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A definition and evaluation index system of aging mines

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ABSTRACT
Because of the limited storage of coal resources, coal production progresses from growth to decline until eventual mine closure. At present, aging mines have no clear name, conception, defined definition, and complete system. Based on the analysis of the mine life cycle and the problems associated with mine development and conceptions in the past, this paper aims to construct an evaluating index system of decrepit mines and define the index of weight layer by application of the analytic hierarchy process (AHP), so as to provide a basis for development planning of mine enterprises, and law-making for resource-based cities and countries.
KEYWORDS: aging mines; define; evaluation index system

1. THE LIFE CYCLE OF A MINE

Due to the fact that mineral resources are finite and non-renewable, mining enterprises trend from birth to death and prosperity to decline, just like organisms. The whole process of mine production and the service cycle must go from exploration, building a well, putting into production, stable industry, aging, and finally being shut down. This is called the life cycle of a mine.

According to "The economic structure transformation of resources city", the statistics from August 2003 by the national development and reform commission, there are altogether 118 resource-based cities in China, including 63 coal cities, 12 non-ferrous metal cities, 8 ferrous metallurgy cities, 9 oil cities, and 5 other cities. These account for about 18% of the number of cities around the country and a total population of 154 million people. China has determined 69 resource-exhausted cities (counties and districts). As of the middle of the 20th century, two-thirds of state-owned mines have entered the aging stage and 440 mines will be closed. 50 resource cities are experiencing resource failure in a total of 390 mines. 3 million workers have been laid-off and 10 million families' lives have been affected.

The definition of aging mines and determination of an evaluation index system is very important due to the complexity of the work of aging mines closed underground material recycling equipment, the shunt placement of mine workers, and the processing and handling of history of creditor's rights debt.

The definition and evaluation index system of aging mines is basic research which includes evaluation theory, research methods, index systems, and a classification scheme. At present, aging mines are short of a scientific definition, complete statistical analysis conclusions and comprehensive research. This has adverse effects on the development of large coal mining enterprises and the decisions of government developing. At the microscopic level the definition and evaluation index system of aging mines can make sure the limited storage characteristics of coal resources are considered in advance. The index can choose the important point and analyze the enterprise development strategy and change into the developing period from the senescence phase, avoid influence on layoffs, cut down the number of persons employed and upper and lower relation in coal mining enterprises. At the macroscopic scale, the index system of aging mines can help to more easily determine the weight index for local government rewards for mining enterprises in provinces. Based on the above reasons, it also provides theoretical support and practical suggestions for macroscopic development strategy, medium-long term plan policies and regulations for local government.

2. DEFINITION OF AGING MINES

The definition of aging mines is a complex problem. Previous scholars have studied resource depletion, but face closed mine appellation is different. Common appellations are old mining, aging depleted mines, resource crisis mines, old mines, middle-late mines and crisis mines, and so on. The definition of aging mines also has different points of view, as follows.

(1) Some people like Lu Guxian believe that resources crisis mines are due to a shortage for mineral resources in the mining areas, the drying up of the recoverable reserves, or due to the change of

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market conditions of the commodity price fluctuations, changes in supply and demand so that the economical development and utilization of its reserves of mineral resources are difficult to continue. This leads to the decline of mine production, significant excess production capacity, and deterioration of operating conditions. Therefore in the present or the future there is a certain period of time where it is difficult to maintain normal production and business operation and facing closure or bankruptcy of mining enterprises.

(2) Jia Yanjie thinks that aging mines mainly have the following signs: consumption of mining reserves more than two-thirds of the mine recoverable reserves; the residual service life of mine is less than 10; the number of tons of coal reaches to 3 people which 1 time more than the period of development and stablity; the tons of coal to investment is 80 yuan, more than 60% higher than the stable stage; the mine production has begun to decline and the Nissan's level has dropped for stability and design ability.

(3) Li Qing and Li Kerong point out the quantitative standard of the coal enterprises in different stages of the life cycle. We can judge it from the mining coefficient of fixed number of years and the mining ability structure coefficient. The so called mining coefficient of fixed number of years is judged mainly from the main business continued ability in the future of coal mining, total reserves, and the perspective of overall production capacity in the future.

(4) On the basis of investigation and research, the original state coal industry bureau made the standard for coal mine resource depletion, and high ash and sulfur turn around. It believes that one of the following two conditions must be met in order to be considered an aging or resource depleted mine. Based on the 1991 No. 211 document on May 13 of the original coal, the mine can adopt reserves to reduce, without augmenting resources at depths and peripheries, with remaining recoverable reserves of around 20% for the original design. According to the actual recoverable reserves, mine design capability must consider the reserve coefficient calculation of residual service life of coal mine of no more than 5 per mine.

(5) In the study of coal aging scrap best point, some people like Huang Shude analyzed the different well types, at different fixed number of years of the production and development trend of production under conditions of mine production and operation and put forward the mine into the aging point judgment index system.

(6) On the basis of the name of mine and its basic concepts, Lu Gang unified the designation of aging mines, defined the concept of aging mines, and pointed out that the aging of mines is to point to recoverable resources drying up, basic coal production capacity experiencing a sharp drop in production, and difficulty maintaining normal production and operation of the mine.

In conclusion, many scholars concentrated on the remaining recoverable reserves, residual length of service, production capacity, tons of coal cost, etc. These scholars did not consider enterprise economic benefits (especially not the income of coal industry to GDP), the degree of deep and peripheral resources available, recycling feasible extent of loss of resources, resources recycling feasible degree, national policies, and regulations compliance and safety. Based on this analysis, the current study puts forward the idea that the aging mine is one that experiences a production plateau, economic downturn, the remaining resources occurrence condition deteriorates, cannot meet the normal mining economic and technological conditions, tons of coal cost, production capacity and the status of the mine is not in conformity with the provisions of the state.

3. CONSTRUCTION EVALUATION INDEX SYSTEM OF AGING MINES

3.1 Evaluation Index System of Aging Mines

According the characteristics of aging mines and the principle of index system construction and introduction the meaning of evaluation index should be settled. The principles of the index system include the objectivity, system, comparability, feasibility, and dynamic.

Table 1: Evaluation index system of aging mines.

Object hierarchy	Rule hierarchy	Indicator layer
Mine grew into senescence phase	Mine economic efficiency(A)	Sales profit ratio(A1)
		Asset-liability ratio(A2)
		Non-Coal Industry income ratio (A3)
	living condition of mineral resources （ quality and quantity）(B)	The residual service life for mine (B1)
		Reserve-production ratio decrease rate (B2)
		The utilization degree of deep department and outer resources (B3)
	Economy technology condition (C)	The economic and reasonable mining depth (C1)
		Feasibility of resources loss recycled (C2)
		Feasibility of resource reutilization(C3)

	the ton coal synthesizes cost (D)	The per ton coal employees (D1)
		The per ton coal funds input (D2)
	productivity and safe condition(E)	Whether match national laws and regulations (E1)
		Megaton coal mortality (E2)
		Safety investment cost rate (E3)
	The social responsibilities performance condition (F)	The social contribution rate (F1)
		Capita income of employee(F2)
		The total tax (F3)

3.2 The assurance of weight of index evaluation index

The layer analytical (AHP) was put forward in the 20th century by a teacher, T.L. Saaty at the American Pittsburgh University. It is a kind of system analysis method that combines fixed amount and quality together and imitates the person's decision thinking process. It is used to solve complicated systems with many factors, especially hard fixed amounts of the analytical method of social systems. AHP belongs to the index sign comparison method, and it can judge with the consistency examination to check whether the related index sign importance has a logic mistake. It gets rid of artificial understanding of limits from a person to a great extent, so it can be extensively applied in each professional field. This text applied layer analytical method assurance the decrepitude mineral well all levels index sign weight of index. The layer analyzes the foundation theory of methods.

(1) Aiming at rule hierarchy weight of index with the AHP method, calculating results are shown in Table 2.

Table 2: Weight of rule hierarchy index.

T	A	B	C	D	E	F	weight of index
A	1	2	3	4	5	6	0.373
B	1/2	1	2	3	4	5	0.252
C	1/3	1/2	1	2	3	4	0.160
D	1/4	1/3	1/2	1	2	3	0.101
E	1/5	1/4	1/3	1/2	1	2	0.064
F	1/6	1/5	1/4	1/3	1/2	1	0.043

Calculating processes are as following：

Firstly, number out each element's product in a judgment matrix, it accumulates: M 1=720; M 2=60; M 3=4;M 4=0.25; M 5=0.0167; M 6=0.00139;

Secondly, computes Mi of 6 $\overline{W_i}$ ； $\overline{W_1}=2.934$； $\overline{W_2}=1.979$； $\overline{W_3}=1.260$； $\overline{W_4}=0.794$； $\overline{W_5}=0.505$； $\overline{W_6}=0.334$

Thirdly, carry on unitary processing or regular processing to $P=(\overline{W_1},\overline{W_2},\overline{W_3},\overline{W_4},\overline{W_5},\overline{W_6})$: that is $W_i=\overline{W_i}/\sum_{i=1}^{6}\overline{W_i}$

W_1=0.373 W_2=0.2518 W_3=0.160 W_4=0.1014 W_5=0.0642 W_6=0.0425

Fourth, the above characteristic vector is the power begged while it still needs to carry on consistency examination towards the judging matrix:

① Compute the biggest characteristic value of matrix $\lambda_{\max}=\sum_{i=1}^{6}(PW)_i/nW_i=1/n\sum_{i=1}^{6}(PW)_i/W_i$

②The consistency examines；

$C_R=C_I/R_I$； $C_I=(\lambda$ max-n）/（n-1）

if n=6 , $R_I=1.24$, λ max=6.12 , $C_R=0.0199<0.1$,the consistency examination passes.

(2) Compute an index sign layer index sign power with reason respectively heavy, as Tables 3-8 show.

1) According to Mine economic efficiency (A1), asset-liability ratio (A2), the non-Coal Industry income ratio (A3) influence toward mine economic efficiency degree is different, calculating the power of each index sign heavy, as Table 3 shows.

Table 3: Weight of mine economic efficiency index.

A	A1	A2	A3	weight of index
A1	1	2	3	0.540
A2	1/2	1	2	0.297
A3	1/3	1/2	1	0.163

2) According to the residual service life for mine (B1), tReserve-production ratio decrease rate (B2), the utilization degree of deep department and outer resources (B3) to measure the degree of different by mineral well resources endow to a condition, compute index weight of index..

Table 4: Weight of resources reserves index.

B	B1	B2	B3	weight of index
B1	1	1/2	2	0.297
B2	2	1	3	0.540
B3	1/2	1/3	1	0.163

3) The economic and reasonable mining depth (C1), study on the feasibility of resources loss recycled (C2), study on the feasibility of resource reutilization (C3), measurement for mineral well economic technique conditional of the important degree is different, to draw out each index sign

weight of index, as shown in Table 5.

Table 5: Weight of economic technique condition index.

C	C1	C2	C3	weight of index
C1	1	2	3	0.540
C2	1/2	1	2	0.297
C3	1/3	1/2	1	0.163

4) The per ton coal funds input (D2) and the per ton coal employees (D1) to the ton coal cost is different which gets the conclusion of an each index sign of weight of index.

Table 6: Weight of ton coal comprehensive cost index.

D	D1	D2	weight of index
D1	1	3	0.75
D2	1/3	1	0.25

5) Whether match national laws and regulations (E1), Megaton coal mortality (E2), safety investment cost rate (E3), these three factor's influence on the productivity and safety condition is different. Compare the matrix and weight of index as Table 7 shows.

Table 7: Weight of productivities and safe condition index.

E	E1	E2	E3	weight of index
E1	1	2	3	0.540
E2	1/2	1	2	0.297
E3	1/3	1/2	1	0.163

6) The social contribution rate (F1) and capita income of employee (F2), total tax amount (F3) three second class index signs towards measuring the importance that the Corporate Social Responsibility implements condition is different to get the comparing matrix and weight of index, as in Table 8.

Table 8: Weight of social responsibilities implement condition index.

F	F1	F2	F3	weight of index
F1	1	1/2	2	0.297
F2	2	1	3	0.540
F3	1/2	1/3	1	0.163

According to the above analysis calculation, we can get a decrepitude mineral well evaluation index sign weight of index, as Table 9 shows.

Table 9: Decrepitude mineral well evaluation index system.

Name of Standard layer index	Weight of index	Index sign layer inde name	Weight of index
Mine economic efficiency (A)	0.373	Sales profit ratio (A1)	0.540
		Asset-liability ratio(A2)	0.297
		Non-Coal Industry income ratio(A3)	0.163
living condition of mineral resources (B)	0.252	The residual service life for mine (B1)	0.297
		Reserve-production ratio decrease rate (B2)	0.540
		The utilization degree of deep department and outer resources(B3)	0.163
Economy technology condition (C)	0.160	The economic and reasonable mining depth (C1)	0.540
		Study on the Feasibility of resources loss recycled (C2)	0.297
		Study on the Feasibility of resource reutilization (C3)	0.163
the ton coal synthesizes cost (D)	0.101	The per ton coal employees (D1)	0.75
		The per ton coal funds input (D2)	0.25
productivity and safe condition (E)	0.064	Whether match national laws and regulations (E1)	0.540
		Megaton coal mortality (E2)	0.297
		Safety investment cost rate (E3)	0.163
The social responsibilities performance condition (F)	0.043	The social contribution rate (F1)	0.297
		Capita income of employee (F2)	0.540
		The total tax (F3)	0.163

Making use of the layer of this text introduction analysis method to draw out the power of each evaluation of index sign can provide a theoretical foundation to see whether the mineral well gets into a decrepitude period, from the decrepitude mineral well evaluated index sign of system index sign analysis, mine economic efficiency A, living condition of mineral resources B, and economic technique condition C takes the most space. Sales profit ratio

A1, reserve-production ratio decrease rate B2, and the economic and reasonable mining depth C1, again occupy an important position in this layer. The index signs of national laws and regulations E1 and capita income of employee F2 should also be considered.

4. CONCLUSION

The main conclusions from the analysis of the conception of the decrepitude mineral well and the decrepitude mineral well definition index system are as follows:

On the foundation of the analytical mineral well life cycle and the decrepitude mineral well conception, we analyzed the existing concepts of shortage and put forward a new decrepitude mineral well conception, namely that a decrepitude mineral well occurs after the mineral well's steady production period, the surplus resources endows with a claim check piece depravation because the economic efficiency falls, the economic technique condition can not satisfy the mine, the ton coal cost significantly increases, and the productivity and safe condition do not satisfy the nation's rules.

(2)Owing to the foundational research on the resource potential of the decrepitude mineral wells and the definition of the decrepitude degree, evaluation theory, research on method, index sign system and classification project, the decrepitude mineral well lacks a scientific definition, integrity statistics, analysis and comprehensive study, and a decrepitude mineral well evaluation index system.

Following the principles of objectivity, system and comparition, possibility and dynamic state were used to set up a decrepitude mineral well evaluation index sign system. Mineral mountain economic efficiency's standard layer index sign is 7, and the sell profit margin index sign layer is 17.

The layer analysis method was applied to assure all levels index sign power in decrepitude mineral well evaluation. This provides a basis for making development programming of mineral mountain enterprises from both the micro view and the macro view for resource cities and nation's farsighted development and law establishment.

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6. REFERENCES

GUO Yuhong. Characteristics of input and output and economic evaluation method of aging mine [J].Coal Economic Research.1990(11):39-41

HUANG Shude, GAO Yongju, ZHENG Guanghua. Research of best point of scrap in aging coal mine [J]. Journal of Henan Polytechnic University(Natural Science). 1993, 34 (5): 28- 29

LU Gang, CHENG Wei ， HAN Keqi. Simulation study on the life cycle identification of the aged coal mine and mine[J]. Journal of Henan Polytechnic University (Natural Science Edition) .2009,28（5）:659～694

LU Gang.Research on Residual Coal Workability Evaluation and Remining Technology of Aged Coal mine[D] China University of Mining and Technology,2010

MA Hui, LIAN Huiqing, ZHU Hongjie. SWOT analysis of aging mines' low carbon development[J]. The 2nd International Symposium on Mine Safety Science and Engineering. 2013,259-261

REN Yixin, HAN Gang, DING Ru, WANG Ning. Construction of circular economy mode of old coal mine. Mining and Metallurgical Engineering, 2008,28（4）:108～113

WANG Chun, WANG Baicheng. Research and practice of old coal mine mining technology[J]. Coal Technology,2006,25(2):48～50

WEI Guangxing. Summary and remarks of enterprise life cycle theory [J].Productivity Research. 2005,(6):52-53