TELKOMNIKA, Vol. 11, No. 10, October 2013, pp. 5995 ~ 6000
ISSN: 2302-4046

Evaluation of Coal Mining Safety Management Information Sytem based on the Internet of Things

Zhu Jianjun*[1], Li Mingxing[2]
[1]Department of Chemistry of Zhenjiang College,
Xuefu Road 61, Zhenjiang, Jiangsu, 212000, China, Ph./Fax: +86-88962533/88962345
[2]Management School of Jiangsu University, 578674566@163.com
Xuefu Road 301, Zhenjiang, Jiangsu, 212013, China, Ph./Fax: +86-88791486/88791711
Corresponding author, e-mail: 578674566@163.com[1], mingxingli6@163.com[2]

Abstract

In this paper, we put forward three-level indicators and 13 secondary indicators via Delphi method. We improved the new fuzzy synthetic evaluation method from the aspect of coal-mining information management. Finally, the fuzzy evaluation matrix of evaluation objects was

$$B = (b_1, \Lambda, b_5) = C * \begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix}$$

. After a comprehensive evaluation, 72.28% of people believed that security levels of Huaibei Mining Group belonged to good & moderate one, and 27.72% of people held that security status of Group was poor & very poor condition on the basis of comprehensive evaluation. Therefore, security management information system in Huaibei Mining Group belonged to the middle level. By using the new indicators and research method, the countermeasures were given to improve safety management on the basis of the internet of things.

Keywords: *safety management, information system, Delphi method, evaluation*

1. Introduction

In 2000 and 2001, the death rate per million tons in Australia's New South Wales was about 0.014. In 2009, 18 people were killed in U.S., and coal mine accidents obviously decreased so that death rate per million tons fell to 0.018. In South Africa death rate per million tons of coal-mining accidents can be controlled less than 0.003 in 2013. But in Canada the rate of coal-mining death was zero. The situation of safe production has improved stability with the progress of security technology and continuously improved safety laws and regulations, but the question is still serious [1]. Roof falling, transport and mechanical equipment accident were the major reasons for death accident in Indian coal-mining, accounting for 53.1% of the total numbers. There are three hot management issues including food safety, campus security and coal production safety in China. According to the State Administration of Safety Supervision, the mortality rate per 1 million tons of coal was 0.564 million tons of coal in 2011, which sharply fell to 15% in China and fell within less than 2000 people for the first time. The number was at or close to the level of medium-developed countries, and there were the first “zero deaths” in three coal provinces and autonomous regions as well as five large coal companies. After National Coal Mine Safety Supervision Bureau organized experts to make the material assessment and on-site assessment in thirty-three coal mine safety training and demonstration bases nominated by the provinces, fifteen bases passed finally. In Daliuta coal of Shenhua Group three-layer such network structure as information layer, automation control layer and equipment layer were accepted to achieve the full mine production process automatic control and information technology management by optical fiber as a transmission channel to build up a more integrated information systems.

Lisa A. Ronald (1998) [2] said that the modern security management program should include several area: people-oriented culture, the active security leader/management sector, man-machine design,security training and incentive,the strong management program, the active support for health security plans in modern security management, and encouraging staffs to

Received April 22, 2013; Revised July 10, 2013; Accepted July 20, 2013

make the participation and implementation aim at the reduced hurt rate. Being the decisive factor of enterprise security management level, the ultimate expression of enterprise security management capabilities is enterprise's safety production status. The current study of coal mine production safety evaluation system in foreign countries are mainly concentrated in the following areas: assessment technology is on the basis of mine probability risk evaluation, the product of the accident probability caused by hazard and damage caused by the accidents represents the risk degree of system status, and the hazard occurrence probability and damages are available through the statistical data. China's coal mine safety evaluation methods include security checklists method, expert risk evaluation method of field observation on questionnaires, application of LEC assessment in check and treat of hidden risk (LEC), fault tree analysis (FTA), as well as preliminary hazard analysis (PHA). Furthermore, the mine sub-station reliability of expected value and accelerated life test of the reliability value is given by setting the number of tests Censored Bayesian methods and Fixed Number Truncated of constant-stress accelerated methods on sub-station reliability research [3]. With the application of the model through simulation, the reliability of ring network, tree network and star network in mine is analyzed [4].

The evaluation problem is discussed because there is apparent disagreement between the coal mine safety evaluation guidelines issued by State Administration of Coal Mine Safety in 2003 and the existing safety evaluation management rules. Owing to problems in the security technology evaluation, the quality of evaluation report is not high. Those problems appear because the evaluation of process control is not in accordance with the requirements of the guidelines for the preparation of total control. The evaluation method is the only qualitative analysis method without quantitative analysis of the risk factors in coal mining enterprises, which pay attention to systematic review rather than security management mode, systematic institution and scientific evaluation. Motivated by economic interests, rating agencies reduce evaluation criteria to issue the false reports.

2. Research Method

Based on the fuzzy mathematics, fuzzy comprehensive evaluation is a method, which puts to use the fuzzy synthesis principle to make the unclear and not quantitative factors quantification, using multiple factors to conduct the comprehensive evaluation to something-related level evaluation. On the basis of the above-mentioned research results, the paper constructs a set of evaluation index system to conduct the coal mine safety management ability evaluation by using the fuzzy synthetic evaluation method.

As for safety management capability of coal-mining enterprises, its evaluation index system is composed of three-level indicators and 13 secondary indicators (see Table 1). Specific indicators have the following meanings.

First of all, the first-level indicator is equipment safety performance optimization capability, which refers to the capability to make operation plan and upgrade security awareness relation to employees in coal mine enterprises. The relevant impact factors include the influence coefficient of safety technology on equipment management (ICSTEM), and the influence coefficient of equipments and facilities on equipment management (ICEFEM). Jacques van Steen (1996) [5] held that devices & equipments, systems and procedures, available leaders and system failure reduction should be made to improve safety performance. Second, security system improvement capability is to improve the capacity at the second level. Dan Petersen (1996) [6] held that security management capability improvement can be divided into the continuous improvement ability, the ability to establish reasonable culture, the ability to improve the managerial skills, the ability to improve staffs' skills, the ability to improve operational capacity and the ability to improve material conditions. Third level indicator is safety culture upgrading capacity. Xu Deshu and Qiu Cheng (2004) [7] held that employees-related safety cultural quality and environment directly affect the management mechanism and employees resilience. Security culture upgrading ability referred to strengthening and improvement ability concerning security consciousness,security target,security responsibility, security literacy, security habits,security technology,security facilities, security management and security system.

Table 1. Index system analysis [8-10]

First level indicators	Second level indicators	Meaning
Equipment safety performance optimization capability	Equipment safety input capacity	Using modern mining and safety equipment
	Upgrading level of an equipment application skills	Operation and maintenance of variable frequency control device and integrated automation system in coal mine enterprises
	Equipment -related digital transformation capability	Combining digital technology and mining equipment
Security system improvement capability	Leadership attention	Senior managers pay attention to safety management in enterprises
	The implementation level of production safety system	Enterprise employees implement comprehensive safety system
	The personnel-related security management quality	Enterprise management personnel strengthen security ethics morality
	Security management department	Safety Management Department is responsible for fire safety fire safety, food hygiene, product safety, and the prevention of natural disasters
	Security communication	Information exchange and share between coal mine enterprises and monitoring and safety supervision agency
Safety culture upgrading capability	Capability to identify safety culture in enterprises	Safety first in production values becomes the universal one
	Capability to conduct universal safety culture in enterprises	To make the safety culture deeply rooted in hearts through training, education and multi-channel publicity
	Capability to promote safety culture in enterprises	To strengthen overall safety awareness and love life so as to become an important production safety code
	Capability to deepen safety culture in enterprises	To enhance employees-related safety awareness and literacy to develop safety habits
	Capability to conduct the innovative safety culture in enterprises	To enhance security image of enterprises

3. Safety Management Model

First step aims to establish judgment matrix of the layers, using the Delphi method and corporate sample. Suppose that judgment matrix is:

$$R_i = \begin{bmatrix} u_{11} & u_{12} \cdots & u_{1j} \\ u_{21} & u_{22} \cdots & u_{2j} \\ \vdots & \vdots & \vdots \\ u_{i1} & u_{i2} \cdots & u_{ij} \end{bmatrix}$$

And so on, the next layer judgment matrix can be given. The element values are denoted by a_{ij}.

The second step is to calculate eigenvalue of maximum and eigenvector of the judgment matrix. The approximate calculation method is used to have access to geometric mean value of all elements of in matrix rows. That is $\overline{w} = \sqrt[n]{\prod_{i=1}^{n} a_{ij}}\ i = 1, \Lambda, n$.

Among them, n=1, Λ,6. And get $\overline{w} = (\overline{w}_1 \Lambda \overline{w}_n)^T$.

Then have the normalization process, that is, $w_i = \frac{\overline{w_i}}{\sum_{j=1}^{n} \overline{w_j}} \quad i = 1, n$.

$\overline{w} = (\overline{w}_1 \Lambda \overline{w}_n)$ is eigenvector approximation, and a factor of relative weight. The maximum eigenvalue of judgment matrix is $\lambda_{\max,}$ $\lambda_{\max,} = \sum_{j=1}^{n} \frac{(A\overline{W})_i}{n\overline{w}_i}$.

Among them, $(A\overline{w})_i$ is i element of the vector. A is judgment matrix.

Next, the consistency indicators are calculated in judgment matrix, and their consistency is validated.

$CI = \frac{\lambda_{\max} - n}{n-1}, CR = \frac{CI}{RI}$, and RI is random consistency index.

If CI≦0.1, its consistency is acceptable.

If its consistency is acceptable, the weight can be got.

Suppose that a target weight of the main guidelines is C=(C1,C2,C3). Among them, c_i represents U_i proportion, i=1,2,3,and $\sum_{i=1}^{3} c_i = 1, c_i \geq 0$.

Set target weights of sub-criteria layer is $C_1 = (c_{11}, \Lambda, c_{1j}), c_2 = (c_{21}, \Lambda, c_{2j}), c_3 = (c_{31}, \Lambda, c_{3j})$. Among them, C_{ik} represents U_{ik} proportion, K=1, Λ,3, and $\sum c_{ik} = 1, c_{ik} \geq 0$. New product development performance reviews set is γ{γ1,Λ γm}={Very satisfied, Satisfied, General, Dissatisfied, Not at all satisfied}.

The portal evaluation matrix is set for main criteria layer evaluation indicators U_i (i = 1, 2, 3) and fuzzy comprehensive evaluation collection B_i (i = 1, 2, 3) is given.

If separately considered indicators U_{ij}, and reviews extent is r_{ijt} , the fuzzy evaluation matrix R_i (i= 1, 2, 3) is followed.

$$R_i = \begin{bmatrix} r_{i11} & \Lambda & r_{i15} \\ M & M & M \\ r_{in1} & \Lambda & r_{in5} \end{bmatrix}$$

Among them, i(i=1,2,3) is the number of indicators for the classification factors, n is the number of evaluation in the relevant sub-criteria layer. Fuzzy comprehensive evaluation set of indicators of the main criteria layer $B_i = (b_{i1}, \Lambda, b_{i5})$ is based on $B_i = C_i * R_i$. Among them, $b_{it} = \vee_{j=1}^{n} (c_{ij} \wedge r_{ijt})$, i=1,2,3, and t=1, Λ,5.

The fuzzy evaluation matrix of evaluation objects is $B = (b_1, \Lambda, b_5) = C * \begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix}$.

Among them, $b_j = \vee_{j=1}^{3} (C_i \wedge b_{it})$, j=1, Λ,5, and t=1, Λ,5.

After the normalization process is made, the evaluation of safety management capability of coal-mining enterprises can be got.

In accordance with the maximum membership degree principle, there are the evaluation results concerning safety management capability in coal-mining enterprises.

4. Results and Analysis

Based on a case of Huaibei Mining Group, the paper conducts the research by using fuzzy comprehensive evaluation method. Thirty coal-mining safety experts are invited to conduct evaluation. After a comprehensive evaluation, 72.28% of people believe that security levels of Huaibei Mining Group belong to good & moderate one, and 27.72% of people hold that security status of Group is poor & very poor condition on the basis of comprehensive evaluation. Therefore, security situation in Huaibei Mining Group belongs to the middle level. However, numerous problems appeared from the aspect of information management.

Firstly, the coal-mining enterprises fall behind the development of information technology, have no enough information technology investment, and lack the comprehensive policy, technical standards and specifications for the safe production on the basis of information construction, as well as assessment and evaluation system.

Secondly, information technology infrastructure, equipment and safety production management techniques are backward and the size and the scope of information are smaller. The level of R&D and industrialization of information technology, electronic information products and information systems for underground coal mines are backward.

Thirdly, production & safety monitoring system is the distributed system with poor openness, and different information can not be shared between systems due to information island. Although most coal-mining products includ the automation equipments, there are no communication functions.

Fouthly, a variety of sensors are used in coal-mining enterprises, but there are the huge gap between China and abroad ones especially in the field of useful life, product quality and sensitivity compared with international standards.

Fifthly, the coal-mining enterprises lack a unified production safety information construction and development planning, there are no clear goals, lack of complex talents with a high level of safety production and information management and the standardized information security production management business processes.

Finally, management information site construction is still at the initial stage in coal-mining enterprises so that page layout, online business, online approval, information interaction, resource sharing, network security and other aspects need to be improved.

5. Conclusion

The necessary security measures are given for Huaibei Mining Group.

First of all, the coal-mining enterprises should conduct the implementation of enterprise information project. The information system of safe production can be established to form a set of technical security system framework such as safety production formation training, safety production information technology R&D, safety production monitoring and control as well as accident rescue electronic equipment. The database group and application systems for production safety information can be established to improve the efficiency of emergency response, rescue command decision-making and overall coordination. The information service network infrastructure can be strengthened to maximize the information protection in case of threat violation to ensure the continuity of business operations. The coal-mining safety production information integration system can be established to improve mine safety and production monitoring technical level.

Secondly, the implementation of to coal mine safety technology measures should be accepted. According to the integration of informatization and industrialization, the coal-mining enterprises can step-by-step expand the internet of things technology, new ventilation equipment, the tunnel reinforcement materials, electrical equipment. Implementation of the mechanization and automation can reduce the number of underground personnel, thereby enhancing the safety indicators. In order to promote the security, the long wall method can be used to replace the traditional tunnel excavation.

Thirdly, the worker security measures should be made. Mines can establish a hedging station. Once the danger appears, workers can hide in the hedge station in case of the invasion of harmful gases, where workers can obtain oxygen and food, and wait for rescue. Workers can carry first-aid device. In underground mines, workers must carry personal emergency device and oxygen device. The former can send a distress signal underground the soil and rock, and the latter can increase the safety factor of workers. Workers can request a security survey. If the coal-mining safety problem is serious prior to government inspection, the coal trade unions has the right to prevent workers to go down. Workers can have access to the vocational training. Government security administrative department should organize the security courses with the roving nature mainly for teaching production safety standards and technical equipment operation. It is free for coal miners to attend the course, and the training expenditure is from the government's special training funds.

Acknowledgement

The authors wish to thank for the financial support of China Metallurgical Education Association Project under contract No. 20100713150203015.

References

[1] Bai-Sheng Nie, Peng-Fei Zhao, Jian-Hua Guo, Peng-Peng Niu, Guo Wang. *Fuzzy comprehensive Evaluation of Coal Mine Safety Investment Structure based on the M(1,2,3) Model*. Energy Procedia. 2012; 16: 592-597.
[2] Liu Tiezhong, Li Zhixiang. Theory Review on Firm's Safety Management. *Science and Technology Management Research*. 2009; 2: 149-152.
[3] Jikun Guo, Yongyan Zhang. *Study of Reliability of Substation for Coal Mine Supervision System.* Energy Procedia. 2012; 17: 513-519.
[4] Trent Harkin, Andrew Hoadley, Barry Hooper. *Process Integration Analysis of a Brown Coal-fired Power Station with CO2 Capture and Storage and Lignite Drying*. Energy Procedia. 2009; 1: 3817-3825.
[5] Jacques van Steen. *Safety Performance Measurement*. London: Institution of Chemical Engineers. 1996.
[6] Dan Petersen. *Analyzing Safety System Effectiveness* (3rd ed.). New York: John Wiley & Sons Inc. 1996.
[7] Chengying HE, Qingzhen Xu, Ying Liu. A New Portfolio Optimization Model in Securities Market: Empirical Evidences from China. *AISS.* 2012; 4: 244 -250.
[8] Li Min.*Evaluation and Optimization of Coal Resource Tax Based on the Comprehensive Analysis Model. AISS*. 2012; 4: 13: 365- 372.
[9] Xudong Yang, Liangliang Jin, Jiachun Li, Dong Sun. Design and Analysis on the Structure of Coal Mine Rescue Capsule. *JCIT.* 2012; 15: 252 -260.
[10] Liu Rong. *The Study on Large-scale Construction Engineering Quality Risk Management.* Energy Procedia. 2011; 13: 2578-2584.