YONGZHI CHANG
and
SUOCHENG DONG

Study on safety evaluation of mining resource environment on the basis of the unascertained measure and the analytic hierarchy process

For safety evaluation of resources environment in the mining area, four aspects related to mining environment are discussed: landscape and relics destruction, mining resources destruction, water resources destruction and land resources destruction. Moreover, the safety index system of resources environment in the mining area is built and the evaluation is carried out based on unascertained measure model and analytic hierarchy process (AHP). First the judgment matrix is established using unascertained measure, and the weights are assigned to the indices by AHP. The safety level of resources and ecological environment in the mining area is evaluated by confidence recognition method. Finally a case study is carried out over a coal mine in Shaanxi Province, and the results show that the integration of unascertained measure and AHP is feasible for safety evaluation of resources and ecological environment in the mining area.

Keywords: *Resources environment in the mining area, unascertained measure, analytic hierarchy process, classification weight, confidence recognition.*

1. Introduction

With the increasing serious of resources and environment destruction, resources and environment security has become a hot field at home and abroad. In the process of development and utilization of mineral resources in our country, there are a series of increasingly serious problems, such as serious resource waste, destruction of ecological environment, frequent safety accidents, and geological relics and historical relics severely damaged, and so on [1-3]. These problems seriously threaten the safety of mining resources and environment in our country, the social, economic, resources, environment coordinated development in mining area are restricted. Therefore, the research on the basis of mining area resources and environment security, how to mining area resources to be comprehensive, coordinate the development and utilization, reduce the waste of mining area resources and increase the use efficiency of mining area resources, reduce the destruction of the mining area ecological environment, restore the mining area ecological environment landscape, it is very urgent that implement the strategy of sustainable development in mining area. So it is necessary to build evaluation system of mining area resources and environment security, safety evaluation of mining area resources and environment for dynamic real-time control mining area resources and environment state, and forecasting, simulation the future environment, so as to make control decision [4-5].

For safety evaluation of resources environment in the mining area, many studies have been carried out by domestic and foreign scholars. Xu [6] and Wei et al. [7] divided geological problems of the mining environment into three categories (geological disasters, environmental pollution and resources destruction) and several indices. They applied fuzzy synthetic evaluation model to the understanding of synthetic risks of the mining area. Zhang et al. [8] adopted fuzzy mathematical for evaluation of synthetic risks in Lala open pit mine. Hao et al. [9] built the destruction degree evaluation model of geological disasters in mines based on information entropy and unascertained measure. Weights of indices were determined by information entropy, which removed the disturbance from subjective factors. The destruction degree of the geological disasters was evaluated using confidence recognition criteria. Yang et al. [10] established the methods of mathematical evaluation and prediction of common geological disasters of Huangling-Binchang mining area in Shaanxi Province Li et al. [11] established the hierarchical neural network for sustainability evaluation of the mining area. Sun [12] applied system dynamics techniques to set system dynamics simulation model of the mining environment. Zhang et al. [13] constructed membership function, used the method of fuzzy mathematics to evaluate the soil heavy metal pollution of Xiaoqinling gold field. Xu et al. [14] adopted weighted method to evaluate comprehensive pollution degree of the river water quality in mine area. Guo et al. [15] evaluated soil heavy metal pollution of baotou tailings area and baiyun obo mining area by Nemerow integrated pollution index. Ejjihamada et al. [16] applied the computer technology and computational psychology methods on environmental

Messrs. Yongzhi Chang and Suocheng Dong, Institute of Geographic Sciences and Natural Resources Research, The Chinese Academy of Sciences, Beijing 100 101, China. Email: fyklbk@126.com; dongsc@igsnrr.ac.cn

evaluation of mining area. The existing studies on resources and ecological environment in the mining area mainly have the following defects: evaluation depth of resources and environment security in the mining area mining is inadequate, and evaluation method is lack of innovation. The existing evaluation models and methods only apply to specific conditions and cases and lack generality or they only address some of the problems present in ecosystem without an all-around evaluation of resources and ecological environment on the mining area.

This study will be based on destruction of landscape and relics, mining resources, water resources and land resources as first indices, set safety evaluation system of mining resource environment. Unascertained measure model, a new type of non-structured decision-making model, will be used for the safety evaluation. Combining with the specific mining area analysis to achieve the evaluation results of environment safety evaluation system of mining resource environment. It will provide measures and reference for mining resources environment security.

2. Establishing evaluation index system of resources environment in the mining area

The extensive economic development mode in our country has brought a series of resources environment problems for mining area. It is particularly serious that mineral resources development caused the destruction of landscape and relics, mining resources, water resources, land resources and mineral resources itself destruction problem in safety evaluation of mining resource environment. Therefore, this paper will base on these aspects and combine reference to literatures [7,8], establish the evaluation index system of mine resource environment security status (Table 1).

The establishment of index system follow the principle of the following aspects [17]:

(1) Scientific principle: the design of evaluation system in the whole process must have a rigorous scientific basis. The connotation of the people-oriented and sustainable development could be scientific and accurately reflect the specific indices.

(2) Systemic principle: the mining area environment is a complex system, it is composed of multi-level, the system is affected and restricted by inside and outside many factors at the same time, the basic idea of system analysis is overall optimization, so the combination of local evaluation and overall evaluation must be considered.

(3) Focus principle: the design of evaluation index system is one of the most important principles that is importance influence. The factors of mining resource environment security are widely and cumulative, so it is impossible to be quantitative each index. So the establishment of index system should select important factors which relate to the project, it can be focused.

3. The unascertained measure

The uncertain information was called fuzzy or random information for a long time, and the nature of fuzzy and random information was considered to be the same. Actually, in terms of their nature, there is tremendous difference between them. Random information refers to the information that the number of the types are confirmed but their types remain unconfirmed. Fuzzy information refers to the information that the number of the types is unconfirmed, and unknown condition and situation may occur.

In 1990, Wang proposed the third concept of the unascertained information that distincts from random and

TABLE 1: THE EVALUATION INDEX SYSTEM OF MINE RESOURCE ENVIRONMENT SECURITY STATUS

Overall index	First index	Secondary index
Safety evaluation of resources environment in the mining area X	Destruction of landscape and relics resources X_1	Destruction of landscape structure X_{11}
		Destruction of cover vegetation X_{12}
		Destruction of stratum structure X_{13}
		Destruction of relics resources X_{14}
	Destruction of mining resources X_2	Recovery plan X_{21}
		Ore mining process X_{22}
		Comprehensive recovery rate X_{23}
		Comprehensive utilization rate X_{24}
	Destruction of water resources X_3	Surface water leakage in the mining area X_{31}
		Shallow groundwater drainage X_{32}
		Deep groundwater drainage X_{33}
		Annual precipitation of the mining area X_{34}
	Destruction of land resources X_4	Land excavation and occupation X_{41}
		Land subsidence X_{42}
		Disuse of excavated land X_{43}
		Deterioration and salinization X_{44}

fuzzy information in the study of architectural engineering theory. The concepts of unascertained information and the previous gray information are the same, and both of them are used to describe the "incomplete information". However, the unascertained and the gray differ from each other, since gray information expresses more certain information than the uncertain information. Based on Wang's idea of unascertained information coupled with the work from Professor Wu, Liu [18,19] and other scholars, the unascertained information now has already become a systematic theory and method.

Set F for the property space of a certain universe U, $\{F_1$ F_2 ... ... $F_n\}$ is some of the division of F, and there are a lot of factors x to affect universe U that called attributes or indices. Suppose there are m attributes $\{I_1$ I_2 ... ... $I_m\}$ affect factors x, then $I = \{I_1$ I_2 ... ... $I_m\}$ can be called attribute space on universe U. If x_i that any given $\in U$, set observed value I_j of factors x about some kind of attribute j as x_{ij} that can be specific measured. But when information is incomplete or under the conditions of unknown, it is difficult or even impossible to show the properties F of factor x_i with observed value x_{ij}. In fact, the embodiment of varying degrees in the nature reflects the difference in quantization of some attributes, and then the degree of quantization can be present in the form of data that can be estimated or indirect measured. But the measurement standards and conditions, including normalization, additivity and non-negativity, must to be met. Only this, can we get a measurement to describe the degree of the nature, which is called "unascertained measure".

4. The establishment of unascertainer measure model

Set $x_1, x_2,...,x_n$ as evaluation objects of news sensitivity, set universe U = $\{x_1, x_2,...,x_n\}$. The evaluation has m first indices I_1 I_2 ... ... I_m, and $\bar{I} = \{I_1, I_2, ..., I_m\}$. For $I_i \in \bar{I}$ has k secondary evaluation indices $I_{i1}, I_{i2}, ..., I_{ik}$, and $\bar{I}_i = \{I_{i1}, I_{i2}, ..., I_{ik}\}$. Therefore, x_{ij} can be expressed as k dimensional vector, $x_{ij} = \{x_{ij1}, x_{ij2}, ..., x_{ijk}\}$, x_{ijr} means the value of the secondary indices of I_j, which is x_i's first index. Each xi_{jr} has p evaluate grades c_1, c_2, ..., c_p, the evaluation space is C = $\{c_1, c_2, ..., c_p\}$.

4.1 The second grade index measure

4.1.1 The single-index measure

Set express the degree that x_{ijr} belongs to c_q, which is the qth evaluation class (rating). μ must meet the conditions as follows:

... (1)

$$\mu(x_{ijr} \in C) = 1, i = 1,2,...,n;\ j = 1,2,...,m; r = 1,2,...,k \quad (2)$$

... (3)

Define formula (2) as the "normalization", formula (3) as the "additivity". μ that meets the three formulas above is unascertained measurement. The matrix

$$(\mu_{ijrq})_{k\times p} = \begin{bmatrix} \mu_{ij11} & \mu_{ij12} & \cdots & \mu_{ij1p} \\ \mu_{ij21} & \mu_{ij22} & \cdots & \mu_{ij2p} \\ \cdots & \cdots & \ddots & \cdots \\ \mu_{ijk1} & \mu_{ijk2} & \cdots & \mu_{ijkp} \end{bmatrix}$$

i = 1,2,...,n; j = 1,2,...,m followed is single index measure matrix [20].

4.1.2 The distinction weight of second grade index

Using the concept of information entropy to define the peak of index I_{ijr}.

$$V_{ijr} = 1 + \frac{1}{\ln p}\sum_{q=1}^{p}\mu_{ijrq}\ln\mu_{ijrq} \quad ... \quad (4)$$

p in the formula (4) represents the number of the evaluate ratings, m_{ijrq} is the measure of single index, and the value of V_{ijr} expresses the degree that I_{ijr} different to each evaluation class. The distinction weight is as follows:

[illegible] (5)

$\sum_{r=1}^{k}\omega_{ijr} = 1, 0 \le \omega_{ijr} \le 1$, ω_{ijr} is the classification weights of I_{jr}. is the classification weight vector of second grade index [21].

4.2 The first grade index measure

4.2.1 The calculation of first grade index's measure evaluation vector

Set $\mu_{iq} = \mu(x_i \in c_q)$ express the degree that sample x_i belongs to c_r, which is the rth evaluation class (rating).

... (6)

Due to $0 \le \mu_{iq} \le 1$, and

, μ_{iq} is the unascertained measure. Define as measure evaluation vector of x_i's composite indicator. The matrix

$$\left(\mu_{iq}\right)_{n\times p}=\begin{bmatrix}\mu_{11} & \mu_{12} & \cdots & \mu_{1p}\\ \mu_{21} & \mu_{22} & \cdots & \mu_{2p}\\ \cdots & \cdots & \ddots & \cdots\\ \mu_{n1} & \mu_{n1} & \cdots & \mu_{np}\end{bmatrix}$$ is measure matrix of comprehensive index [22].

4.2.2 The weights of the first grade index significance

The primary index's judgment matrix built by the estimate rule of division 1-9 is as follow.

TABLE 2: 1-9 SCALE JUDGMENT CRITERIA

Scale	Meaning
1	Two factors have the same importance
3	One factor is more important than another factor slightly
5	One factor is more important than another factor obviously
7	One factor is more important than another factor strongly
9	A factor than another factor is extremely important
2,4,6,8	The middle of the two adjacent judgment value

Based on this primary index's judgment matrix, the weights of every first grade index can be calculated by the geometric calculation method of mean:

$$\overline{\omega}_i=\sqrt[n]{\prod_{j=1}^{n}a_{ij}}\ \left(i=1,2,...,n\right) \quad ... \quad (7)$$

Then making the normalized processing. Formula is shown below:

$$\omega_i=\frac{\overline{\omega}_i}{\sum_{i=1}^{n}\overline{\omega}_i} \quad ... \quad (8)$$

Get the weight vector of primary index,

$$\omega=\left(\omega_1,\omega_2,...,\omega_n\right)^T$$

The biggest characteristic roots λ_{max} can be calculated by the formula that followed:

$$\lambda_{max}=\frac{1}{n}\sum_{i=1}^{n}\frac{\left(AW\right)_i}{W_i} \quad ... \quad (9)$$

But due to the extremely complexity of objective things, the influence factors of subjective understanding can't match the requirement of consistency condition entirely sometimes. so consistency checking of matrix is necessary, and the process is as follow.

The consistency ratio requirements: $C.R=\frac{C.I}{R.I}<0.1$,

$$C.I=\frac{\lambda_{max}-n}{n-1},\lambda_{max}=\frac{1}{n}\sum_{i=1}^{n}\frac{\left(AW\right)_i}{W_i}.$$

4.3 IDENTIFICATION

Due to the evaluation space C is an ordered partition class, the recognition criterion of maximum membership degree is inapplicable. Therefore, credible degree criteria is introduced. Set

$$k_0=\min_k\left\{k:\sum_{l=1}^{k}\mu_{il}\geq\lambda,k=1,2,...,p\right\} \quad ... \quad (10)$$

Usually, or 0.7, so the evaluation objects can be classified into.

5 CASE STUDY

The coal mine under study is located in Shaanxi Province and the landform mainly consists of loess tableland, loess ridges and river valley terrace. The objects of ecological protection within the coal mine include surface vegetation, farm land, villages, surface water and groundwater resources. On the whole, the mining area is dominated by agricultural ecosystem and grasses and trees with a scarcity of water resources and great variation of precipitation. The agricultural vegetation and natural grassland are predominant in the mining area, and there is a lack of biodiversity. The soils are barren and the land suffers from severe water loss and soil erosion. The climatic disasters such as drought and storms further weaken the anti-shock capacity of the ecosystem. Surface vegetation of permanently and temporarily occupied regions of the mines is damaged to varying extent with aggravated water loss and soil erosion. The mining area has 17 sites of cultural relics, among which 1 site is under state-level key cultural relics protection, 2 under provincial-level protection, 3 under city-level protection and 13 under county-level protection.

The statistics used in this paper come from 2015 Statistical Yearbook of Fugu County, Shaanxi Province, and statistical data of the Shaanxi Provincial Yulin national land resource bureau in 2015. Safety evaluation of the resources environment of the coal mine is carried out based on the unascertained measure model, and all secondary index are quantified. An expert group consisting of 10 people is built and each secondary index is scored from 0 to 100 point based on the experts' experience. The mean scores for each index are shown in Table. 4.

The grade division in risk index evaluation of mine resources destruction is refer to literature [23], the safety evaluation of mines resources environment of is divided into by the cascade theory: C = {c_1, c_2, c_3, c_4, c_5}, 5 safety levels

TABLE 3: THE MEAN RANDOM CONSISTENCY INDEX

Order	2	3	4	5	6	7	8	9	10	11	12	13	14
R.I.	0	0.52	0.86	1.10	1.26	1.34	1.40	1.43	1.49	1.51	1.54	1.56	1.58

TABLE 4: THE EXPERT SCORING AND EVALUATION INDEX OF MINE RESOURCE ENVIRONMENT SAFETY STATUS

Overall index	First index	Secondary index	Score value
Safety evaluation of resources environment in the mining area X	Destruction of landscape and relics resources X_1	Destruction of landscape structure X_1	89
		Destruction of cover vegetation X_{12}	92
		Destruction of stratum structure X_{13}	92
		Destruction of relics resources X_{14}	89
	Destruction of mining resources X_2	Recovery plan X_{21}	92
		Ore mining process X_{22}	91
		Comprehensive recovery rate X_{23}	93
		Comprehensive utilization rate X_{24}	89
	Destruction of water resources X_3	Surface water leakage in the mining area X_{31}	88
		Shallow groundwater drainage X_{32}	93
		Deep groundwater drainage X_{33}	92
		Annual precipitation of the mining area X_{34}	76
	Destruction of land resources X_4	Land excavation and occupation X_{41}	84
		Land subsidence X_{42}	88
		Disuse of excavated land X_{43}	87
		Deterioration and salinization X_{44}	79

TABLE 5: THE LEVELS OF SAFETY EVALUATION OF MINING RESOURCE ENVIRONMENT

Level	Very unsafety	Unsafety	General safety	Comparative safety	Very safety
Score	60~70	70~80	80~90	90~95	?95

are set: they correspond to very unsafey, unsafey, general safety, comparative safety and very safey, respectively. The scores are shown in Table 5.

Membership function is built as follows according to the level of sustainable development:

$$\mu(x \in c_1) = \begin{cases} 1 & x \le 60 \\ \dfrac{70-x}{70-60} & 60 < x \le 70 \\ 0 & x > 70 \end{cases}$$

$$\mu(x \in c_2) = \begin{cases} \dfrac{80-x}{80-70} & 70 < x \le 80 \\ \dfrac{x-60}{70-60} & 60 < x \le 70 \\ 0 & others \end{cases}$$

$$\mu(x \in c_3) = \begin{cases} \dfrac{90-x}{90-80} & 80 < x \le 90 \\ \dfrac{x-70}{80-70} & 70 < x \le 80 \\ 0 & others \end{cases}$$

$$\mu(x \in c_4) = \begin{cases} \dfrac{95-x}{95-90} & 90 < x \le 95 \\ \dfrac{x-80}{90-80} & 80 < x \le 90 \\ 0 & others \end{cases}$$

$$\mu(x \in c_5) = \begin{cases} 1 & x > 95 \\ \dfrac{x-90}{95-90} & 90 < x \le 95 \\ 0 & x \le 90 \end{cases}$$

The measurement vector of each secondary index is calculated using the membership function according to Table 4. The calculation of measurement vector for the first index of destruction of landscape and relics resources (X_1) is illustrated below:

$$\mu_{111}(x \in c_1) = \mu_{112}(x \in c_2) = \mu_{115}(x \in c_5) = 0$$

$$\mu_{113}(x \in c_3) = \frac{90-89}{90-80} = 0.1$$

$$\mu_{114}(x \in c_4) = \frac{89-80}{90-80} = 0.9$$

The measurement vector for the secondary index of destruction of landscape structure (X_{11}) is calculated as (0, 0, 0.3, 0.7, 0); the measurement vector for destruction of cover vegetation (X_{12}), (0, 0, 0.7 ,0.3, 0); the measurement vector for destruction of stratum structure (X_{13}), (0,0,0,0.6,0.4); the measurement vector for destruction of relics resources (X_{14}), (0, 0.7, 0.3, 0, 0).

Thus the measurement matrix for the first index of destruction of landscape and relics resources (X_1) is established as follows:

$$I_1 : \bar{\mu}_1 = \begin{pmatrix} 0 & 0 & 0.1 & 0.9 & 0 \\ 0 & 0 & 0 & 0.6 & 0.4 \\ 0 & 0 & 0 & 0.6 & 0.4 \\ 0 & 0 & 0.1 & 0.9 & 0 \end{pmatrix}$$

Similarly, the measurement matrices for the primary indicators of destruction of mining resources (X_2), destruction of water resources (X_3) and destruction of land resources (X_4) are built as follows:

$$I_2 : \overline{\mu}_2 = \begin{pmatrix} 0 & 0 & 0 & 0.6 & 0.4 \\ 0 & 0 & 0 & 0.8 & 0.2 \\ 0 & 0 & 0 & 0.4 & 0.6 \\ 0 & 0 & 0.1 & 0.9 & 0 \end{pmatrix}$$

$$I_3 : \overline{\mu}_3 = \begin{pmatrix} 0 & 0 & 0.2 & 0.8 & 0 \\ 0 & 0 & 0 & 0.4 & 0.6 \\ 0 & 0 & 0 & 0.6 & 0.4 \\ 0 & 0.6 & 0.4 & 0 & 0 \end{pmatrix}$$

$$I_4 : \overline{\mu}_4 = \begin{pmatrix} 0 & 0 & 0.6 & 0.4 & 0 \\ 0 & 0 & 0.2 & 0.8 & 0 \\ 0 & 0 & 0.3 & 0.7 & 0 \\ 0 & 0.1 & 0.9 & 0 & 0 \end{pmatrix}$$

5.1 The weight calculation of second grade index

The measurement matrix for first index of destruction of landscape and relics resources (X_1) is built as follows:

$$I_1 : \overline{\mu}_1 = \begin{pmatrix} 0 & 0 & 0.1 & 0.9 & 0 \\ 0 & 0 & 0 & 0.6 & 0.4 \\ 0 & 0 & 0 & 0.6 & 0.4 \\ 0 & 0 & 0.1 & 0.9 & 0 \end{pmatrix}$$

By formula (4) can be obtained, $V_{11} = 0.7655$, $V_{12} = 0.5145$, $V_{13} = 0.5145$, $V_{14} = 0.7655$

From formula (5) the classification weight of evaluating index (X_1) is obtained:

$$\overline{\omega}_1 = \begin{pmatrix} 0.2990 & 0.2010 & 0.2010 & 0.2990 \end{pmatrix}$$

The same way can be concluded as follows:

$$\overline{\omega}_2 = \begin{pmatrix} 0.2196 & 0.2729 & 0.2196 & 0.2881 \end{pmatrix}$$

$$\overline{\omega}_3 = \begin{pmatrix} 0.2928 & 0.2357 & 0.2357 & 0.2357 \end{pmatrix}$$

$$\overline{\omega}_4 = \begin{pmatrix} 0.2076 & 0.2578 & 0.2257 & 0.3089 \end{pmatrix}$$

5.2 The measure calculation of first grade index

By formula (6) the measurement vector for the first grade index of destruction of landscape and relics resources (X_1) is:

$$\mu_1 = \overline{\omega}_1 \times \overline{\mu}_1 = \begin{bmatrix} 0.2990 \\ 0.2010 \\ 0.2010 \\ 0.2990 \end{bmatrix}^T \times \begin{bmatrix} 0 & 0 & 0.1 & 0.9 & 0 \\ 0 & 0 & 0 & 0.6 & 0.4 \\ 0 & 0 & 0 & 0.6 & 0.4 \\ 0 & 0 & 0.1 & 0.9 & 0 \end{bmatrix}$$

$$= \begin{pmatrix} 0 & 0 & 0.0598 & 0.7794 & 0.1608 \end{pmatrix}$$

The measurement vector for the first index of destruction of mineral resources (X_2) is:

$$\mu_2 = \overline{\omega}_2 \times \overline{\mu}_2 = \begin{bmatrix} 0.2196 \\ 0.2729 \\ 0.2196 \\ 0.2188 \end{bmatrix}^T \times \begin{bmatrix} 0 & 0 & 0 & 0.6 & 0.4 \\ 0 & 0 & 0 & 0.8 & 0.2 \\ 0 & 0 & 0 & 0.4 & 0.6 \\ 0 & 0 & 0.1 & 0.9 & 0 \end{bmatrix}$$

$$= \begin{pmatrix} 0 & 0 & 0.0219 & 0.6348 & 0.2742 \end{pmatrix}$$

The measurement vector for the first index of destruction of water resources (X_3) is:

$$\mu_3 = \overline{\omega}_3 \times \overline{\mu}_3 = \begin{bmatrix} 0.2928 \\ 0.2357 \\ 0.2357 \\ 0.2357 \end{bmatrix}^T \times \begin{bmatrix} 0 & 0 & 0.2 & 0.8 & 0 \\ 0 & 0 & 0 & 0.4 & 0.6 \\ 0 & 0 & 0 & 0.6 & 0.4 \\ 0 & 0.6 & 0.4 & 0 & 0 \end{bmatrix}$$

$$= \begin{pmatrix} 0 & 0.1414 & 0.1528 & 0.4699 & 0.2357 \end{pmatrix}$$

The measurement vector for the first index of land resources (X_4) is:

$$\mu_4 = \overline{\omega}_4 \times \overline{\mu}_4 = \begin{bmatrix} 0.2076 \\ 0.2578 \\ 0.2257 \\ 0.3089 \end{bmatrix}^T \times \begin{bmatrix} 0 & 0 & 0.6 & 0.4 & 0 \\ 0 & 0 & 0.2 & 0.8 & 0 \\ 0 & 0 & 0.3 & 0.7 & 0 \\ 0 & 0.1 & 0.9 & 0 & 0 \end{bmatrix}$$

$$= \begin{pmatrix} 0 & 0.0309 & 0.5218 & 0.4473 & 0 \end{pmatrix}$$

Thus the measurement matrix of first index is:

$$\overline{\mu} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0.0598 & 0.7794 & 0.1608 \\ 0 & 0 & 0.0219 & 0.6348 & 0.2742 \\ 0 & 0.1414 & 0.1528 & 0.4699 & 0.2357 \\ 0 & 0.0309 & 0.5218 & 0.4473 & 0 \end{bmatrix}$$

5.3 Determining the classification weight of first grade index

AHP is applied to calculate the weights of first indices as follows. First index judgment matrix is built using Saaty's 1-9 scale.

TABLE 6: THE FIRST INDEX JUDGMENT MATRIX

X	X_1	X_2	X_3	X_4
X_1	1	2	1/2	1
X_2	1/2	1	2	3
X_3	2	1/2	1	4
X_4	1	1/3	1/4	1

So according to the formula (7) and (8) can get the classification weights of the first index, as shown in Table 7.

TABLE 7: THE CLASSIFICATION WEIGHTS OF FIRST INDEX

	X_1	X_2	X_3	X_4
w_i	1	1.3161	1.4142	0.5373
w_i^0	0.2343	0.3084	0.3314	0.1259

Thus the weights of each first index are calculated using the formula (9):

First,

$$\frac{AW_1}{W_1} = \frac{(0.2343 \quad 0.3084 \quad 0.3314 \quad 0.1259)}{0.2343} \times (121/21)^T = 4.1771$$ is obtained.

Similarly, $\frac{AW_2}{W_2} = 4.1577$, $\frac{AW_3}{W_3} = 4.0989$,

$$\frac{AW_4}{W_4} = 4.0352$$

Thus the maximum eigen value is: $\lambda_{max} = 4.1172$

Since there are 3 factors, R.I value of the matrix is set as 0.86. From $C.R = \frac{C.I}{R.I} < 0.1$ it can be known that the consistency test is passed.

Point multiplification of first index weight and first measurement matrix results in judgment matrix:

$$B = \omega_i^0 \cdot \bar{\mu} = [0 \quad 0.0508 \quad 0.1371 \quad 0.5904 \quad 0.2003]$$

Thus the score is calculated by:

$$S = B \cdot A^T = [0 \quad 0.0508 \quad 0.1371 \quad 0.5904 \quad 0.2003] \cdot [70 \quad 80 \quad 90 \quad 95 \quad 100]^T = 92.52$$

From the above it can be known that safety evaluation of resource environment of the mine is comparative safety.

5.4 Confidence level recognition

Confidence level recognition is performed using the formula (10). Here λ is set as 0.7:

When $\lambda = 0.7$, $k_0 = \min \sum_{l=1}^{k} \mu_{il} \geq 0.7$, $k = 2$, it shows that the confidence level recognition is high.

Combination of evaluation grades and their corresponding score vector, the resources environment of the mining area is classified as "comparative safety". Overall reflect the safety degree of resources environment in the mining area. The mechanization degree is higher in the coal mine area, with the small coal mines in Shanxi Province in recent years are controlled and closed, comprehensive exploitation rate and utilization rate of the resources in the mining area are improved. In the mine area prevention and governance of the environment security situation in investment is larger. But the evaluation score of index of land resources security is low, mainly presented as soil degradation, due to the mining area is located in dry areas, vegetation sparse. The small coal mines mining caused the original sparse vegetation destroyed and wind erosion in early years, accelerated the speed of soil desertification. Therefore, in order to protect the resources environment security of the mining area, treating work of land desertification should be strengthened.

6. Conclusions

1. This study comprehensively consider the many factors affecting the safety of mining resources environment, the index system of mining resources environment security is established from 4 aspects: destruction of landscape and relics resources, destruction of mineral resources, destruction of water resources and destruction of land resources. The safety comprehensive evaluation is carried out using the unascertained measure model and AHP, it provide reliable basis for developing rapid and accurate safety control measures and management solutions of mine resources environment.
2. The importance of the various evaluation factors is not the same in the safety evaluation system of mining resources environmental, so it is necessary to determine the weight of each factor. The modified AHP that achieves qualitative and quantitative evaluation simultaneously is used. The weights are assigned more scientific, reasonable and satisfies the requirement of consistency, thus fully reflecting the significance level of each safety index.
3. The level decision problem of the resources environment security in the mining area is solved using the confidence recognition criteria.
4. The judgment matrices are built based on the unascertained measure model which fully represents the uncertainty in the evaluation.

References

1. Zhang, B. L. (2001): "The system research about the environmental accounting check." *Contemp Financ Econ*, (7): 71-73.
2. Xu, Y. N., Wu, Z. and Zhao, Z. C. (2001): "The environmental geological problems and types of mineral resources exploitation in the Northwest China." *Northwest Geol*, 34(2): 71-73.
3. He, F., Xu, Y. N., Chen, H. Q. and Zhang, J. H. (2008): "Present status of mine geohazards in the northwest region of China and characteristics of their temporal-spatial distribution." *Geol Bul China*, 27(8): 1245-1255.
4. Wang, Y. J. (2002): "China's mineral resources security under economic globalization." *J China Coal Soc*, 27(5): 450-453.
5. Wang, Y. J. (2003): "On China's mineral resources security." *Sci Tech Rev*, (2): 58-61.
6. Xu, Y. N., Yuan, H. C., He, F., Chen, S. B. and Zhang, J. H. (2003): "Comprehensive evaluation index system of

the environmental geological problems of mines.” *Reg Geol China*, 22(10): 829-832.

7. Wei, Y. C. and Xu, Y. N. (2004): “Research of quantificational assessment model of mining environments.” *Geol Miner Resour S China*, (4): 47-50.
8. Zhang, J., Yang, W. P., Yang, L. G. and Sun, Y. (2011): “Comprehensive fuzzy evaluation method and its application to the open-air mine safety forecasting.” *J Saf Environ*, 11(6): 259-263.
9. Hao, C. B. and Dai, S. J. (2008): “Information entropy and unascertained measure methods of mine geological disasters evaluation.” *J Heilongjiang Inst Sci Tech*, 18(5): 344-346.
10. Yang, M. Z., Li, P. and Song, J. H. (2001): “Analysis and prediction of geological disasters in Huangling Binchang Mining districtin in Shanxi.” *J Geol Hazards Environ Preserv*, 12(3): 38-41.
11. Li, X. C., Sun, Y. and Tao, X. Y. (2001): “Application of neural network in evaluating sustainable development for mining areas.” *J China Univ Min Tech*, 30(4): 392-395.
12. Sun, Y. F. (2006): “Establishment of system dynamic simulation model for environment of mining area.” *J Liaoning Tech University*, 25(2): 308-311.
13. Zhang, K. J., Wei, C. Y. and Xu, Y. N. (2013): “Application of fuzzy mathematics method to soil heavy metal pollution evaluation in a gold mining area of Xiao Qinling.” *Hydrogeol Eng Geol*, 40(5): 124-128.
14. Xu, Y. N., Zhang, J. H., Ke, H. L., Chen, H. Q., Liu, R. P., Q, G. and Shi, Y. F. (2014): “An assessment method for heavy metal cumulative risk on farmland soil in the mining area: a case study of the Xiaoqinling gold mining area.” *Geol Bul China*, 33(8): 1097-1105.
15. Guo, W., Zhao, R. X., Zhang, J., Bao, Y. Y., Wang, H., Yang, M., Sun, X. L. and Fan, J. (2011): “Distribution characteristic and assessment of soil heavy metal pollution in the iron mining of Baotou in Inner Mongolia.” *Environ Sci*, 32(10): 3009-3105.
16. Ejjihamada, H. and Kono, Y. (1994): “Prediction and assessment of landscape change by the influence of open pit mining.” *Foreign Met Min Mag*, 64-71.
17. Kundakci, N. (2011): “Notebook selection with the combination of FAHP and PROMETHEE methods.” *J Mul-Valued Log Soft Comput*, 17(1): 25-45.
18. Liu, K. D., Pang, Y. J., Wu, H. Q. and Yao, L. G. (1999): “Information and its mathematical expression systems.” *Eng Theor Pract*, (8): 91-93.
19. Wu, H. Q. (1998): “The four fundanmenal operations of arithmetic of blind numbers.” *J Hebei Inst Archit Sci Tech*, 15(1): 6-9.
20. Liu, K. D., Pang, Y. J., Wu, H. Q. and Yao, L. G. (2000): “The unascertained measure model of the synthetical evaluation on atmosphere environmental qualities.” *Eng Theor Pract*, (8): 91-93.
21. Li, W. Q., Zhang, L. N. and Meng, W. Q. (2005): “Comprehensive evaluation on MIS based on information entropy and unascertained measure model.” *J Hebei Inst Archit Sci Tech*, 22(1): 49-53.
22. Wu, F. D. and Wu, N. L. and Wang, C. L. (2011): “Safety evaluation model of "six systems" in coal mine underground based on the unascertained measure theory.” *J China Coal Soc*, 36(10): 1731-1735.
23. Lu, Q. Q., Pan, C. B. and Huang, G. Q. (2013): “A mining resource environment evaluation model based on the fuzzy attribute hierarchical analysis.” *J Saf Environ*, 13(1): 234-240.