Human Factors Analysis of Coal Mine Safety Accident Based on HFACS and AHP

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Abstract

In order to objectively analyze the causes of coal mine accidents. Using the method of consulting the literature, the main human factors in the causes of coal mine accidents are sorted out, and an improved HFACS model is established. Combining with an example of gas explosion in a coal mine in Inner Mongolia, AHP is used to analyze the weight of each element in the model. The result shows that the premise of unsafe behavior and unsafe behavior is the highest weight among all factors., and the relevant coal mining enterprises can start from these two aspects to prevent the occurrence of coal mine accidents and improve the safety of coal mining enterprises.

Keywords

Human Factors Analysis and Classification System(HFACS), Analytic Hierarchy Process (AHP), coal mine safety accident,human factor analysis.

1. Introduction

In China, the main cause of safety accidents in coal mines is human factors. Therefore, it is particularly important to use the Human Factors Analysis and Classification System (HFACS) to classify and analyze the factors that cause coal mine accidents and identify the main causes.

The HFACS model was established by Wiegmann and Shappell [1] ,it is based on the cheese model proposed by Reason. It mainly includes four parts: unsafe behavior, the premise of unsafe behavior, unsafe supervision, and organizational influence. After continuous development and research, HFACS has made great changes and is widely used in medical, railway, coal and other fields. Krulak [2] used the HFACS-ME classification to analyze 1016 aircraft accidents caused by human factors and found that among the many factors, the most important factors were inadequate monitoring, poor attention and judgment errors. Michael [3] and others used the HFACS model to analyze 263 major coal mine accidents in Australia from 2007 to 2008 as a sample. The analysis results showed that reducing unsafe behavior requires focusing on the organization atmosphere, lack of planning, and inadequate supervision. aspect. Patterson[4] et al. used a modified version classification system for human factor analysis to analyze 508 coal mine safety accidents in Australia Queensland, identified human factors and system defects in mining, and data analysis showed that skill-based errors were the most common unsafe behavior. Song Zeyang, et al. [5] improved the HFACS model and established a HFACS framework suitable for coal mine safety. Through the study of relevant documents, it is found that applying the HFACS model to the coal mine safety field needs improvement. It should increase the organizational external factors that are not involved in the model, and then use the quantitative analysis method to calculate the weight of each factor.

2. HFACS Model Reconstruction

Although HFACS has been widely used in the field of coal, its own limitations still exist. The HFACS model was originally established for the investigation and analysis of aviation safety accidents. The aviation field and the coal field are two different fields, and their respective constituent elements are different. For example, the unit resources under the premise of unsafe behavior in the HFACS model should be replaced by team resource management in the coal field. HFACS analyzes the causes of accidents in terms of "man, machines, environment, management". However, accidents are also affected by social factors [6].

Based on the above analysis, an improved HFACS coal mine accident human analysis model has been established as shown in Figure 1. The social factors has been added to the original model of the HFACS. The impact of the model from top to bottom on the occurrence of accidents has increased.

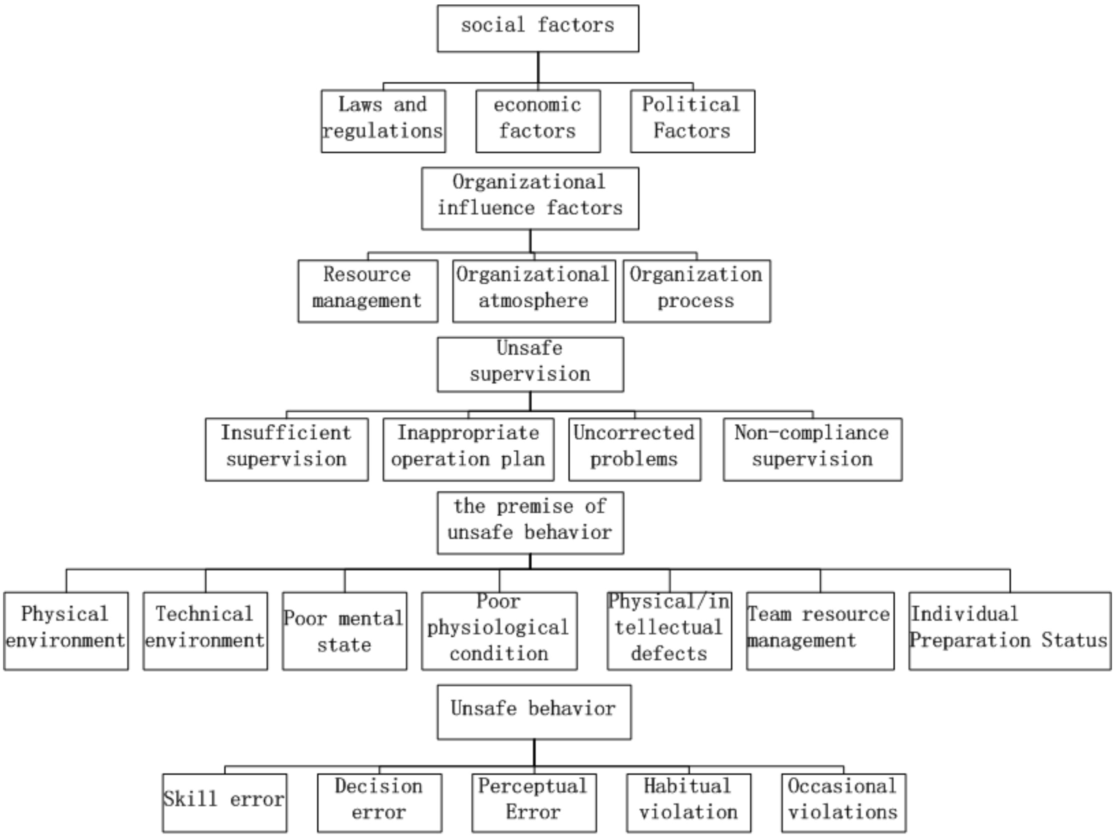

Fig.1. Improved HFACS Coal Mine Safety Incident Human Model

The connotation of each index of the improved HFACS model is shown in the table below. Table 1 elaborates the influencing factors of the five levels of the model in detail to facilitate the accurate identification of the level of each factor and provides a basis for the analysis of the causes of the accident.

3. Accident Quantitative Analysis Method

Accurate and objective evaluation and analysis of accidents requires the combination of qualitative and quantitative methods. HFACS is a qualitative analysis method. The analysis results obtained are not objective enough and need a quantitative analysis method to support it. AHP is a relatively objective quantitative analysis method. Therefore, the quantitative analysis of the causes of accidents in this paper uses the AHP method.

AHP is a method of analysis proposed by Professor T.L. Satty of the United States. It is now widely used in various fields to resolve complex problems into several levels.

The steps for using the AHP method are: (1) Establish a hierarchical model based on the problem to be solved. (2) Construct a judgment matrix based on the relative relationship between various factors. This step is the most important step in the entire AHP. (3) Through the calculation of the judgment matrix, the weight value of each factor is obtained, and the consistency is checked and then the level is singled. (4) Total ranking of all elements.

Table 1. HFACS index and index content overview

Human Factors Content		Description
social factors	Laws and regulations	Coal Mine Safety Laws and Regulations promulgated by the State Council and relevant regulatory policies announced by the State Administration of Work Safety
	economic factors	National economic regulation of the coal industry
	Political Factors	National policy factors on coal mines, such as energy conservation and emission reduction
Organizational influence factors	Resource management	The human and material resources required for production
	Organizational atmosphere	Corporate atmosphere, employee responsibility and other spiritual factors
	Organization process	The process of production and supervision
Unsafe supervision	Insufficient supervision	Inadequate management of human and material resources
	Inappropriate operation plan	Enterprise production and operation management
	Uncorrected problems	Failure to take timely measures to correct existing equipment and personnel problems
	Non-compliance supervision	In the on-site supervision of production operations, it was not carried out in accordance with the system prescribed in advance.
the premise of unsafe behavior	Physical environment	The Physical environment is also production environment, includes factors such as temperature, humidity, light, noise and ventilation.
	Technological environment	Including the use of machinery and equipment, production processes and other technical factors
	Mental aberration	Workers suffer mental fatigue, job burnout, etc. due to psychological reasons
	Poor physiological condition	Employees cannot guarantee work safety because of their own physical conditions (disease, poisoning, etc.). Such as illness, etc.
	Physical/intellectual limitations	Physical conditions, IQ, etc. do not meet the requirements of human safety in production, such as defects in vision, hearing, intelligence, etc.
	Team resource management	Human and material management of team
	Personal preparation status	Work training, eating conditions, schedules, etc.
unsafe behavior	Skill error	It is mainly because employees do not possess a certain level of knowledge, skills, experience, or lack of skills and experience necessary for work, resulting in accidents.
	Decision errors	Wrong or unilateral plan, manifested as execution error, selection error, etc.
	Perceptual errors	Workers lack sufficient self-knowledge about their work environment and the risks that may exist during production operations[7]
	Habitual violation	Formed in the long-term production process and evolved into a habitual behavior that is acquiesced by internal supervision
	Occasional violations	In the production process, accidental irregularities

4. Case Study of Coal Mine Safety Accidents

The improved HFACS model was applied to specific coal mine safety accidents to verify its effectiveness and feasibility.

4.1 Overview of the Accident

A particularly significant gas explosion occurred in the Baofeng mine in Chifeng, Inner Mongolia, in December 2016. The accident caused a total of 32 deaths, more than 20 injuries, and direct economic losses of 43.99 million yuan.

4.2 Accident Cause Identification

Based on the improved HFACS model, the cause of this serious gas explosion accident was analyzed. According to the cause category in the model framework and associated accident information in the accident report [8], the following causes of the accident are sorted out and analyzed using the AHP method.

According to the five secondary factors listed in Table 2, 17 tertiary factors, relevant experts and business leaders in the field of coal mine gas safety research were hired to score them. Sort the scoring data, construct a judgment matrix, use Yaahp software to calculate the weight of each factor and its consistency ratio. The results are shown in Table 3.

From the above table, it can be seen that the consistency ratio of each criterion layer is less than 0.1 and the weight value is available. The consistency check formula for the total order of levels is

$$CR = \frac{\sum_{j=1}^{m} a_j CI_j}{\sum_{j=1}^{m} a_j RI_j} \tag{1}$$

After calculation CR=0.0066<0.1. So the weight of each factor is available.

4.3 Analysis of Results

From Table 3, we can see that in this gas explosion accident, unsafe behavior is the main source of the causal factor, followed by the premise of unsafe behavior and unsafe supervision. Among all the causal factors, the skill errors, violations, and personal preparation status of the incident's measure layer are relatively high, indicating that these factors are the source of the accident. Therefore, companies can strengthen related aspects of prevention and management to achieve the goal of safe production.

5. Conclusion

(1) According to the special circumstances of coal mining enterprises, improve the HFACS model and analyze the human factors that cause major accidents in coal mines from five aspects: unsafe behavior, the premise of unsafe behavior, unsafe supervision, organizational influence, and social factors. There are 22 human factors that affect the safety of coal mines.

(2) In order to make the analysis results more persuasive, a quantitative gas analysis method was used to analyze the major gas explosion accidents in the Baoma Coal Mine in Inner Mongolia in 2016. The analysis showed that the main cause of the accident was the failure of the miners and their managers. The premise of safe behavior and unsafe behavior are two levels. Therefore, in the prevention of gas accidents in coal mines, it is important to manage this factor.

(3) Combine the HFACS model with AHP and apply it to the field of coal mine safety. The combination of these two methods can improve the subjectivity of coal mine safety accident investigations, avoid the omission of influencing factors, and provide a reference for the management of coal mine safety production.

Table 2. Statistics of Causes of Accidents

Guidelines level	Measures Layer	Unsafe factors Description
Social Factors B1	Laws and Regulations C1	Employees are unaware of compliance with relevant laws and regulations.
	Economic Factors C2	Coal Price Increase Leads to Coal Mining Increase
	Political factors C3	Relevant authorities of the state have not overseen the violation of development regulations
Organizations influencing B2	resource management C4	special jobs, too few staff, insufficient safety inputs, etc.
	Organizational climate C5	Long-term violation of laws and regulations, did not form a good atmosphere for safe production
	Organizational Process C6	Production of Illegal Organizations
Unsafe supervision B3	Insufficient supervision C7	Under the mine production only one inspector
	Inappropriate operation plan C8	Production management is confusing, adopting the state-prohibited "roadway type coal mining" process
	Supervision and non-compliance C9	did not implement ventilation management according to the prescribed system, and the electrical equipment management system was not implemented.
the premise of unsafe behavior B4	Physical environment C10	Poor production environment, with under mine oxygen concentration greater than 12%, meeting gas explosion conditions
	Technical environment C11	Defective technical equipment, using a local fan to supply wind to two excavation sites at the same time
	The team resource management C12	is not equipped with a methane detection alarm, illegal command
	Individual Preparation Status C13	Under the mine operation procedures not understudied
Unsafe behavior B5	Skill error C14	The electrician did not test the gas concentration as required and started the local fan.
	Decision error C15	Failure to withdraw to a safe area during a power outage, but resting before the blind alley is closed
	Perceptual Error C16	Adventure operation
	ViolationC17	Welder's illegal welding bracket

Table 3. Causes of Gas Explosion Accident Factors

Guidelines level	Weights	Consistency Ratio CR	Measures Layer	Weights
Social Factors B1	0.0598	0.0032	Laws and Regulations C1	0.0255
			Economic Factors C2	0.0185
			Political factors C3	0.0159
Organizational influencing B2	0.0683	0.0002	Resource management C4	0.0218
			Organizational climate C5	0.0184
			Organizational Process C6	0.0280
Unsafe supervision B3	0.2105	0.0013	Insufficient supervision C7	0.0583
			Inappropriate operation plan C8	0.0675
			Supervision and non-compliance C9	0.0864
the premise of unsafe behavior B4	0.2800	0.0168	Physical environment C10 Individual	0.0496
			Technical environment C11	0.0617
			The team resource management C12	0.0826
			Preparation Status C13	0.0861
Unsafe behavior B5	0.3815	0.0021	Skill error C14	0.1324
			Decision error C15	0.0740
			Perceptual Error C16	0.0639
			ViolationC17	0.1111

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