

Comprehensive Evaluation of Working Environment under Mining Based on Unascertained Analytic Hierarchical Model

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Abstract—Working environment under mining plays an important role in safety of coal mines. The paper analyzes the eight factors of working environment under mining: gas density, dust, temperature, humidity level, air velocity, and harmful air, noise, and working space, calculates the weight of factors and establishes the comprehensive evaluation model with analytic hierarchical model based on unascertained measure. This paper develops the module by the use of VC++6.0 and SQL Server2000 which can display the gas density curve and Evaluation curve with the help of ProEssentials. This method has been proved usable and reasonable by using the example. And there will be a promising future in its application.

Index Terms—Unascertained measure; AHM; working environment under mining; ProEssentials

In human-machine-environment system, environment is a significant factor which can deeply affect the safety of a system. Working environment underground directly affects the efficiency of human-machine system, mental and physical health and safety of operators as well. Those situation that large numbers of harmful air released in the course of coal production, rising of air temperature along with the increase of temperature of surrounding rock, high humidity level, large amounts of dust and noise source, and narrowness of working space, will easily cause fatigue for workers, which are key threats to safe production of coal mining.

Synchronously, gas density also plays an important role in the safety of working environment under mining. With the increase of gas density, oxygen density will decrease, which cause workers suffer oxygen-poor and suffocation. Explosion will take place when gas density is beyond the limitation and confronted with origin of heat which is high temperature, and all these will bring about injuries and deaths. Different coal mining face has different limitation of gas density according to coal mine safety rules^[1]. Take coal mining face for an example, computing formula of reliability of gas density is $Y=1-x/0.2$. The real-time value of x can be gotten from sensor monitoring system, then it can compute the value of index. In the actual project, in order to detect and assess the influence of working environment under mining on coal mine safety, this article achieves the comprehensive evaluation of working environment under mining which

also has been proved more reasonable and direct viewing by utilizing Unascertained and AHM theory and using ProEssentials.

I. INTRODUCTION TO PROESSENTIALS

ProEssentials is the product of GigaSoft. GigaSoft is a company develops charting components in USA and provides custom programmed charting solutions to the world's leading companies, including IBM, Microsoft and so on^[4].

GigaSoft ProEssentials is a set of charting components for Windows client-side and server-side development. It comes with NET, DLL, ActiveX, VCL, WinForms, and WebForms interfaces which provide convenience for developer to apply in a variety of development with Visual Studio. NET, VC6, VB6, ASP, ASP.NET, Delphi, Builder.

ProEssentials consists of five charting components: Graph, Scientific Graph, 3D Scientific Graph, Polar, Pie Chart and that realize the 2-dimension & 3-dimension graphics functions using Cartesian's coordinate system, Polaris/Smith/Rose Char and Pie Char under the polar coordinates system.

2-dimension graphics function can be realized under linearity and logarithmic coordinates system. Methods of drawing include point, line, bar, area and contour, and it can also create shadow and 3D effects, display a variety of bitmap types: JPEG, PNG and BMP, support print output, message and events mechanism which make it convenient for users to interact with the displayed data directly

There are three kinds of data displayed in graphics type: (1) $Y = \{y_1, y_2, \dots, y_n\}$; (2) $Y = f(x)$; (3) $Y = f(x, z)$ in normal application. (1) is array or set, (2) and (3) are continuous functions. ProEssentials use Graph, Scientific Graph and 3D Scientific Graph to express these three types of graphic images. The term of variable Y in above formula is subset. One graph can have six subgraph at the most. Every subgraph includes two ordinate axis (y axis and right y axis) and two cross shafts (x axis and top x axis). The scale of axis can be adjusted on the basis of inputted data automatically or be set up in the program in advance.

II. EVALUATION INDEX SYSTEM OF WORKING ENVIRONMENT UNDER COAL MINES

A. The Establishment of Indexes

Working environment under coal mines is a set of correlated influencing factors concerning comfortable quality, working efficiency and system reliability within the space of coal mining face.

Based on the definition and characteristics of working environment under coal mines, and on the principle of scientific nature, systematic nature, comparability and operability, we conclude multi-level comprehensive index of working environment under coal mines: gas density, dust, temperature, humidity level, air velocity, and harmful air, noise, and working space.

B. The Division of Evaluation Grade

In this article, working environment under coal mines is divided into four grades: very safe, safe, dangerous, very dangerous.

III. UNASCERTAINED ATTRIBUTE AHM

set x_1, x_2, \dots, x_n as n objects for evaluation, then $X = \{x_1, x_2, \dots, x_n\}$ as evaluation object space; Each object of study has m kinds of attribute I_1, I_2, \dots, I_m which can be measured; $I = \{I_1, I_2, \dots, I_m\}$ are attribute space. x_{ij} is evaluation value of x_i on I_j . Evaluation value x_{ij} could be calculated, so evaluation matrix $(x_{ij})_{n \times m}$ is known. Line i in this matrix expresses observed value of object i on m kinds of attribute, $i=1, 2, \dots, n$; Row j expresses observed value of various objects on attribute I_j , $j=1, 2, \dots, m$.

For every x_{ij} , we can calculate the μ_{ijk} which represent the grade of object x_i on c_k ($k=1, 2, \dots, K$); the process above is also calculating the grade Evaluation of x_{ij} on every c_k . set c_k represents the grade of project risk, the grade K is prior to the grade $K+1$. If $\{c_1, c_2, \dots, c_k\}$ accords with $c_1 > c_2 > \dots > c_k$, $\{c_1, c_2, \dots, c_k\}$ is called a ordered division genus of evaluation space U .

A. Single Index Recognition

For every single factor index (attribute) I_j ($j=1, 2, \dots, m$), x_{ij} is given (i is solid). Calculating the measure of x_i that has observed value x_{ij} on c_k ($k=1, 2, \dots, K$) grades is equal to calculating the grade measure of observed value x_{ij} on c_k .

Conforming the measure function $\mu_{ij}(x)$ and calculating the μ_{ijk} for every quality grade k ($k=1, 2, \dots, K$), we can get the Unascertained Measure recognition matrix under the single index:

$$\mu_i = \begin{pmatrix} \mu_{i11} & \mu_{i12} & \dots & \mu_{i1k} \\ \mu_{i21} & \mu_{i22} & \dots & \mu_{i2k} \\ \vdots & \vdots & \ddots & \vdots \\ \mu_{im1} & \mu_{im2} & \dots & \mu_{imk} \end{pmatrix} = (\mu_{ijk})_{m \times n} \quad (1)$$

Thereinto, the line t expresses the measure of object x_i belongs to each quality grade about the t th kind of observed value; The rows expressed measure that x_i

belongs to the s th quality grade about various attribute observed value.

B. The Essentiality Weight of Every Index Determined by Applying AHM

(1) Introduction of AHM

AHM is a non-structure decision method, and it is improved from AHP. Compared with AHP, AHM is much easier to do. AHM does not need to calculate eigenvector, and it does not need to check the consistency. It only needs to make multiplication and addition operation.

(2) Steps of calculating weight based on AHM

1) There are many influence factors of working environment under coal mines, so it needs many experts to participate in the evaluation. The basic idea is: firstly evaluate the index's importance on each level separately by the experts; finally the experts calculate the arithmetic average of the index in corresponding level to get the synthetic evaluation result. In identical level, the various indexes get corresponding importance by comparing.

Suppose that there are n factors b_1, b_2, \dots, b_n , if the importance of b_i are the same as the importance of b_j , then $b_{ij}=1$; if b_i is slightly important than b_j , then $b_{ij}=3$; if b_i is obviously important than b_j , then $b_{ij}=5$; if b_i is more important than b_j , then $b_{ij}=7$; if b_i is absolutely important than b_j , then $b_{ij}=9$. Between them there are $b_{ij}=2, 4, 6$ or 8 . It is obvious that $b_{ij}=1/b_{ji}$.

2) Transforms 1-9 scale judgment matrix into AHM, and the transformation procedure is as follows:

$$\mu_{ij} = \begin{cases} \frac{2k}{2k+1} & a_{ij} = k \\ \frac{1}{2k+1} & a_{ij} = \frac{1}{k} \\ 0.5 & a_{ij} = 1 \quad i \neq j \\ 0 & a_{ij} = 1 \quad i = j \end{cases} \quad (2)$$

It is Obvious that $\mu_{ij}=0$, $\mu_{ij} \geq 0$, $\mu_{ji} \geq 0$, $\mu_{ij} + \mu_{ji} = 1$ ($i \neq j$), μ_{ij} is called the measure under AHM. When $\mu_{ij} \geq \mu_{ji}$, it means that the plan P_i is better than the plan P_j .

3) Make that

$$f_i = \mu_{i1} + \mu_{i2} + \dots + \mu_{in} = \sum_{j=1}^n \mu_{ij} \quad (i=1, 2, \dots, n) \quad (3)$$

$$c_i = \frac{2f_i}{n(n-1)} \quad (4)$$

c_i expresses the score rate of μ_i , then $c = (c_1, c_2, \dots, c_n)$ and $\sum_{i=1}^n c_i = 1$. According to the above, the place of each plan can be calculated, named essentiality order.

C. Identified Rule

A confidence threshold is pre-determined called λ ($\lambda > 0.5$). According to the background and needs of the problem, λ is normally be admitted between 0.6 and 0.8, if $F_i > F_{i+1}$, $\{F_1, F_2, \dots, F_k\}$ is ordered division, then

$$k_0 = \min_k \left(k : \sum_{l=1}^k \mu_{il} \geq \lambda, 1 \leq k \leq K \right) \quad (5)$$

Sample x_i belongs to k_0 genus F_{k_0} , and the confidence is λ .

The implication is that: the confidence that grade of x_i is not higher than F_{k_0} is λ or the confidence of that grade of sample x_i is higher than k_0+1 is $1-\lambda$.

IV. EXAMPLE ANALYSIS

Table 1 is evaluation indexes of working environment under coal mines according to the site data of coal mine in Shanxi province. There are eight evaluation indexes in table 1.

TABLE I. EVALUATION INDEXES OF WORKING ENVIRONMENT UNDER MINING

working environment under coal mines I							
gas density	dust	temperature	humidity level	air velocity	harmful air	noise	working space

A. Determination of Evaluation Index System of working environment under coal mines

The evaluating index system of working environment under coal mines is shown in Table 1.

B. Determination of Various Factors' Weight based on AHM

Synthesizing opinions of the fellow experts and technician, obtains the importance comparison matrix during various factors concerning working environment under coal mines is obtained:

$$R = \begin{bmatrix} 1 & 8 & 7 & 6 & 9 & 6 & 9 & 9 \\ 1/8 & 1 & 1/3 & 1/2 & 2 & 1/4 & 3 & 3 \\ 1/7 & 3 & 1 & 2 & 4 & 1/2 & 4 & 4 \\ 1/6 & 2 & 1/2 & 1 & 2 & 1/3 & 3 & 3 \\ 1/9 & 1/2 & 1/4 & 1/2 & 1 & 1/5 & 2 & 2 \\ 1/6 & 4 & 2 & 3 & 5 & 1 & 5 & 5 \\ 1/9 & 1/3 & 1/4 & 1/3 & 1/2 & 1/5 & 1 & 1 \\ 1/9 & 1/3 & 1/4 & 1/3 & 1/2 & 1/5 & 1 & 1 \end{bmatrix}$$

Transform it to the judgment matrix under AHM by using (2),

$$R' = \begin{bmatrix} 0 & 0.941 & 0.933 & 0.923 & 0.947 & 0.923 & 0.943 & 0.943 \\ 0.0588 & 0 & 0.143 & 0.200 & 0.800 & 0.111 & 0.143 & 0.143 \\ 0.0667 & 0.857 & 0 & 0.800 & 0.889 & 0.200 & 0.889 & 0.889 \\ 0.0769 & 0.800 & 0.200 & 0 & 0.800 & 0.143 & 0.857 & 0.857 \\ 0.0526 & 0.200 & 0.111 & 0.200 & 0 & 0.0909 & 0.800 & 0.800 \\ 0.0769 & 0.889 & 0.800 & 0.857 & 0.938 & 0 & 0.938 & 0.938 \\ 0.0526 & 0.143 & 0.111 & 0.143 & 0.200 & 0.0625 & 0 & 0.500 \\ 0.0526 & 0.143 & 0.111 & 0.143 & 0.200 & 0.0625 & 0.500 & 0 \end{bmatrix}$$

By Using (3) and (4), we can get:

$$W'=(4.64,1.61,6.21,9.07,2.26,5.45,0.72,0.72)$$

The unitary weight is:

$$W=(0.23,0.06,0.17,0.14,0.11,0.19,0.05,0.05)$$

C. Inviting Many Experts to carry on the Risk Evaluation, the Various Indexes Evaluation Matrix are Obtained, they are as follow:

$$I = \begin{bmatrix} 0.4 & 0.3 & 0.2 & 0.1 \\ 0.5 & 0.3 & 0.1 & 0.1 \\ 0.4 & 0.2 & 0.2 & 0.2 \\ 0.5 & 0.2 & 0.1 & 0.2 \\ 0.6 & 0.2 & 0.1 & 0.1 \\ 0.4 & 0.2 & 0.2 & 0.2 \\ 0.3 & 0.3 & 0.2 & 0.2 \\ 0.5 & 0.2 & 0.2 & 0.1 \end{bmatrix}$$

So,

$$W_{\text{comprehensive}}=(0.442,0.234,0.169,0.155)$$

D. Recognition, taxis and actual measurement and analysis with ProEssentials

In this article the grade of working environment under coal mines is divided into four grades: "very safe, safe, dangerous, very dangerous", which is ordered division, therefore we use the confidence criterion, and make the confidence $\lambda=0.6$, and the identified matrix of single index recognition measure can result in the evaluation result: the working environment under coal mine is safe.

Actually, ProEssentials provide five interfaces for developer to use. The paper choose VC++6.0 [6] [7] and SQL Server 2000[8] as tools, with database technology to develop application software.

Figure 1 is Evaluation curve by use of ProEssentials. Lateral axis is using Scientific Graph to display time axis, longitudinal axis is realized with Scientific Graph. Left-longitudinal axis expresses gas density; right-longitudinal axis indicates comprehensive evaluation index number of working environment under mining. The scale of axis is set up in the program.

As figure 1 shown, active line states gas density, short dash line expresses index number of risk evaluation. Gas density is the most significant factor result that the program display gas density specially. It can be seen in figure 1 that comprehensive evaluation index number of working environment under mining is 87.5 which indicate that working environment under coal mines at present is in safe state.

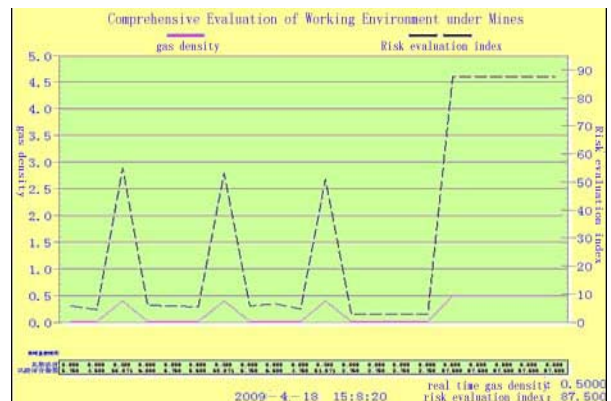


Figure 1. Evaluation curve.

V. CONCLUSION

Integrating unascertained and AHM theory, this article calculates the weight of factors with analytic hierarchical model based on unascertained measure and then applies the unascertained theory to working environment under coal mines, achieves the comprehensive evaluation finally that is creative to some extent. The unascertained measure method pays attention to "the ordered nature" of the evaluation space, and makes the reasonable confidence identify and taxis grade criterion, which make the evaluation result more clarity and more reasonable. In this article, the structure decision theory and the non-structure decision theory have been effectively unified. Synchronously, it realizes the combination of a qualitative analysis and quantitative analysis. Finally, this method has been proved applicable and reasonable with the example. This paper develops the module by VC++6.0 and SQL Server2000 which can display the gas density curve and Evaluation curve with ProEssentials. It will be widely used in the future.

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