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Full length research paper

Systematic analysis of impact factors and level of coal miners' safety behavior

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This paper indicates that coal miners' unsafe behavior is the major internal reason causing coal mine accidents. Factors affecting coal miners' unsafe behavior were identified. The relatively entire system of coal miners' safety behavior was built accordingly. Coal miners' unsafe behavior system was analyzed quantitatively. Path and divergence of impact factors within the system were explained in detail. Management decision can be formulated to advance management level in coal mine industry.

Keywords: Coal Mine; Safety Behavior; Systematic Analysis

INTRODUCTION

Coal miners' safety behavior management poses a direct role in safe production in the coal mining industry. Statistics indicated that accidents that occur are mostly related to coal miners' unsafe behavior. Relevant cases in *Collection of Expert Review of Coal Accidents in China* show that 55.37% of all major accidents are caused by violation of coal mine regulations and laws. 300 typical cases of coal mine accidents collected by the author of the paper were thoroughly analyzed. Factors causing the accidents can be classified into the followings: management deficiency, coal miner's operation violation, mechanical failure, bad natural condition, poor supervision, illegal exploitation, coal miner's lack of safety skills, insufficient safety technology, excessive power production etc. These are leading factors within the coal mine accidents causes, actually 87% coal mine accidents are caused by these main factors. Therefore, coal mine accidents can be controlled to a certain degree. As a result, coal miners' safety behavior management has been the focus of safety management for the collieries.

Impact factors

Coal miners' safety behavior directly affects safe production in coal mine. The degree of controlling Coal miner's unsafe behavior will directly affect the safety level of the coal mining system. Statistics indicates that almost all sorts of accidents are involved with coal miner's unsafe behavior (Chen, 2006). There exist such many factors affecting coal miners' safety behavior as safety quality, physiological and psychological quality, education level, length of employment, autonomic management, and work condition. These factors are not independent but interact with each other, which is the starting point to systematically research coal miner's safety behavior. The impact factors of coal miners' safety behavior are shown as figure 1.

Factors relevance

Factors in the coal miners' safety behavior system interact with each other. For example, the higher the coal miners' educational level, the better their physiological and psychological quality, and the longer the coal miners are employed, the stronger their safety awareness becomes, and the securer they master knowledge of safety. This relationship usually shows the positive force (Cao Yu et al., 2008). Therefore, improving safety awareness and safety knowledge of coal miners and strengthening safety skills training are clearly the key to improving the safety level in the coal mining industry.

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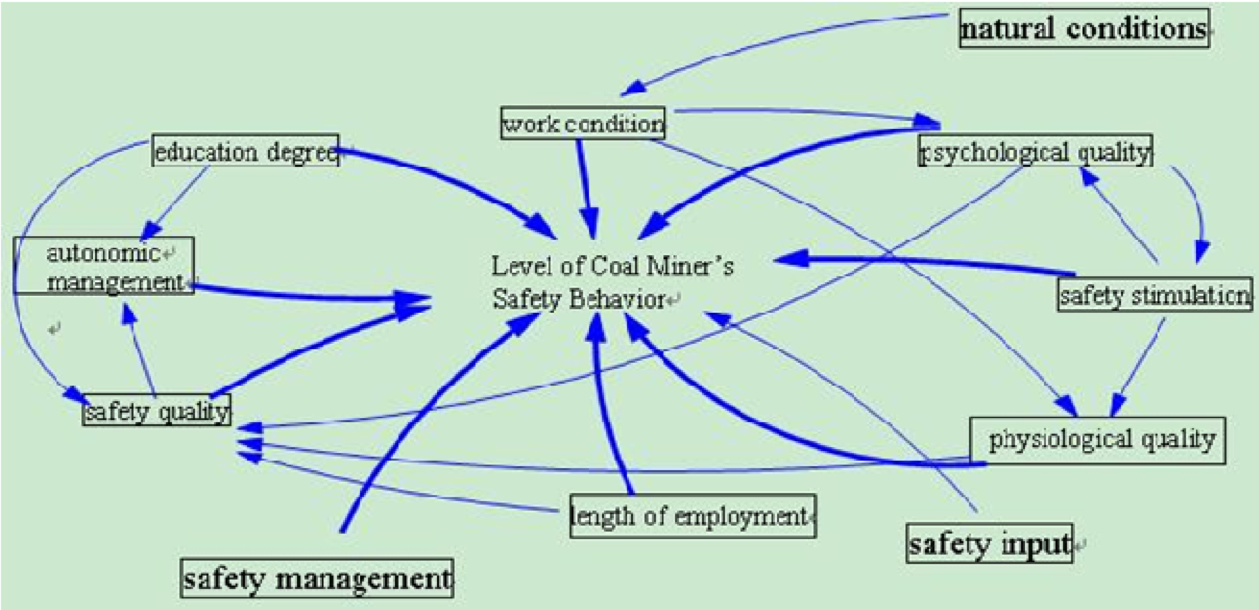

Figure 1: Impact Factors of Main Human Behavior Subsystem

The coal miners with longer employment period have more safety skills, experiences and higher safety quality
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(Hyung et al., 2007).

However, some experienced coal miners with longer employment period think coal mine accidents are always rare have the fluke mind, and developed poor safety awareness otherwise. People's psychological quality is influenced by genetic, physiological, family and social factors, meanwhile it can be influenced by safety incentives, within a certain period, positive incentives will enhance the psychological quality of people's safety. Incentive level is influenced by human resource management in safety management, some effective ways like salary system, guarantee system and so on can help implement safety management, which can affect psychological quality of the coal miners in turn (Dimitrios Vlachos, Patroklos Georgiadis, 2007) (Mao Shan-jun et al., 2009). Coal miner's education level also affects their safety quality. That is why many researchers of coal mine safety consider educational level as the index of the coal miners safety. The lower their educational level, the less they realize safety problem, the more difficult they are trained safety training, and the worse the result of training will be, the harder they feel importance of safety awareness (Ying Lu, Xingdong Li, 2011). One online survey conducted by *Workers Daily* (http://txzx.workercn.cn) found in large and medium-sized state-owned coal mines of more than 300,000 tons coal productivity the percentage of coal miners with above the junior high school level is 62.67%, while those with above junior college level is 5.44%. By contrast, the coal mines of less than 300,000 tons coal productivity, the percentage of coal miners with above junior college level is less than three in average. As a result, education level of coal miners both in the state-owned enterprises and private enterprises is worryingly low, which produces great negative impact on the miners' psychological safety. Coal miners' independent management consciousness is connected with their safety quality, education degree. In fact, the higher the miner's safety quality and education degree become, generally they violate regulations and law to a lesser extent, when they abide by labor discipline.

Systematic analysis of coal miner's safety behavior level

System Dynamics (SD), a quantitative research method to perform simulation experiment by means of computer, is the study of analyzing information feedback system based on system theory, information science, kybernetics and computer technology, it reflects the dynamic mechanism of real system according to state, control and information feedback of system and simulation model can be built accordingly.

By contrast with other analysis tools, SD can do chronological dynamic analysis and coordination among departments as well. Hence, SD acts as an effective tool to research complex system. To analyze correlation among the affecting factors of coal miner's safety behavior, and to decide the function difference of affecting coal miner's safety behavior, the author used SD to simulate coal miner's safety level, and the flow chart of system dynamics of coal miner's safety behavior

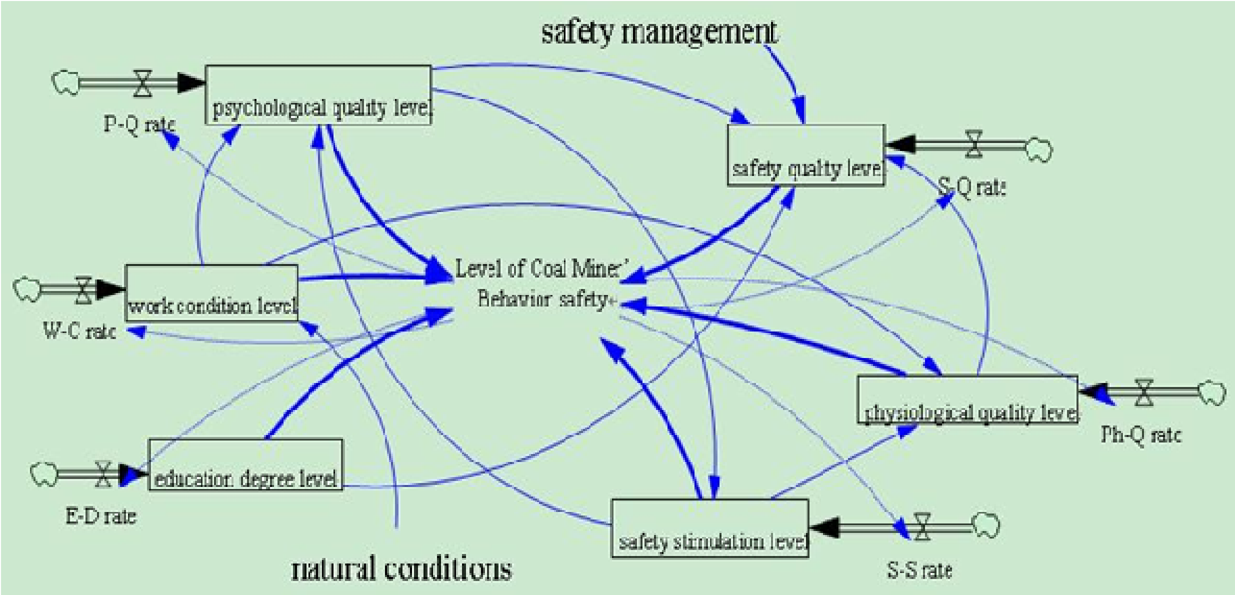


Figure 2: SD Flow of Coal Miner's Safety Behavior Subsystem

Table 1: Different Adjustment Plans for Subsystem of Human's Behavior

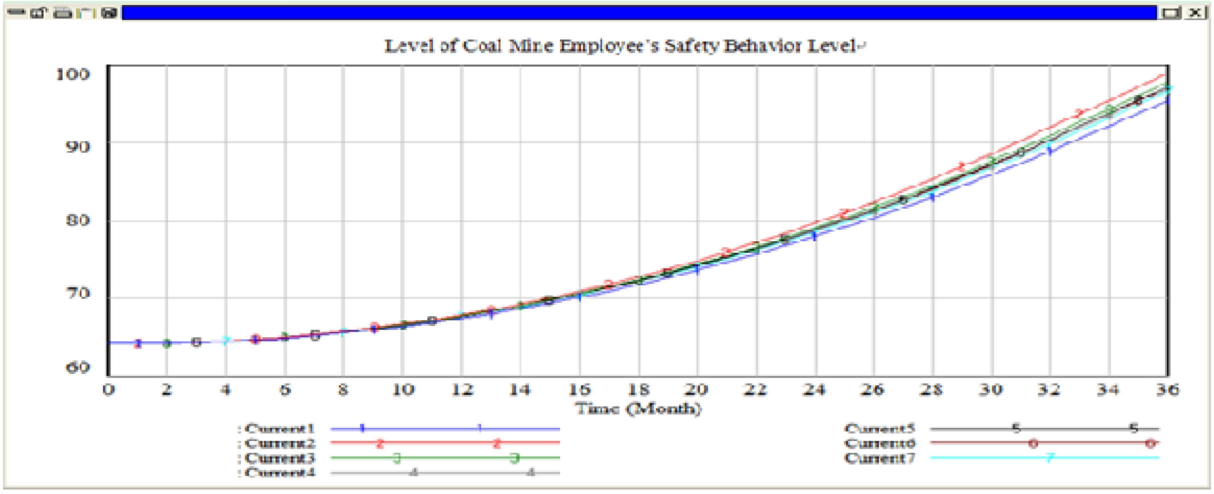
Sequence	Plan	Adjustment
0	Current1	Horizontal increasing rate of each factor's level was added to 0.04 averagely (initial value).
1	Current 2	Horizontal increasing rate of safety quality was added to 0.06, horizontal increasing rate of other factors remain unchanged.
2	Current 3	Horizontal increasing rate of safety incentives was added to 0.06, horizontal increasing rate of other factors remain unchanged.
3	Current 4	Horizontal increasing rate of psychological quality was added to 0.06, horizontal increasing rate of other factors remain unchanged.
4	Current 5	Horizontal increasing rate of work condition improvement was added to 0.06, horizontal increasing rate of other factors remain unchanged.
5	Current 6	Horizontal increasing rate of education level was added to 0.06, horizontal increasing rate of other factors remain unchanged.
6	Current 7	Horizontal increasing rate of physiological quality was added to 0.06, horizontal increasing rate of other factors remain unchanged.

level was built on the basis of impact factors system of coal miner's safety behavior level（see figure 2）. Data from one of coal mines in Huainan city has been collected as experiment data. In the experiment, initial value of human's behavior system variables was decided, initial value of horizontal increasing rate (non-dimensional parameter) of each factor in subsystem was decided, horizontal increasing rate of each factor selected in turn was increased by 0.02%, that is regulation increment when in simulation. Then, horizontal change of subsystem before and after the change of regulation variables can be studied. At the same, other variables were decided non-regulation variables.

The horizontal target value of subsystem was set 90 (non-dimensional), the length of simulating period was 36 months, and time step length was 1 month. The horizontal increasing rate of each factor within subsystem was regulated for simulating, practical action rate of each factor in human's safety behavior subsystem can be calculated. Horizontal increasing rate of each factor selected in turn was increased 0.02%. Regulation plan is shown as Table 1.

After the plan was established, simulation software began to work according to established plan respectively, and the simulation result was observed as follows in figure 3.

Based on the table above, compared with the original plan，we can found that 6 adjusting plan exert to different degrees of improvement. Current2's increasing is the most distinct, it adds up to 90.2278 in the 31st month. It is



Time (Month)		27	28	29	30	31	32	33	34	35
	Runs:	Current1	Current2	Current3	Current4	Current5	Current6	Current7		
		81.6612	83.0082	84.4051	85.8519	87.3486	88.8952	90.4916	92.138	93.7843
: Current2		83.8345	85.3487	86.919	88.5453	90.2278	91.9663	93.7048	95.4433	97.1819
: Current3		83.0652	84.5202	86.0251	87.5919	89.2086	90.8792	92.6036	94.3281	96.0526
: Current4		82.5826	84.0005	85.4709	86.9938	88.5692	90.1972	91.8776	93.5581	95.2385
: Current5		82.7493	84.18	85.6637	87.2004	88.7901	90.4328	92.1284	93.8241	95.5198
: Current6		82.7142	84.1422	85.6231	87.1569	88.7436	90.3832	92.0756	93.7681	95.4605
: Current7		82.3281	83.7264	85.1765	86.6784	88.2321	89.8376	91.4948	93.2039	94.9129

Figure 3: Horizontal Change of Man's Behavior under Different Regulation Plans

two months earlier than the original plan. In order to precisely gain the affecting difference of each adjusting variables, we will calculate the practical action rates of each variables in the accordance with these simulating plans. Simulating data was used to calculate practical action rate of each factor. Software Vensim can automatically generates data of horizontal change within simulation period. According to the data in Current1, the average value of safety level was averaged 74.9123, then safety level data of subsystem of each month in Current2 was used to deduct that of Current1 respectively, the average value was 1.2832, and next this average value was divided by the average value of safety level 74.9123 in Current1, the ratio was 0.01713 which means safety quality (factors changed under plan Current 2) was to the practical action rate of man's safety behavior level. Namely, this ratio tells that human's safety behavior subsystem can be increased 1.713%, under the condition that horizontal increasing rate of other factors remains unchanged. Likewise, practical action rate of other factors can be calculated. The practical action rates of safety quality, safety incentives, psychological quality, work condition, education level and physiological quality are 0.01713, 0.01103, 0.00744, 0.00881, 0.00852, and 0.00547 respectively.

CONCLUSION

(1) In contrast with weight, practical action rate can grasp more accurately the influence degree of different factors. By simulation, because of complex interaction existing among various impact factors, the degree of practical action rate of man's safety behavior differs. While weight only means contributions made by each impact factor under the steady condition, in fact, the practical action rate tells the practical role under interaction in system, which is more beneficial to specific decision making strategy for coal mine enterprises.

(2) Safety quality and safety incentives play a vital role in both improving coal miners' safety behavior level and preventing coal mine accidents. Simulation experiment found that safety quality and security incentives have the greatest impact on human's safety behavior level, their action rates being 0.01713 and 0.01103 respectively. As a result, the practical starting point in coal mine safety management lies in how to improve coal miner's safety quality and formulating safety incentives measures scientifically.

Case study of 300 typical coal mine accidents in this article discovered that human's unsafe behavior is the major internal reason causing coal mine accidents. System dynamics adopted in the paper, systematically analyzed relations among impact factors, decided the differences among impact factors of coal miner's safety behavior. In spite of analysis in depth, there still leaves much to be done. The complex relations of each impact factor still require further discussions. For instance, the longer the coal miners' work seniority becomes, the more firmly they grasp safety skills, and the stronger their awareness of complying discipline. On the other hand, it is well-known that the longer they are employed the more easily they drop their guard. Just for this reason, the complex relation between coal miner's awareness of independent management and work seniority remains to be researched. Simultaneously, more successive study is required about how to decide quantative relations among these factors so as to research coal miners' safety behavior system deeply and systematically.

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