



Research on the Human Causes of Coal Mine Roof Accidents Based on Association Analysis

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Abstract. Unsafe human factors are significant cause of coal mine accidents, and roof accidents are the key prevention accidents in coal mines. In this paper, 115 reports of roof accidents are deeply mined and combined with HFACS model theory to form a table of human factors of roof accidents with three primary factors of supervision-management-production and 22 secondary factors such as unscientific formulation of safety supervision plan, to determine the existence of human factors in accidents through retrospective reports, to generate the RAHCS, and to propose control measures for different levels of roof accidents from supervision, management and production under Apriori association algorithm, to provide theoretical data support for enhancing human factors control.

Keywords: Association Analysis · Apriori · HFACS · Topside Accident · Human Factors Analysis

1 Introduction

Accident statistics show that the coal mine safety situation has improved greatly in recent years, but coal mine accidents still occur one after another, and the overall safety situation is still severe [10], of which, human causes account for more than 70% of accident causation, to scientifically control human causes and avoid accidents, domestic and foreign scholars have been involved from the neural mechanism at the micro-level [8] to the safety supervision mechanism at the macro-level [6]. However, the existing research treats accident human factors as a specific behavior mostly, ignoring the behavior generating triggering mechanism as well as the behavior law, and the development of control strategies are easy to treat the symptoms but not the root cause, so based on macroscopic, the study of accident human factors law to achieve a reasonable allocation of safety resources and improve the efficiency of human factors control has a certain novelty.

According to the statistical analysis of accidents from 2008 to 2020, among the eight types of coal mine accidents: roofing, gas, water damage, fire, electromechanical, transportation, cannon discharge, and others, roofing accidents occur most frequently and account for the second-largest number of fatalities, indicating that roofing accidents and disasters are the key prevention objects in the process of coal mine safety production,

and it is important to research them. The accident report [9] is a deep investigation of the accident by relevant experts and government personnel to collect information at the accident site, etc. It can be used as a text-based early warning tool to prevent accidents [3]. With the development of computer technology, data mining technology has been extended in various fields [1], and currently, Jue Li et al. [5] analyzed the accident causation network for text mining of fall from height accidents in the construction industry. Chen [2] established an HFACS analysis model containing six types of accident causal factors and adapted it to the building construction industry based on the current situation of building construction safety and accident statistics. The above study combined data mining techniques and accident reports to provide a reference for accident prevention. Therefore, in this paper, based on the HFACS model and association rule mining technology, the accident human factors study is carried out on the roof accident report to provide opinions and countermeasures to improve the control of the human factor and prevent the occurrence of roof accidents in coal mines.

2 Accident Report Collection and Processing

Since accident reports have a generally high degree of detail reduction, credibility, and authenticity, and also contain specific unsafe behaviors of coal mine workers in the production process, they can be used as a data basis for worker control. In this thesis, by collecting more than 130 accident reports from the National Emergency Management Bureau website, the coal mine safety production network of each province, and other websites, after manually removing accident reports such as insufficient information, a total of 115 available data were obtained, which were sorted by time and systematically organized to obtain Table 1. Among them, the obtained accident reports were from 2016 to 2021, involving 19 provinces, with Sichuan and Hainan provinces being the most numerous. Followed by Hebei, Xinjiang, and Jilin provinces and the accident types included three major categories of general accidents, larger accidents, and major accidents, with no particularly major accidents.

3 Research on the Human Factors

3.1 Analysis of Human Causes Of Coal Mine Accidents

HFACS model is a theoretical tool for human factors analysis, which can be appropriately adjusted according to the specific characteristics of the study area, mainly including four levels of organizational management influence, unsafe supervision, unsafe behavior preconditions, and unsafe behavior, the framework model not only takes into account human unsafe behavior and its potential factors but also can systematically analyze human factors, which is of great significance for determining the human causes of accidents and It is of great significance to determine the human causes of accidents and formulate corresponding accident prevention measures.

Based on the review summary of roof accident reports, under the theory of the HFACS model, it is determined that the subdivision is carried out from three levels of supervision, management, and production to form the framework of human factors of roof accidents as shown in Fig. 1.

Table 1. Roof accident report statistics table

Num	Time	Accident Name	Level	Province	Accident Report Contents
1	2021	Shaanxi Binchang Company Hujiahe coal mine 1011 impact ground pressure accident	Larger Accident	Shaanxi	October 11, 2021, Shaanxi Binchang Company.....
2	2021	Qitaihe Lushan Quality Coal Co., Ltd.'s second well "10-7" large impact ground pressure accident	Larger Accident	Heilongjiang	October 7, 2021, 18:00, Qitaihe City.....
.....
115	2016	Huabei Mining (Group) Co., Ltd. Yuandian a good coal mine "1-2" roof accident	General Accident	Anhui	January 2, 2016, 9:02 pm Huabei Mining.....

3.2 Determination of The Human Cause Matrix For Roof Accidents

To determine whether the factors in Fig. 1 existed for each event, the current factors were coded as "1" if they existed, and "0" if they did not exist, and to judge the influence of subjective determination, three statisticians performed the statistics at the same time, and if there were differences, the differences were decided through retrospective reports and discussions, and Table 2 was obtained.

Each incident report in the above table is represented by transforming it into a one-dimensional matrix of length 25, as follows:

$$[0 \ 0 \ 1 \ 0 \ 1 \ 1 \ 1 \ 1 \ 1 \ 0 \ 1 \ 1 \ 0 \ 0 \ 1 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 1 \ 0 \ 1 \ 0]$$

The resulting RAHCS (Roof Accident Human Causes Set) is represented by a 115*25 matrix, with each row representing the human cause information of a specific accident. After obtaining the analysis data, the next step is to perform correlation analysis on the obtained RAHCS with Python code under the Jupyter plugin with the help of the Pandas library.

4 Human Factors Association Analysis

4.1 Association Analysis and Apriori Algorithm

Association analysis [7] is an algorithm to find frequent patterns between sets of items or sets of objects, and the analysis needs to determine the determination of frequent item

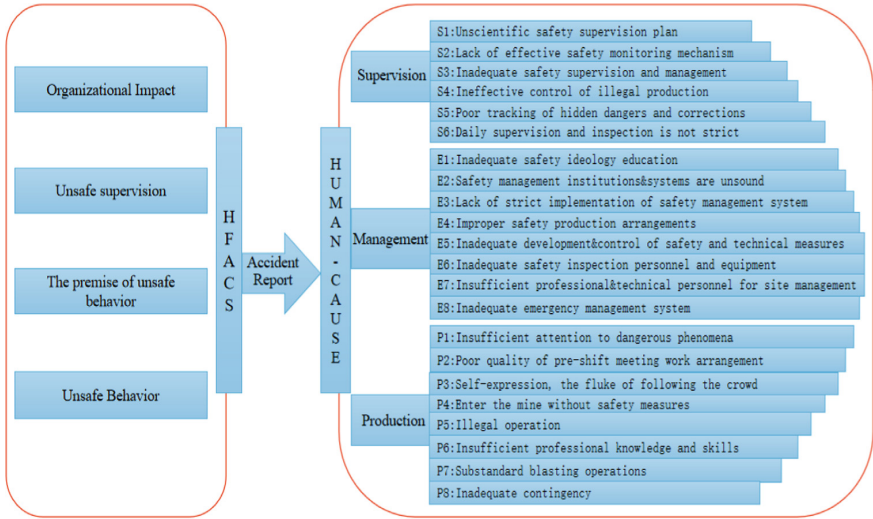


Fig. 1. Human factors framework for roofing accidents

Table 2. Roof accident human cause matrix

Id	Supervisory Level						Management Level								Production level								Accident level		
	S1	S2	S3	S4	S5	S6	E1	E2	E3	E4	E5	E6	E7	E8	P1	P2	P3	P4	P5	P6	P7	P8	L1	L2	L3
1	0	0	1	0	1	1	1	1	1	0	1	1	0	0	1	0	0	0	0	0	0	1	0	1	0
2	0	0	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	1	0	1	0
...
115	0	0	1	0	1	1	1	0	0	1	0	1	1	0	1	0	1	0	1	1	0	0	1	0	0

sets as well as association rules, and the Apriori algorithm is chosen in this paper to find hidden association patterns between human causes of topside accidents.

In the association analysis, let $I = \{I_1, I_2, \dots, I_m\}$ be a set of factor terms; let $D = \{t_1, t_2, t_3, \dots, t_n\}$ be the accident-related data. Each data in D is non-empty and at the same time, a subset of item I . The association rule can be defined as:

$$A \Rightarrow B, \text{ where } A \subseteq I, B \subseteq I, A \neq \varphi, B \neq \varphi \text{ and } A \cap B = \varphi \tag{1}$$

$$\text{support}(A \Rightarrow B) = P(A \cup B) \tag{2}$$

$$\text{confidence}(A \Rightarrow B) = P(B|A) \tag{3}$$

$$\text{lift}(A \Rightarrow B) = \frac{\text{confidence}(A \Rightarrow B)}{\text{support}(B)} = \frac{P(B|A)}{P(B)} \tag{4}$$

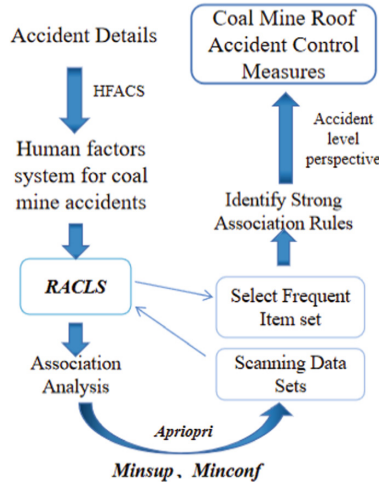


Fig. 2. Human factors association analysis

Each rule generated contains two different sets of items, A and B, where A is referred to as the antecedent and B is referred to as the precedent. The association between the anterior and posterior items in the relationship is based on Support, Confidence, and Lift to achieve the metric ordering of the rules [4]. Perform Apriori correlation analysis on the collected data based on the principle of correlation Analysis.

4.2 Human Factors Association Results

According to the flow shown in Fig. 2, the minimum support and confidence thresholds are determined after debugging, which are 0.1 and 0.6 respectively, and a total of 180030 rules are inferred by using the Apriori algorithm, relying on the confidence and support meanings, and the rules are cleaned to extract important human-caused strong association rules from the accident level perspective to start the analysis, as shown in the following statement.

4.2.1 General Roof Accident Human Cause Analysis

Discussion of Table 3 the supervision level involves S3, S5, and S6; the management level involves E1, E3, and E5; the production level involves P1, P3, and P5; it can be seen that the three levels of supervision, management and production can be used to avoid the occurrence of general accidents - the supervision level needs to implement the responsibility of supervising coal mine production, strengthen the production of At the management level, safety education should not be relaxed, and coal mine safety management system and safety technical measures should be implemented in the actual production; at the production level, workers need to pay more attention to dangerous phenomena, and special education and training should be conducted.

for the precursors of dangerous situations in the mine to raise their alertness. At the same time, from the perspective of rewards and penalties to reduce the elimination

Table 3. General roof accident human factors correlation rules

Num	antecedent	precedent	Support	Confidence	Lift
1	P3	L1	0.652173913043478	0.903614457831325	1.09384908053265
2	P5, P3, E1	L1	0.626086956521739	0.9	1.08947368421052
3	P5, P3, P1, E1	L1	0.591304347826087	0.894736842105263	1.08310249307479
4	S6, E6, E1, E5, P6	L1	0.139130434782608	0.888888888888888	1.07602339181286
5	E1, P4, P1, E5	L1	0.130434782608695	0.88235294117647	1.06811145510835
6	S3, P5, E3, E1, P3, P1	L1	0.252173913043478	0.878787878787878	1.06379585326953
7	P5, E6, S5, E1, E5, P3, P1	L1	0.208695652173913	0.827586206896551	1.00181488203266

Table 4. Larger roof accident human factors correlation rules

Num	antecedent	precedent	Support	Confidence	Lift
1	S6, S5, P1	L2	0.104347826086956	0.75	1.56818181818181
2	E3, S5, P1	L2	0.104347826086956	0.75	1.46186440677966
3	S6, P1, E5	L2	0.104347826086956	0.75	1.4375
4	S6, P1, E1	L2	0.104347826086956	0.75	1.30681818181818
5	P1, S5, E1, E5	L2	0.104347826086956	0.75	1.18150684931506

Table 5. Analysis of human causes of major roof accidents

Num	antecedent	precedent
1	S5, E1, E3, E4, E5, E6, P1, P2, P3, P4, P5, P6	L3
2	S3, S5, S6, E1, E3, E4, E5, P1, P5, P6	L3
3	S3, S4, S5, S6, E1, E3, E4, E5, E7, P6, P8	L3
4	S3, S5, S6, E1, E2, E3, E4, E5, E6, E7, P1, P3, P5, P6	L3

of illegal behavior, to avoid the occurrence of unsafe behavior taken because of unsafe psychology such as fluke (Table 5).

4.2.2 Analysis of Human Causes of Large Roof Accidents

Discussion of Table 4 involves S5 and S6 at the supervision level; E1 and E5 at the management level; and P1 at the production level; therefore, measures can be taken at the supervision, management, and production levels to avoid large accidents - first, the supervision level requires daily supervision and inspection and hidden danger investigation and rectification to control the risks and hidden dangers in the coal mine production process in the bud. Secondly, the management level is focused on safety education, whether the technical safety measures are scientific and comprehensive, and whether the implementation is in place is closely related to the safety of the actual production process, which is the focus of management needs to be strengthened; finally, the production level to strengthen the education and training of workers to understand the phenomenon of danger, so that they can find the danger in time in the daily production process, to make the corresponding emergency response. Lastly, to strengthen the education and training of workers' awareness of hazards at the production level, so that they can detect hazards in the daily production process and make corresponding emergency countermeasures to ensure life safety to the greatest extent.

4.2.3 Analysis of Human Causes of Major Roof Accidents

Since only 4 cases of major accidents are collected in the roof accident report, these 4 cases are extracted for research and analysis, and countermeasures are proposed for the control of human causes of major roof accidents. Firstly, the supervision level needs to complete the implementation of safety supervision responsibilities, control illegal production, strengthen hidden danger investigation and rectification, and daily supervision and inspection; secondly, at the management level, safety awareness needs to be deeply rooted in people's hearts, and at the same time, the safety management system needs to be improved, safety responsibilities need to be clarified, production needs to be reasonably organized, and corresponding safety technical measures and safety professionals need to be equipped to eliminate the existence of dangerous human factors from the management perspective; finally, the production Finally, the process needs to do a good job of pre-shift work arrangement and education, strengthen the education and emphasis of professional knowledge and skills, pay attention to the actual behavior of workers on site, avoid unsafe psychology and illegal operation, and control the human causes of accidents in actual production.

5 Conclusions

In this paper, we use accident reports as the data source and combine association rule mining technology under the framework of the HFACS model to study the human causes of roof accidents.

- 1) HFACS theory is combined with accident reports to extract accident causative human factors from the reports, forming a roofing accident human factors system with three primary factors of supervision-management-production and 22 secondary factors such as unscientific formulation of safety supervision plan.

- 2) By generating RAHCS with Apriori correlation rule mining through accident retrieval, we analyze and study the strong correlation between accident human factors and accident levels, and propose targeted control measures for general accidents, large accidents, and major accidents from three levels of supervision, management and production, which further promote the improvement of coal mine safety management and prevention of coal mine roof accidents.

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