The Research of Coal Hazard Evaluation Based on Fuzzy Probability

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Abstract: The hazard assessment is the fundamental work of safety risk management work. Hazard investigation and defensive are important for preventing and controlling accidents. Coals as a complex system, its hazards have the randomness and fuzziness, which belongs to the category of fuzzy probability. Using the fuzzy synthetic evaluation method of classic study will produce a reasonable result. To introduce fuzzy probability theory into coal hazard assessment and analysis of the coal hazard will solve such problems with random uncertainties. This paper shows that the method is reasonable and reliable.

Keywords: coal hazard; evaluation; fuzzy probability

1 Introduction

In the traditional hazard assessment, random uncertain information often described by random variables, and the fuzzy reliability analysis and fuzzy membership function with information is paste, which described the common fuzzy variable is to describe fuzzy uncertain information. In the hazard assessment of uncertain information is random variables, or use the fuzzy variables to description, this is the nature of uncertain information to determine. If the uncertain information in a data base, it should be used to describe the uncertainty stochastic quantity of information, If the uncertain information is based on experience and judgment on the basis of fuzzy variables, are described. If two kind of uncertain information may also exists, and establish the fuzzy variables and random variables, the evaluation model is very necessary.

At present, the fuzzy comprehensive evaluation was widely used in coal mine. The basic ideas of the hazard assessment were that using subordinate function to form some attribute of some things. Then to multiple factors synthetically evaluate phenomenon or things. But this evaluation method was also obvious deficiency: index weight values of uncertainty described by the way, and ignored the weight value of fuzziness [1]. Therefore, the uncertainty of hazards in coal mine by fuzzy mathematics, and the complexity of fuzzy probability theory to deal with this problem, it was very reasonable and necessary. This paper introduced evaluation based on fuzzy probability theory into coal hazard evaluation and established the evaluation model for the probability of coal mine. In this way, this paper provided new ideas for hazards assessment system of coal mine.

2 Fuzzy Evaluation Model of Probability

Probability of fuzzy comprehensive evaluation model of fuzzy set theory is an object of a comprehensive evaluation method. The decision making process is introduced in the evaluation of fuzzy concepts, principles of fuzzy synthesized from the relationship between multiple factors of membership grade status evaluation things of a kind of comprehensive evaluation method. According to the relevant fuzzy probability theory [2, 3], establishing fuzzy comprehensive evaluation model of probability.

1) To fix the main influence factors $u_i (i=1,2,\cdots,n)$ and the rating evaluation $v_j (j=1,2,\cdots;m)$, then establish evaluation factors U and the rating factors V, namely to determine the two fields:

$$U=\{u_1,u_2,\cdots u_n\} \quad (1)$$

$$V=\{v_1,v_2,\cdots v_m\} \quad (2)$$

2) To hold the single factor evaluation on the influence factors $u_i (i=1,2,\cdots,n)$ of U Namely according to the fuzzy relation between u_i and the rating v_j, to ascertain or to choose their membership functions $v_j(U_i)$.In

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this way v_j is determined on the domain of fuzzy subsets:

$$v_j = \frac{v_j(u_1)}{u_1} + \frac{v_j(u_2)}{u_2} + \cdots + \frac{v_j(u_n)}{u_n} \qquad (3)$$

Thus it can determine the fuzzy matrix relations between factors concerning domain U and evaluation V:

$$R = (r_{ji})_{m\times n} \qquad (4)$$

The elements r_{ji} are membership $v_j(u_i)$.

3) To determine the fuzzy weights $\pi_i(1,2,\cdots,n)$ of evaluation factors u_i .Namely taking the weight as a fuzzy number:

$$\pi_i = \frac{\beta_{i,1}}{\lambda_{i,1}} + \cdots + \frac{\beta_{i,k}}{\lambda_{i,k}} + \frac{1}{\lambda_{i,0}} + \frac{\beta_{i,k+1}}{\lambda_{i,k+1}} + \cdots + \frac{\beta_{i,2k}}{\lambda_{i,2k}} \qquad (5)$$

In Formula (5), $\lambda_{i,0}$ is the relative weight, which can be ascertained by using he analytic hierarchy process (AHP). It should meet $\sum_{i=1}^{n} \lambda_{i,0} = 1$.

The coefficient $\beta_{i,l}(i=1,2,\cdots,n; l=1,2,\cdots,2k)$ can be choused according to the actual situation.0.6, 0.7, 0.8and 0.9 can be accepted according to the fuzzy theory. The value $\lambda_{i,l}(l=1,2,\cdots,2k)$ can be determined by value $\lambda_{i,0}$.

4) By using the fuzzy probability language, formula (3) is as follows:

$$P(v_j) = v_j(u_1)\pi_1 + v_j(u_2)\pi_2 + \cdots + v_j(u_n)\pi_n \qquad (6)$$

Among them, π_i is the evaluation factor of fuzzy weight and p_i is the corresponding value on the field $\{\lambda_{i,1},\cdots, \lambda_{i,k}, \lambda_{i,0}, \lambda_{i,k+1},\cdots,\lambda_{i,2k}\}$.For any rating, a_i is the membership in a rating. As far as anything, then a_i for $v_j(u_i)$ .Thus, the fuzzy probability $P(v_j)$ can be acquired.

5) By the principle of information centralization, comprehensive evaluation can be obtained. By concentrated principle, fuzzy probability $P(V_j)$ is:

$$P(v_j) = \frac{a_{i1}}{x_{j1}} + \frac{a_{i2}}{x_{j2}} + \cdots + \frac{a_{ip}}{x_{ip}} \qquad (7)$$

$$\sigma_j = \sum_{i=1}^{p} a_{jl} a_{jl} \qquad j = 1,2,\cdots,m \qquad (8)$$

Among them, a_{jl} belonging to x_{jl} $(l = 1,2,\cdots,p)$.

Formula (8) is normalized, namely:

$$\overline{\sigma}_j = \frac{\sigma_j}{\sum_{j=1}^{m} \sigma_j}, \overline{\sigma}_N = \max_j [\overline{\sigma}_j] \qquad (9)$$

Then the conclusion can be get that the rating is N.

3 Fuzzy Probability Evaluation Index System

The existence of coal hazard has abruptness and complexity. And it is controlled and influenced by the geological and geomorphic, meteorological and hydrological, forest vegetation and artificial factors. Because of this the coal hazard evaluation is a comprehensive effect of many factors. According to sources, it can be divided into different types, such as coal gas accident hazards, roof dangerous accidents hazards, transportation ascending accident hazard and fire accident hazards, etc. Due to the huge number, complex coal hazards, the work of entire range of coal judge is very heavy. Therefore this paper takes roof hazards in coal mine as specific example. The judge of entire coal can complete through the multiple evaluation levels.

The existence of hazards was the root cause of the accident. Mine accident was resulted by the first and the second category hazards. The first is the energy body accidents, which decide the severity of the accident consequences. The second category hazards were the necessary conditions for the first category. The third class hazard was hidden in the first and the second category hazards. The third class hazard beheaded the organization. Fig1can reveal hazards and the dialectical relations between accidents.

The first category hazards: The mine geological structure, such as faults fracture and bedding structure in roof, had cut the roof into discrete instability. After the instability, prop-pulling rock caused in break; the roof in goal felt bad and the hanging area was excessive.

The second category hazards: Prop-pulling operation sequence was not reasonable; the support of working surface was not well enough, the supporting density was lower, and the angle meeting mountain was unreasonable; when facing the geological structure which has not met, the staff of coal didn't take timely measures; When the roadway excavation, under the influence of Stress redistribution, the early support of roadway is too poor, which result in the direct roof sinks, loose even damage. Especially in advance supporting pressure, roof sank seriously and devices' mobile repeatedly supported roof. Because the reasons above, the roof broken more as a result. These constituted the coal roof accidents second category hazards.

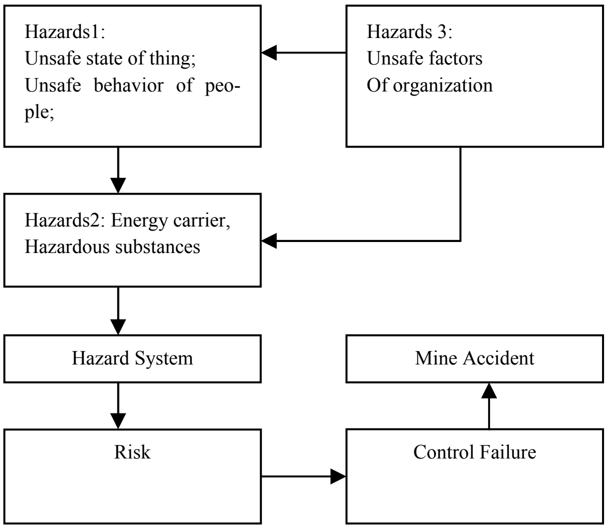

Fig1. Hazard Classification and Accident Diagram

Third class: Inadequate security; Operators lacked skill and operated inexperience; Coal mine workers lack of experience; Coal mine workers cultural level is not high; Lack of personnel training or coal job training effect was not well etc.

Therefore, this paper selects 12 indexes as coal roof accident risk evaluation index system, hazards such as shown in table1.

Table 1. Coal roof hazard evaluation on index system

Level Evaluation Index	Secondary Evaluation Index	
	Geologic Structure	u_1
Article 1	Roof Characteristic	u_2
U_1	Tunnel Characteristics	u_3
	Shock Bump	u_4
	Construction Quality	u_5
Article 2	Equipment Reliability	u_6
U_2	Blast Firing Shock	u_7
	Bare Roof	u_8
	Safety Financing	u_9
Article 3	Employee Training	u_{10}
U_3	Employee Skill	u_{11}
	Management Level	u_{12}

4 Fuzzy Probability Evaluation Example

1) Determine elements set

According to the theory of three sources of coal [4], in combination with the actual situation and characteristics of coal mine and using principal component analysis method to determine the roof accident factors such as table 2.

2) Determine evaluation set

While coal hazard danger level can be divided into four levels, Risk-free, mild risk, Medium Risk and Extreme Risk. Namely $V=\{v_1,v_2,\cdots v_m\}=$ {Risk-free, Mild Risk, Medium Risk, Extreme Risk}.

3) Determines the index weight

The evaluation indexes are multiple and have many factors. Therefore, in evaluation index system, the scientific and reasonable distribution of weight is very important. This paper used the AHP method to identify weight. Then it adopted 1 ~ 9 Scale methods, got judgment matrix through expert scoring, and used Rad method to calculate the weight of each index. At last through the consistency inspection, the CR is less than 0.1and the consistency is acceptable.

Table 2. Hazard assessment index roof

Level Evaluation Index	Secondary Evaluation Index	Fuzzy Weighted	Relative Weight
	u1	0.3	0.105
UI(0.35)	u2	0.25	0.088
	u3	0.3	0.105
	u4	0.15	0.053
	u5	0.3	0.131
U2(0.45)	u6	0.3	0.131
	u7	0.1	0.045
	u8	0.2	0.090
	u9	0.35	0.070
U3(0.2)	u10	0.2	0.040
	u11	0.2	0.040
	u12	0.25	0.050

4) Determine membership functions

After the fuzzy information processing, the calculation of the fuzzy probability is one of the key problems to fuzzy comprehensive analysis. Generally, fuzzy probability theory can be used to calculate the probability theory of fuzzy events. At this time, setting reasonable and proper fuzzy membership functions and using them to calculate the probability of fuzzy events are of vital importance.

In this paper, it selected 15 coal management experts to compose the assessment team. Each member of that team developed each level of evaluation factors comments referencing evaluation standard. The evaluation to the membership is calculated by:

$$r_{ij} = \frac{n}{15}$$

N is the number of the choice comments level.

5) Fuzzy comprehensive evaluation

To hold roof hazard assessments according to the data in 2009 for a coal mine. The influence factors u_i for the evaluation of the level v_j are fuzzy relations, namely the membership $v_j(u_i)$, as shown in table 3.

Table 3. Fuzzy relations between factors and grades

Evaluation Factors	Evaluation Grades Risk-free	Mild risk	Medium Risk	Extreme Risk
u_1	0.1	0.3	0.4	0.2
u_2	0.1	0.2	0.3	0.3
u_3	0.2	0.25	0.35	0.2
u_4	0.2	0.3	0.3	0.2
u_5	0.3	0.4	0.2	0.1
u_6	0.35	0.45	0.2	0.1
u_7	0.4	0.3	0.15	0.15
u_8	0.3	0.45	0.15	0.1
u_9	0.2	0.2	0.3	0.3
u_{10}	0.3	0.4	0.2	0.1
u_{11}	0.1	0.3	0.4	0.2
u_{12}	0.3	0.3	0.2	0.2

On the basis of relative weight determined, according to fuzzy probability theory, it suggests that the evaluation factors of fuzzy weights as:

$$\pi_i = \frac{\beta_{i,1}}{\lambda_{i,1}} + \frac{1}{\lambda_{i,0}} + \frac{\beta_{i,2}}{\lambda_{i,2}}$$

In consideration of the relative weight of fluctuating range, the coefficient $\lambda_{i,1} = \lambda_{i,0} - 0.04$ and $\lambda_{i,2} = \lambda_{i,0} + 0.04$. In addition, according to the fuzzy probability theory, take coefficient:

$$\beta_{i,l} = 0.8(i = 1,2,\cdots,12; l = 1,2,3,4)$$

So far, it can use formula (2), (6) to calculate fuzzy probability $P(v_j)$ of each rating $v_j(j=1,2,3,4)$. The information can be obtained according to the principle of the rating normalized information value, namely: (0.2311, 0.3199, 0.2728, 0.1791). So the roof of the risk evaluation of coal mine is light sources of danger, thus obtains evaluation results, and actual condition.

5 Theory

This paper utilizes the fuzzy probability method to establish the coal hazard evaluation model, and in some coal roof of hazard risk evaluation, objective and reasonable evaluation results. Fuzzy probability method of fuzzy comprehensive evaluation method in inherits the advantages of the thoughts and overcome the influence factors of uncertainty weight values, the rationality of the obvious. So as to effectively colliery accident prevention provides reliable scientific basis.

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