Research on Safety Risk Pre-control Management System and Its Application in Coal Mines

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Abstract. In order to minimize safety accidents in coal mines, this paper starts from the basic theory on risk management, summarizing the status quo of work safety and existing problems in China’s coal mines. Based on the present safety risk pre-control management system of coal mines, a new safety risk pre-control management system satisfying hazard identification, assessment and management standard formulation process is designed. Through the implementation of the system, a systematic prevention management mechanism and effective preventive and control measures ensure that all kinds of safety dangers fall within the tolerable scope of coal mines.

1. Introduction
Work safety serves as the lifeline of a coal mine enterprise, and is a top priority among its work. However, poor working condition, strong work intensity and various accidents involving fatalities are the features in the work safety of a coal mine. More than ninety percent of the safety accidents in China’s coal mines are related to improper safety management or human errors [1]. In view of the safety management for mines and other risky industries in other countries, risk pre-control has evolved into a popular accident pre-control management mode [2]. It is of significance for coal mines to identify and assess the hazards and then take measures before an accident occurs. Based on this, this paper designs a safety risk pre-control management system, which can effectively enhance the safety management and guarantee the work safety of coal mines.

2. Status quo of and problems in China’s coal mines
In 2016, the fatality rate per million tons of coal in China’s coal mines was 0.156 thanks to improved scientific and technological advancement and safety management. This is much better than years ago. Compared with the developed countries like the United States of America, a big gap exists. China’s coal mine enterprises are found to be puzzled by the following problems, through investigating and analyzing the status quo of their safety management:
2.1. *A set of effective safety management system yet to be formed*

Although a coal mine enterprise has established a lot of safety management measures and systems, they are inadequate in mutual support. For example, through training its employees, the enterprise has largely identified the hazards, and then established relatively complete safety management systems, but such systems are isolated and scattered, and no effective risk pre-control system centering on the hazards has not been formed. This leads to poor pre-control result and hardness in enhancing safety management [3].

2.2. *Poor enforcement of work safety management*

In some coal mine enterprises, a range of reward and punishment systems for hazard identification and deficiency screening have been established, but no omnibearing, all-employee and entire-process management is not realized, so the systems are inadequately enforced. The underlying reason is lack of a set of scientific and perfect work flow of safety management, and failure to form a closed-loop system for deficiency screening, correction and reexamination, leading to unsatisfactory safety management [4].

2.3. *Safety management mechanism and method demands innovations.*

Many coal mine enterprises advocate the management concept of “everyone is a safety inspector, everyone is a safety manager”, but no supporting management mechanism is available. At present, they rely mainly on safety inspectors to strictly perform their duties for safety management. Once the safety inspectors find safety problems, they will impose heavy fines. Such punishment is likely to trigger a confrontation between the safety inspectors and frontline workers. Meanwhile, heavy fines are a post-control way of management, but safety management should stress on “problems need to be nipped in the bud”. Hence, a safety management reporting mechanism should be established by which the whistle blowers of safety deficiency are rewarded, forming a work pattern of everyone participating in safety management [5].

3. *Connotation and general approach of safety risk pre-control management system*

Against the problems in safety management of coal mines, the safety risk pre-control management system applies a systematic analysis methodology for omnibearing and systematic risk analysis of the entire process of a coal mine enterprise operation activities, to determine the possible harms among the production activities and the consequences in health and environment. Through systematic preventive management mechanism and effective preventive and control measures, the system serves to ensure all safety deficiencies falling within the tolerable scope of the enterprises.

Research on the safety risk pre-control management system mainly consists of three stages: hazard identification, safety risk management model construction and system construction. The system is constructed according to what to manage, how to manage, and how to efficiently manage, as follows:

In the first stage, such methods as field observation and job task analysis are employed to systematically analyze and identify hazards, to perform risk analysis as to the entire process of coal mine production activities, to determine the root causes likely leading to death, injury, occupational diseases, property loss or their combinations, and their possible consequences, to establish and improve the system of hazard level criteria, and to form a hazard database.

In the second stage, based on hazard identification and grading, such methods as fault tree analysis, causal analysis and dynamic risk grade assessment are employed to construct the safety risk early warning model, to optimize safety risk management process, to establish and improve the safety management standard system on how to report, how to correct, whom to correct, whom to reexamine safety risks, and to form the safety culture and system.

In the third stage, computer information technology is introduced into safety management [6]. All jobs involved in coal mine safety management are integrated by relying on object-oriented analysis and design technology, SQL Server as backstage database, and VS.Net2008 as development platform,
to form the safety risk management information system platform. The design ideas are shown in Figure 1.

**Figure 1.** Design concept of safety risk pre-control management system

### 4. Design of safety risk pre-control management system

According to the item connotation and research idea, the safety risk pre-control management system includes four modules: safety risk database, safety risk accident model, safety risk management system and safety risk pre-control management information system.

#### 4.1. Safety risk database

**4.1.1. Hazard database** [7]. Hazards are the root causes or states which may lead coal miners at work to die, be injured, suffer from occupational diseases, property loss, working environment to be damaged or the combinations, which are the preconditions for accidents to happen. Major tasks of hazard identification include, in the working environment of coal mines, identifying safety risk hazards, defining safety risk types, unifying safety risk language, and forming the safety risk database unique to the coal mine enterprises, to provide information basis for determining the management objects and responsible subjects.

**4.1.2. Safety risk control criteria system.** Safety risk control criteria system is, during the operation of coal mines, the operation standard and criterion formulated to guarantee the operators to operate safely, correctly, effectively and by standard. Based on the available safety job process made by the coal mine enterprises, and by integrating these job procedures with the potential danger, presence conditions and triggering factors of hazards, different safety risk control criteria systems are worked out for different type of work, to ensure the completeness and correctness of the safety risk control system.

#### 4.2. Safety risk pre-control management model

Safety risk pre-control management model is a preventive management mechanism established following building of the safety risk database, and also the management means to eliminate deficiencies through effective preventive and control measures [8]. The safety risk pre-control
management model is the core part of the safety risk pre-control criteria system, which mainly comprises three aspects: fault tree analysis, hazard grade assessment and safety early warning model.

4.2.1. Fault tree analysis. Fault tree analysis is a deductive inference method. By qualitative and quantitative analysis of fault tree, main or potential cause of accidents are found out, and their logical relationship with the top event is revealed, the relevance of hazards is identified, to provide reliable ground for safety decision making [9]. Fault tree is unfolded from the idea of analyzing the causes of accidents. By depicting fault tree, one can familiarize himself with the production process, and get to know the conditions for accidents to happen. Therefore, it is a good means for safety education on technicians or operators.

4.2.2. Hazard grade assessment. Hazard grade assessment tends to provide grounds for drawing up hazard control strategy. Different from the previous safety management giving each hazard a fixed grade, we give dynamic assessment of the hazard. Namely, in consideration of the approximation of the reported value and critical value of the hazard urgency degree, the contribution of the hazard to the accident and the loss of the accident, the dynamic assessment model for the hazard is built. According to the model, control measures to be formulated for the hazards at different grades can effectively avoid the accidents or troubles. The idea for building dynamic safety risk grade model is shown as Figure 2.

![Diagram](image.png)

**Figure 2.** The idea for building dynamic safety risk grade model

4.2.3. Safety early warning model.

The idea on building the safety early warning model is: First, through the analysis of fault tree, the association of hazards is found out. When a hazard is reported as a deficiency, other associated hazards that trigger an accident are considered focal supervised objects, thus the inducing causes of the accident are cut off, and the accident is avoided. Second, based on the early warning of safety management objective, the objective of coal mines is decomposed and fulfilled to each hazard, and the hazard control standard is formed. In safety management process, actual safety condition is compared with control objective to determine periodic focus of safety management. The idea on building the safety early warning model is shown as Figure 3.
4.3. Safety risk management system
Safety risk management system is the support for coal mine enterprises to carry out safety risk pre-control management, and guarantees the implementation of safety risk pre-control system [10]. Safety risk management system is built mainly from management process and supporting system.

4.3.1. Optimization of management process. Real time pre-control management process of safety risk is a work process of closed-loop circulation, and is the basic work mechanism by which real time early warning and pre-control management function of safety risk gives to play [4]. In order to optimize the existing safety risk pre-control management process, based on sorting out the existing process, work process of safety risk management process is optimized, which includes how to report, correct, improve safety risk and whom to correct it. The concept of real time pre-control management of safety risk is added. Subsequently, a closed-loop and reciprocal management process is formed, from hazards being reported and addressed, ensuring the real time early warning pre-control management function giving to play.

4.3.2. Establishment of safety risk pre-control assurance system. Safety risk pre-control assurance system is built to assure smooth realization of safety risk pre-control management system. By establishing hazard reporting mechanism, the whistle blower is rewarded materially or spiritually. By scoring method, assessment is made from reporting quantity, reporting grade, deficiency confirmation and correction, and the number of safety accidents. Ultimately the mark of safety risk pre-control appraisal is obtained, and material reward is given according to the mark. In addition, safety risk management culture system is established from conceptual culture, system culture, behavioral culture and material culture. Conceptual culture is the core and soul of safety culture, and is the basis and cause of forming and improving safety behavioral culture, system culture and material culture.

4.4. Safety risk pre-control management information system
Safety risk pre-control management information system is the system platform on which the performance of safety risk management of coal mine enterprises is enhanced, is the information system by which safety deficiencies are transmitted and dealt with, and is the important means by which safety risk pre-control management system is implemented [11].

Safety risk pre-control management information system consists of deficiency management, three violations management, accident management, pre-control management and performance appraisal.

4.4.1. Deficiency management. In deficiency distribution, the location of deficiency being reported is shown, and is visually displayed in process chart. After the deficiency is confirmed, red light will twinkle on the location of the process chart, serving for continual alarm.

Figure 3. The idea on building safety early warning model
4.4.2. **Three violations management.** Three violations management records in details the time of occurrence of three violations, risk grade, the violating person, investigating person, executing person and handling suggestion, while the accident analysis report and all kinds of statistical forms of the accident are automatically generated.

4.4.3. **Accident management.** Accident management records, in details, the time and location of occurrence, type, grade, responsible person, course, reason of and handling suggestion for the accident. The system can automatically generate accident analysis report and all kinds of statistical forms of the accident.

4.4.4. **Risk pre-control.** Risk pre-control includes fault tree analysis, early warning query, LED screen and short message.

4.4.5. **Performance appraisal.** Performance appraisal includes deficiency reporting statistics, safety performance appraisal, and appraisal system query. Deficiency reporting statistics mainly target to count the quantity of the deficiencies reported by employees from the inspected department, type of inspection, and expected location. Safety performance appraisal announces the performance appraisal result of employees according to the result of deficiency reporting statistics. The appraisal system provides employees with a safety appraisal management system, to facilitate employees to clearly know the appraisal system.

5. **Conclusion**
The paper designs a safety risk pre-control management system, which integrates the safety management, three violations management and accident management of coal mine enterprises. Main conclusions include:

1) According to hazard identification and risk assessment system process, hazard grade criteria system is drawn up, and a safety risk database is formed, which builds the grounds for building and application of the later safety risk early warning model.

2) By integrating fault tree analysis, hazard grade assessment and safety early warning model, effective preventive and control measures are adopted to eliminate various safety accidents and guarantee the work safety of coal mines.

3) For the safety deficiencies to be reported in real time, the system can receive information, in time and keep track of the hazard processing information in real time, and keep track of and deal with the hazards for safety managers, realizing the prevention of the accident.

4) The safety risk pre-control management function contained in the system is state-of-the-art, which to large extent prevents accidents or finds out the accident sign in time, thus guarantees the work safety of coal mines.

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