Research on construction method and information system of double prevention mechanism in iron mine

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Abstract. At present, there are many problems in the construction process of the double prevention mechanism in iron mine, such as unclear construction steps, disconnection of construction process, and deviation of construction priorities, et al. Based on the PDCA cycle mode and the improved risk assessment method for working conditions, the construction method of double prevention mechanism in iron mine is analyzed and studied. The yaahp meta-decision software (Analytic Hierarchy Process software) is used to determine the weight of hazardous factors and their corresponding control measures. The concept of "failure frequency" is put forward and the calculation method of accident probability (L) is modified to realize the accurate hierarchical control of accident risk; At the same time, the failure of control measures is defined as "hidden danger", and then the transmission mechanism of hidden danger investigation and management and risk grading management and control is established. The "Information management system of double prevention mechanism in iron mine" is developed by adopting the B/S structure to realize the informatization of the double prevention mechanism construction. According to the above methods and steps, the double prevention system of iron mine can be reasonably established to effectively identify risks and control hidden dangers and provide favorable guarantee for the safe production of iron ore.

1. Introduction

Most iron mine enterprises in China are small in scale, widely distributed, poor in foundation, chaotic in safety management and the accidents happen frequently. The situation of safety production in iron mine industry is still grim. In accordance with the latest requirements of the State Council’s "Opinions on Implementing the Guidelines for Preventing Major and Major Accidents and Establishing a Double Prevention Mechanism" (2016) [1] and "Work Safety Law of the People's Republic of China" (revised in 2021), all enterprises need to establish double prevention mechanism which contains the grading management and control of risk and the investigation and management of hidden danger. Since 2016, all parts of the country have studied and explored for the construction of double prevention mechanism, such as Shandong, Henan, Zhejiang, and so on. Some provinces have issued local standards, guidance manuals or implementation guidelines for the construction of the double prevention mechanism; Lei Changqun [2], Wu Daming [3], Li Quanming [4] and other scholars have...
deeply analyzed and studied for the construction of double prevention mechanism in mine industry; Shenhua Group Co., Ltd., Henan Xin Anli Safety Technology Co., Ltd, Xuzhou Kean Safety Equipment Co., Ltd. and other companies have also developed a supporting information system for the construction of enterprise double prevention mechanism and have a good application effect. Nevertheless, the construction of double prevention mechanism in iron mine enterprises still has big problems, such as hidden danger troubleshooting and risk assessment are out of step, emphasis on form over effect, and difficulty in the implementation of management information system. Therefore, this paper puts forward double prevention mechanism construction process and method based on PDCA mode, the improved risk assessment method for working conditions and hierarchical analysis method, to realize dynamic risk assessment and hidden danger investigation and management; At the same time, the B/S structure is adopted to develop the supporting "information system of double prevention mechanism in iron mine" to improve the informatization level of the construction of double prevention mechanism in iron mine. The double prevention mechanism and the establishment in iron mine can change its traditional safety management mode, realize the pass forward and active defense, and effectively improve the safety management level in iron mine.

2. PDCA operation mode of the double prevention mechanism of iron mine

According to the principle of the system, the principle of correlation and the requirements of continuous improvement, the specific working steps of the construction of the double prevention mechanism of iron mine are divided into the four major links of the PDCA Deming cycle (Plan-Do-Check-Act), which can make the project more organized, more scientific and more rational. Each step of the PDCA Deming cycle organically combined and interrelated, the whole operation mode should ensure the process control and effectiveness, and ultimately achieve continuous improvement.

The PDCA operation mode of the iron mine double prevention mechanism is shown in Figure 1.

![PDCA operation mode of iron mine double prevention mechanism](image)

Figure 1. PDCA operation mode of iron mine double prevention mechanism.

3. Specific implementation steps for the construction of the double prevention mechanism for iron mine

3.1. Preparation phase

To make the double prevention mechanism effective, relevant iron mine departments must make relevant preparations. The first is to determine and improve the relevant work institutions and work systems for the construction of the double prevention mechanism, clarify the content of work, division of responsibilities, safeguard measures and other related content; the second is to carry out training
work, specifically including special sessions by relevant experts for key mine personnel training, intensive training for professional and technical personnel, and training for all employees on risk control and double prevention mechanism construction.

3.2. Identification of hazard sources
(1) Division of risk assessment unit
Divide the plant area into risk assessment units (risk points) according to facilities, locations, locations, areas, operations and operations activities, and divide them into main units, sub-units, smaller sub-units, and post (equipment facility/operation activity) units level by level, Where the post unit is the most basic unit of safety risk assessment.

The divided risk assessment units can be numbered at different levels for subsequent use. Taking the mining (D3) main unit of an iron mine as an example, the division of risk assessment units is shown in Table 1. It is explained that D3,F1,F2,Z1,Z2,G1,G2,G3 and G4 in Table 1 are the coding symbols for different level units, and different people can make different coding rules.

Table 1. Division of mining (D3) unit of a certain iron mine.

| Serial number | Unit        | Sub-unit    | Smaller sub-unit | Post (equipment facility/operation activity) unit       |
|---------------|-------------|-------------|------------------|-------------------------------------------------------|
| 1             | Mining      | Mine room   | Mining (D3-F1)   | Rock drilling (D3-F1-Z1-G1)                            |
|               |             |             |                  | Blasting (D3-F1-Z1-G2)                                 |
|               |             | Draw ore    | Draw ore (D3-F1-Z2) | Roof cleaning (D3-F1-Z1-G3)                           |
|               |             | Substructure| Substructure (D3-F2-Z1) | Ventilation (D3-F1-Z1-G4)                            |
|               | Substructure|             |                  | Draw ore (D3-F1-Z2-G1)                                |

(2) Identification of hazard sources (dangerous and harmful factors)
According to the standards such as "Classification and Code of Hazardous and Harmful Factors in Production Process" (GB/T13861-2009), "Classification of Accidents of Enterprise Employees" (GB6441-1986) and other standards, identify each risk assessment unit (risk point) in the production process and equipment Sources of hazards (dangerous and harmful factors) in facilities, operating environment, personnel behavior, and management systems.

When identifying hazards, the risk assessment unit is subdivided in the following order: risk assessment unit (risk point) → accident type contained in the unit → each accident is from the unsafe behavior of people (R) and the unsafe state of objects (W, including environmental factors) and management factors (G) to find hazards → specific hazards (dangerous and harmful factors) → recommended control measures.

3.3. Risk assessment
(1) Traditional risk analysis and evaluation methods
Safety personnel should choose different risk analysis and evaluation methods to determine when faced with hazard sources with different characteristics. At present, the risk assessment methods widely used in the market include the risk assessment method of working conditions, the risk matrix method, and the preliminary hazard analysis [5-7]. In the traditional operating condition risk assessment method, the calculation is generally carried out according to Formula (1), based on on-site working conditions (or analog working conditions), an expert group is formed by personnel familiar with working conditions, and L and E are given according to the prescribed standards, C are scored separately, take the average of the three component values as the calculated scores of L, E, C, and use the calculated risk score D to determine the risk level of the working conditions. The value of the
probability of accident (L) in this law is mostly determined by the evaluator according to the evaluation target's situation and the value standard, which cannot reflect the degree of control of dangerous and harmful factors, and there is a large deviation.

\[ D = LEC \]  

In the formula, D is the risk score; L is the probability of an accident; E is the frequency of exposure of the human body to this dangerous environment; C is the consequence of loss once an accident occurs. There are established value tables for L, E, and C, so I won’t repeat them here.

(2) Improved risk assessment method for working conditions

The research team proposed an improved method for evaluating the risk of working conditions. The value of the likelihood of accident (L) was adjusted to the sum of the quantitative assignments of the actual control degree of all dangerous and harmful factors by the accident category. A judgment matrix is constructed for the hazard and harmful factors contained in each accident category and the weight of hazard and harmful factors at each level is calculated by the Analytic Hierarchy Process software (Analytic Hierarchy Process software) which is developed by Shanyi Meta-decision Software Technology Co., Ltd. And then L value is finally determined according to Formula (2); the value and calculation method of E, C, D are the same as Formula (1). The improved work condition risk assessment method introduces the concept of "failure frequency", which can reflect the actual degree of control over dangerous and harmful factors, and can make more accurate judgments on the L value.

\[ L_i = L_{\text{max}} q_{ci} \frac{n}{N} \]  

In the formula, L is the actual calculated value of the possibility of accident. Considering that the risk in actual work is often too large, then the value of L is selected in the score table close to and greater than the value of Li, L_{\text{max}} is the maximum value of L; q_{ci} is the recommended control measure. The weight of; n/N is the failure frequency, where N is the total number of inspections, and n is the number of failures of existing control measures in the total number of inspections.

Since the yaahp meta-decision software is completely developed based on the analytic hierarchy process, the calculation process of analytic hierarchy process will not be described repeatedly here and only the calculation results obtained by using this software will be introduced. For example, the hierarchical structure model and weight of the dangerous and harmful factors and control measures for the roof fall and side falling accident is shown in Figure 2.

![Figure 2](image-url)

Figure 2. D3-F1-Z1-G1 hierarchy model and weight of dangerous and harmful factors and control measures of roof fall and side falling accident.

(3) Carry out risk assessment classification

In the improved risk assessment method for working conditions, the classification method of risk levels is the same as the traditional classification method, which is also divided into five levels according to the magnitude of the risk score (D). Table 2 shows the corresponding relationship between hazard level, risk level, control level and logo color.
Table 2. Comparison table of risk level, control level and accident hidden danger level.

| Corresponding improved LEC method risk level | Level 1 | Level 2 | Level 3 | Level 4 and Level 5 |
|---------------------------------------------|---------|---------|---------|---------------------|
| Risk level                                  | Significant risk | Greater risk | General risk | Low risk            |
| Corresponding color                         | Red     | Orange  | Yellow  | Blue               |
| Control level                               | The company | The company | Workshop | Team, position     |
| General accident hidden danger level         | Level 1 hidden danger | Level 2 hidden danger | Level 3 hidden danger | Level 4 hidden danger |

Table 3 shows the accident risk assessment and analysis of the roof fall and side falling accident in D3-F1-Z1-G1 assessment unit of an iron mine by using the improved LEC Method, where D is determined by Formula (1), L is determined by Formula (2), and C and E are determined by the traditional method.

Table 3. D3-F1-Z1-G1 risk level table of roof fall and side falling accident.

| Serial number | Accident category | Risk and harmful factor category (weight) Qi | Proposed control measures and weights | Existing measures | Failure frequency | Li value | Accident risk assessment (LEC method) D=LEC Grade | Supplement measures |
|---------------|-------------------|---------------------------------------------|--------------------------------------|-------------------|------------------|---------|---------------------------------|-------------------|
|               |                   | Dangerous and harmful factors (code) (weight) | Method training of roof cleaning       | Method training of roof cleaning | 1/3              | 0.6350  | L actual calculated value E C D | Roof cleaning test |
|               |                   |                                             | Strengthen roof inspection            | Strengthen roof inspection | 0               | 0.0000  |                                  | Inspection of operating procedures |
| R(0.5)        | Incomplete roof cleaning (1202) (0.2857) | Operating procedures training             | 0.1169                               | Operating procedures training | 1/3              | 0.3897  |                                  | Strengthen safety awareness |
|               |                   | Strengthen site management                 | 0.0390                               | Strengthen site management | 0               | 0.0000  |                                  |                                  |
|               |                   | Strengthen safety education                | 0.0584                               | Strengthen safety education | 1/3              | 0.1947  |                                  |                                  |
| 1             | Roof fall and side falling accident | The empty roof area is larger than the requirements of operation regulations (210103) (0.1400) | Clarify operating procedures, strict requirements | 0.0933 | 1 | 0.9330 | First level | Clarify operating procedures and strict requirements |
|               |                   |                                            | Strengthen roof inspection            | 0.0467 | 1 | 0.4670 |                                  | strengthen roof an examination |
|               |                   | The empty roof area is larger than the requirements of operation regulations (210103) (0.1400) | Take measures when geological conditions change | 0.0750 | Taken when geological conditions change measures | Strengthen stope observation, inspection | 0 | 0.0000 |                                  |                                  |
|               |                   |                                            | Strengthen the stope observation, inspection | 0.0250 | 0 | 0.0000 |                                  |                                  |
|                                                                 | Time support | Timely support | 0.0379 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
|-----------------------------------------------------------------|--------------|----------------|--------|--------|--------|--------|--------|--------|
| Should be supported but not timely supported                     | Strengthen bolt inspection | 0.0095 | Strengthen bolt inspection | 0.0095 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| (210204)                                                      | Strengthen operation training | 0.0126 | Strengthen operation training | 0.0126 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| No operation requirements or no operation rules                  | Clarify operating procedures, strict requirements | 0.0909 | 1.0000 | 0.9090 | 0.9090 | 0.9090 | 0.9090 | 0.9090 |
| (4304)                                                      | Clarify operating procedures and strict requirements | 0.0909 | 1.0000 | 0.9090 | 0.9090 | 0.9090 | 0.9090 | 0.9090 |
| Employee training is inadequate or untrained                     | Strengthen operation procedure training | 0.0364 | Strengthen operation procedure training | 0.0364 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| (4304)                                                      | Strengthen safety awareness training | 0.0182 | Strengthen safety awareness training | 0.0182 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| G(0.2)                                                            | Risk disclosure | 0.0364 | Risk disclosure | 0.0364 | 1.0000 | 0.3640 | 0.3640 | 0.3640 |
| Job risk not disclosed                                            | Compiling qualified emergency plans | 0.0061 | Compiling qualified emergency plans | 0.0061 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| (4303)                                                      | Have an accident respond in time | 0.0121 | Have an accident respond in time | 0.0121 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

The improved risk assessment method for working conditions can concisely and efficiently express the typical accidents of each evaluation unit, such as occupational injury accidents, poisoning suffocation accidents, mechanical injury accidents, and falls from heights, and their risk levels, as well as the various typical accidents corresponding to each. The weight of control measures enables iron mine to implement targeted measures to reduce the incidence of typical accidents and also effectively reduce the risk level of each evaluation unit.

### 3.4 Risk grading management and control

According to the results of the risk assessment, the enterprise shall conduct management and control of different risk levels. Risk grading management and control should follow the principle that the higher the risk, the higher the level of control. Operational activities that are difficult to operate, have a high level of risk, the operation activities that may cause serious consequences should be focused on management and control. Risk management and control levels can be added or merged. Enterprises should reasonably determine the management and control levels of risks at all levels based on the basic principles of risk grading management and control, combined with the organization settings of the unit; at the same time, the enterprise should supervise and urge the implementation of control measures and responsibilities, and strengthen the risk of change control and carry out security risk announcements. The flowchart of hazard identification, risk assessment and risk grading management and control are shown in Figure 3.
Figure 3. Flow chart of identification of hazard sources, risk assessment and risk grading management and control.

3.5. Hidden danger investigation and management

According to the "Interim Regulations on the Investigation and Treatment of Potential Hazards in Work Safety", hidden accidents are divided into general accident hidden dangers and major accident hidden dangers. The research team defined the failure of control measures as "hidden dangers", and classified the hidden dangers of accidents into one, two, three, and four levels, and the four colors of red, orange, yellow, and blue were also used to identify them. If all hazard sources (dangerous and harmful factors) and their control measures contained in the risk assessment unit (risk point) meet the national standards for determining the hidden dangers of major accidents in various industries, no matter what the risk level of the risk assessment unit (risk point) is, all hazard sources (dangerous and harmful factors) and their control measures included in the unit are classified as major potential accidents, and all major accident hazards are marked in red. The criteria for determining the hidden dangers of major iron mine accidents stipulated by the state will not be repeated here.

Based on the results of the risk assessment, the enterprise shall formulate a checklist of hidden dangers, carry out the investigation and management of hidden dangers in a timely manner according to the risk control level, and pay close attention to whether the control measures are effective. If the control measures fail, they shall immediately re-apply the risk assessment classification and the hidden danger classification. In this way, a transmission mechanism of hidden danger investigation and management and risk grading management and control has been established, which helps to achieve precise prevention and control of accident risks and hidden dangers.

Hidden danger investigation and management also includes assessment and acceptance of hidden danger management, information recording, notification and submission, so as to realize closed-loop management of continuous improvement such as hidden danger investigation, registration, evaluation, management, acceptance, report and cancellation. The flow chart of hidden danger investigation and management is shown in Figure 4.
3.6. Management review and continuous improvement

In the process of construction and operation of the double prevention mechanism, as long as it is found that the management and control measures are invalid or the implementation is not in place, resulting in the change of risk level or hidden danger level, it is necessary to review and grade again, at the same time, because the internal and external conditions of the mine are constantly changing, in order to make the application of the double prevention mechanism closely follow the actual changes, dynamic risk assessment should be carried out to achieve the purpose of continuous improvement [8-11].

4. "Iron mine double prevention mechanism information management system"

4.1. System development technology and operating environment

The main technical support of the system: the information system development language is Java; the database is mysql; the framework is springboot+mybatis plus; the front-end framework is layui. The server operating environment is Windows 2003 Server (Chinese Version). The client workstation operating environment can be Windows 7, Windows 8, Windows XP or Windows Vista; A mainstream browser can be used, such as Chrome or Firefox.

4.2. System function realization

According to the basic process of iron mine double prevention mechanism construction proposed in this article, the "Iron Mine Double Prevention Mechanism Information Management System" is developed by using computer technology, which can provide corresponding operations for each process in the browser. The functional structure of the system is shown in Figure 5, and the risk management and hidden danger management interfaces are shown in Figure 6 and Figure 7. As the system is developed in Chinese, Figures 6 and 7 cannot be displayed in English.

In general, the "Iron Mine Double Prevention Mechanism Information Management System" mainly implements the following functions.

1) The application system based on the B/S mode can support hierarchical browsing with different permissions [12-15];

2) Be able to upload, search, and manage the legal and regulatory documents, corporate documents, and risk assessment method documents involved in the construction of the double prevention mechanism to form a document database;

3) It can realize the functions of comprehensive identification of hazard sources, accurate risk assessment, risk grading management and control, comprehensive management of hidden danger, closed-loop management of hidden danger acceptance and number cancellation;

4) The system provides a complete iron mine double prevention mechanism database, including a risk database, a hidden danger checklist database, etc., to provide a reliable data source for managers to query data and assist decision-making;
(5) Dynamically monitor the construction and application of the double prevention mechanism, release and update iron mine safety information, plans and notices in a timely manner, and provide early warnings for major risks and first-level hidden dangers.

Figure 5. "Iron mine double prevention mechanism information management system" functional module diagram.

Figure 6. Risk control interface.

Figure 7. Hidden danger management interface.
5. **Current problems in the construction of the double prevention mechanism for iron mine**

   (1) It is difficult to realize the comprehensive construction of the double prevention mechanism

   Although the state has explicitly required iron mines and other non-coal mines to establish a double prevention mechanism, due to factors such as the existence of our country’s iron mines, personnel factors, and management status, most iron mines cannot build construction work of double prevention mechanism actively and positively. It is believed that for a long time, it is still difficult for most iron mines to realize the comprehensive construction of double prevention mechanism.

   (2) Hidden danger investigation and risk assessment are out of touch

   According to the results of risk assessment, the identified dangerous and harmful factors should be investigated and treated in time, so as to realize the function of dual defense barrier. However, at present, the majority of iron mines are only based on laws, regulations and rules when carrying out the hidden danger investigation, which leads to the deviation between the key points of hidden danger investigation and the actual risk points of iron mines. The transmission mechanism of hidden danger investigation and management and risk grading management and control is not established, which not only wastes human and material resources, but also weakens the effect of the double prevention mechanism.

   (3) Pay more attention to construction form than actual effect

   The construction and review and maintenance of the iron mine double prevention mechanism are mostly carried out by safety management personnel. However, in fact, most iron mine safety management personnel are scarce and do not have professional safety capabilities. Therefore, only relying on the safety management personnel for risk grading management and control and hidden danger investigation and management has a big loophole, which can not effectively control the risk and hidden danger, thus making the construction of iron mine dual system become a mere formality [16-17].

   (4) The implementation of the information management system is difficult

   At present, the research and development and construction of information management system of double prevention mechanism have been carried out in mines, but the implementation of information management system involves many aspects such as production process, system and safety management. In order to make the information system play a role effectively, all staff need to participate in and do a good job in the handover work, so the implementation of information management system is difficult.

6. **Discussions and conclusions**

   (1) Combine the iron mine double prevention mechanism with the PDCA operation mode, clarify the specific implementation steps of the iron mine double prevention mechanism construction and explain in detail. The weight of the recommended control measures for dangerous and harmful factors and the "failure frequency" are used to improve the calculation method of the probability of accident (L), and then realize the accurate hierarchical control of accident risk.

   (2) The failure of control measures is defined as "hidden danger", and the transmission mechanism of hidden danger investigation and risk grading control is established to avoid the disconnection between hidden danger investigation and risk assessment, and ensure the construction effect of double prevention mechanism in iron mine.

   (3) According to the actual needs of non-coal mining enterprises, the "double prevention mechanism information management system for non-coal mine" is developed by using B/S architecture. It can be promoted and applied to other mining companies. The application of the system can systematically standardize and improve the mine safety management, and further improve the modern safety management level of enterprises.

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