

4.2 Establishing the evaluation set

Rating scale V is divided into five levels. V= (0.1, 0.3, 0.5, 0.7, 0.9) respectively indicate {low, lower, medium, high, higher} [9].According to the results of experts scoring, we calculate the rate of the comments corresponding to various risk items for each sub-factors. For example, among natural hazard (U_1), there are three persons who think the risk of geological factors(U_{11}) is low-risk (V_1).That is to say that the degree of membership of the risk item is 0.5.While,other risk factors are similarly determined, thus we compose of membership degree matrix can be seen as following:

$$R_1 = \begin{bmatrix} 0.5 & 0.2 & 0.2 & 0.1 & 0 \\ 0.6 & 0.2 & 0.2 & 0 & 0 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} 0.6 & 0.2 & 0.1 & 0.1 & 0 \\ 0.5 & 0.2 & 0.2 & 0.1 & 0 \\ 0.4 & 0.4 & 0.1 & 0.1 & 0 \\ 0.6 & 0.2 & 0.2 & 0 & 0 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 0.6 & 0.1 & 0.2 & 0.1 & 0 \\ 0.3 & 0.3 & 0.2 & 0.1 & 0.1 \\ 0.1 & 0.2 & 0.3 & 0.2 & 0.2 \\ 0.4 & 0.4 & 0.2 & 0 & 0 \end{bmatrix}$$

$$R_4 = \begin{bmatrix} 0.3 & 0.3 & 0.2 & 0.1 & 0.1 \\ 0.1 & 0.2 & 0.3 & 0.2 & 0.2 \\ 0.4 & 0.4 & 0.2 & 0 & 0 \\ 0.6 & 0.2 & 0.2 & 0 & 0 \end{bmatrix}$$

$$R_5 = \begin{bmatrix} 0.1 & 0.2 & 0.3 & 0.2 & 0.2 \\ 0.4 & 0.4 & 0.2 & 0 & 0 \\ 0.6 & 0.2 & 0.2 & 0 & 0 \\ 0.6 & 0.1 & 0.2 & 0.1 & 0 \end{bmatrix}$$

$$R_6 = \begin{bmatrix} 0.3 & 0.3 & 0.2 & 0.1 & 0.1 \\ 0.1 & 0.2 & 0.3 & 0.2 & 0.2 \\ 0.4 & 0.4 & 0.2 & 0 & 0 \end{bmatrix}$$

$$R_7 = \begin{bmatrix} 0.1 & 0.2 & 0.3 & 0.2 & 0.2 \\ 0.3 & 0.3 & 0.2 & 0.1 & 0.1 \\ 0.6 & 0.2 & 0.2 & 0 & 0 \end{bmatrix}$$

$$R_8 = \begin{bmatrix} 0.4 & 0.4 & 0.1 & 0.1 & 0 \\ 0.6 & 0.2 & 0.2 & 0 & 0 \end{bmatrix}$$

4.3 Calculating primary fuzzy comprehensive evaluation matrix

The weight matrix of each subset multiplying with the membership matrixes is primary evaluation matrix, that is $B_k = A_k * R_k$, obtaining E:

$$E = \begin{bmatrix} 0.55 & 0.2 & 0.2 & 0.05 & 0 \\ 0.55677 & 0.22882 & 0.14643 & 0.06798 & 0 \\ 0.44615 & 0.21489 & 0.20974 & 0.08871 & 0.04051 \\ 0.26009 & 0.25286 & 0.24941 & 0.11882 & 0.11882 \\ 0.4957 & 0.18905 & 0.21698 & 0.06431 & 0.03396 \\ 0.22166 & 0.27071 & 0.24905 & 0.12929 & 0.12929 \\ 0.2568 & 0.2429 & 0.2429 & 0.1287 & 0.1287 \\ 0.5094 & 0.2906 & 0.1547 & 0.0453 & 0 \end{bmatrix}$$

Fuzzy subset E is the result of the first level fuzzy comprehensive evaluation.

4.4 Calculating the second-level fuzzy comprehensive evaluation matrix

Corresponding weight vector of the main factors A={a_1, a_2, …, a_8},then R is carried out comprehensive fuzzy evaluation operation for the second time, finally subjection vector of target level indicators U relative to the reviews set is got.

$$B = A * E = (0.424732, 0.231848, 0.207087, 0.083705, 0.052629)$$

So the occurrence probability of risks in the drilling cooperation project is defined as $P_f = B * V^T$

$P_f = B * V^T$ =(0.424732, 0.231848, 0.207087, 0.083705, 0.052629)*(0.1, 0.3, 0.5, 0.7, and 0.9)

=0.321531

5 Conclusions

Using above model we can calculate the final result is 0.3 <P_f<0.7, which belongs to moderate risk range, so the drilling cooperation project can be carried out. At the same time, that individual factor still faces a greater risk should attract the enterprise's attention, and the science and technology sector still needs to control in time in order to avoid developing into the high-risk direction. The above model can assess and early warn project risks, thus for risks reflected in the model, we take targeted measures to improve and prevent them.

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