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Research on influential factors of transportation near-misses in coal mine based on structural equation model

The sporadic near-misses in the process of coal mine transportation causes interference to the safe and smooth production of coal mine. In order to scientifically prevent and control the occurrence of near-misses in coal mine transportation, the influential factors of near-misses in coal mine transportation have to be defined so as to take corresponding control strategies. Based on the initial established evaluation index system of influencing factors of near-misses in coal mine transportation, this paper constructed the structural equation model. Then questionnaire was designed, and questionnaire survey was carried out. The reliability and validity of the sample data were tested using SPSS24.0 and the model was verified and corrected using AMOS21.0. Results show that near-misses in coal mine transportation are influenced by such factors as transportation equipment system, organization and management system, quality of staff and workplace environment, with the influence degree of the above factors presenting a descending order. Moreover, the system of organization management exerts different degree of impact on the transportation equipment system, quality of staff and the workplace environment and the impact gets smaller and smaller following this order. Finally, the paper put forward the strategy of implementing standard operating procedures, establishing management mechanisms, strengthening safety culture construction, carrying out closed-loop education and training strategies, etc.

Keywords: *Coal mine, transportation near-miss, safety management, influential factors.*

1. Introduction

The coal transportation distance is long and the transportation is vulnerable to multiple factors including the roadway conditions, mechanical property, personnel status, and surrounding environment. Compared to coal digging, coal transportation is relatively easier, and the safety level is higher, so it is not easy to raise the attention of operators and is a weak point in the monitoring and management. It has been one of the links where production accidents are frequent for coal mine enterprises. The statistics of accident casualties on the website of State Administration of Work Safety show that the death toll caused by the accidents in coal mine transportation in China is up to 133 persons from July 2009 to December 2014, bringing serious losses to the society, enterprises and families. Therefore, it is urgent to conduct researches on the safety of coal mine transportation and improve the safety management level of coal mine transportation.

There will be signs before an accident. The Heinrich accident law intuitively shows that before the occurrence of any severe accidents, there will be numerous minor events occurring which do not cause injury or loss and are known as near-misses. Domestic scholars call them differently. Schaaf(1995) studied the content of reports of near-misses, and then related studies on the near-miss management were carried out step by step. Currently, a lot of researches on near-miss in the aviation, firefighting and petrochemical industries have been carried out both at home and abroad (Delmar et al., 2011; Ritwik, 2002; Zoe et al., 2006). Several studies have been focused on analyzing the Near-miss Management System (Gnoni et al., 2013; Maria and Gianni, 2012; Grazia and Joseph, 2017;Bihina Bella and Eloff, 2016; Rachel,2017).

Domestic research on near-miss began late. Zhou (2009) setof researches on near-miss management system in subway construction. In recent years, the concept of near-miss systematic management was gradually brought into the research area of coal security management. Yu(2013) studied the operation mechanism and reporting process of coal mine near-misses based on the theory of three kinds of hazard sources. Zhang et al. (2014), Gao (2016) and Tian et al. (2016) respectively conducted researches on the reasons and types of coal and gas outburst and fire near-misses and their relationship with the unsafe behaviours, and the influential factors, levels and control measures of coal mine water disaster. These series of research studied the causation mechanism and management counter-measures of the coal mine near-miss from different perspectives, involving researches on many types of near-misses, including gas, fire disaster and water damage near-misses, but still lacks in-

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TABLE 1: INDEX SYSTEM OF INFLUENCING FACTORS OF NEAR-MISSES IN COAL MINE TRANSPORTATION

Principal factors	Core category	Main category
Principal factors	Organization and management system	Security command and control, safety system setting, safety training situation, enterprise emergency drills, corporate safety culture and safety supervision and inspection
Behavioural factors	Quality of staff	Staff safety operations, employee safety skills, employee safety awareness, employee physiology and psychology
Physical factors	Transportation equipment system	Quality technology status, maintenance and repair situation, supervisory and monitoring system
	Workplace environment	Operating space conditions, operating environment conditions, safety protection facilities

depth analysis of the reasons for the near-miss of coal mine transportation. Therefore, it is urgent to study the near-misses in coal mine transportation to clarify its occurrence mechanism and influential factors and take corresponding measures, thus reducing the possibility of transportation accidents from the source.

2. Index system and model building of influencing factors of near-misses in coal mine transportation

Using the grounded theory research method, Sun and Tian (2017) got the category of open coding through in-depth interview and case analysis and summed up the main category and core category through axial coding, selective coding and theoretical saturation test. The main category is summarized as physical factors and behavioural factors. Ultimately, the index system of the influential factors of near-misses in coal mine transportation is constructed (see Table 1 for detail).

Yu (2013) pointed out in his research that in the management of coal mine near-misses, the reporting, analysis, and handling are especially important. Proper treatment of these key links is conducive to reducing or preventing the occurrence of coal mine near-miss. The research of Gao (2016) also showed that the organizational security atmosphere, safety education and training, safety supervision and management and other factors of organizational management system all have certain degree of cross-layer impact on coal mine near-misses and employee safety behavior. The research of Lei (2013)also indicated that the third category of dangerous sources, namely, the invalidation of the security system, poor security atmosphere, absence of the sense of safety mission, safety communication failure and other management dimensions all have direct or indirect impact on the unsafe behavior of employees and near-misses in coal mine transportation. Therefore, on the basis of preliminary researches, corresponding assumptions are put forward, and the initial model of the influential factors of near-miss in coal mine transportation is constructed as shown in Fig.1.

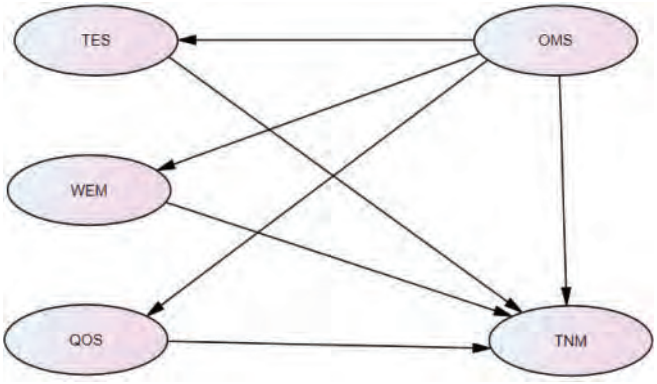

Fig.1 Initial model of the influential factors of near-miss in coal mine transportation

3. Questionnaire design and data collection

On the basis of referring to domestic and foreign studies on the near-misses in the transportation, and combining with the actual situation of coal enterprises, modification to the existing questionnaire was done to form the final draft of the questionnaire, with the guide language added. Each question in the questionnaire adopts the Likert-type scale, and there are five grades, namely “1,2,3,4,5”, representing “strongly disagree, disagree, general, agree, strongly agree” respectively. The higher the score, the more consistent it is with the actual situation. After the completion of the initial questionnaire, it was revised repeatedly to delete the items with inaccurate expressions, ambiguity or multiple concepts. And then the first draft of the questionnaire was confirmed. Surveys were carried out targeting at the workers of the production line in Bulianta Coal Mine, Daliuta Coal Mine, Liujiahe Coal Mine, Qinyuan and other coal mine enterprises. 300 questionnaires were distributed and 262 were taken back. The unqualified questionnaires (two or more questions were not answered; the answers to different questions are the same; the number of questions with more than one answer surpasses three) were eliminated, after which 239 valid questionnaires were obtained.

SPS24.0 is adopted to process the data collected. CITC analysis is conducted at first and the measurement terms with small value is deleted based on the analysis results, including “catching up the process, convenient operation, and equipment aging”. And then, reliability and validity analysis is carried out on the basis to get the Cronbach's Alpha of the questionnaire. The Cronbach's Alpha of the questionnaire is

TABLE 2: MODEL FITTING RESULTS

Index name	Index of fitting	Reference value	Before correction		After correction	
			Analysis result	Evaluation result	Analysis result	Evaluation result
Absolute fitting index	χ^2/df	χ^2/df<4	2.76	Conform	2.52	Conform
	RMSEA	0.05<RMSEX	.079	Acceptable	.061	Acceptable
	AGFI	A<0.08	.912	Acceptable	.924	Acceptable
		AGFI>0.9				
Comparative fit index	NFI	NFI>0.9	.663	Unacceptable	.916	Acceptable
	IFI	IFI>0.9	.772	Unacceptable	.915	Acceptable
	CFI	CFI>0.9	.766	Unacceptable	.923	Acceptable
	RFI	RFI>0.8	.609	Unacceptable	.812	Acceptable
Residual	RMR	<0.05	.005	Acceptable	0.01	Acceptable

0.942, larger than 0.9, indicating a fairly high degree of reliability. KMO and Bartlett sphericity test results signify that the KMO value is 0.893, representing fairly high correlation among the items and that the original variables are suitable for factor analysis; the p value after Bartlett's sphericity test is 0.000, reaching the significant level and is suitable for factor analysis.

4. Model verification and correction

After the preliminary processing of the data collected by the questionnaire, the model is matched with the software AMOS21.0 and analyzes the suitability of the model, The comparative analysis of various fitting indexes of the initial model and the standard data shows that the Goodness of Fit of the model and data is low, so it is necessary to revise the model. According to the path analysis, the influence path coefficient of the chaos on the organization and management system and the influence path coefficient of working in spite of malfunction on the failure of transportation equipment system are both small, indicating small influences of these two factors, so these two variables could be deleted and a revised model is established. The comparative analysis of various fitting indexes of the revised model and the standard data shows that the Goodness of Fit of the revised model and data is high, so the corrected model can be accepted. The specific results are shown in Table 2.

The measured value of the error variance in the model shows no existence of negative error variance and none of the absolute values of the standardized coefficient values surpassed 0.95. There was not any overlarge estimated value of the standard deviation. So there were no violations of the estimation. The identification of the model was tested using AMOS21.0 and df = 78>0. So it is an over identifying model. Further analysis can be done to the model. The analysis results are presented in Fig.2.

5. Results analysis

The validation analysis results of this model are presented in Fig.2. It can be observed in Fig.2 that the relation model of near-misses in coal mine transportation is fitting well with the

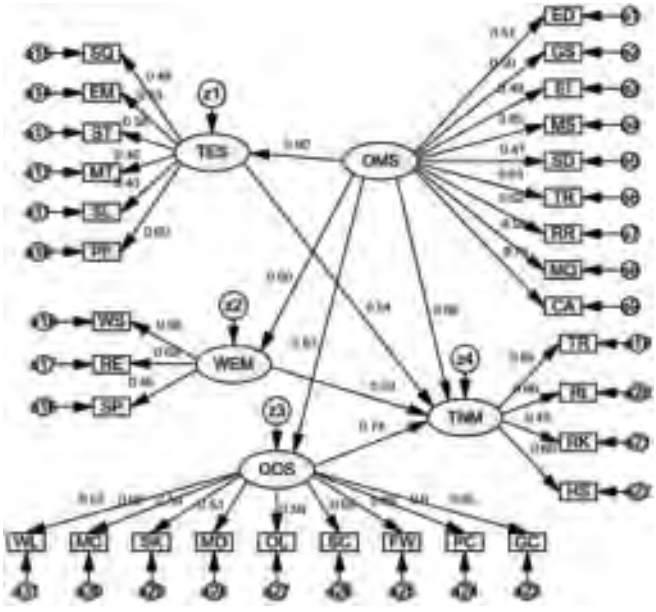

Fig.2 Path diagram of revised model

data, suggesting reasonable structure of the model. Specific analysis results are as follows:

(1) The four variables of transportation equipment system, workplace environment, organization and management system, and the quality of staff can directly exert an impact on the near-misses in coal mine transportation. The standardized factor load values were 0.54, 033,0.86,0.74 respectively, indicating that organizational management and personnel quality have relatively large impact on the near-misses in coal mine transportation. Management on these two aspects shall be enhanced. The more standardized is the management of coal mining enterprises, better is the safety rules and regulations, and the stronger the sense of safety of the employees, the easier it is to identify the signs of near-misses in the work and control it in time. Therefore, it will be much easier to eliminate the accident in the bud.

(2) The organization management system has certain impact on the transportation equipment system, workplace

environment, and quality of staff, with the path coefficients being 0.9, 0.8 and 0.83 respectively. It shows that sound safety organization and management is quite important to the coal mine. Therefore, enterprises must attach extraordinary importance to safety management. The intensified safety management will also facilitate the equipment overhaul, skill improvement of staff and improvement of workplace, thus preventing the occurrence of near-misses in coal mine transportation.

(3) From the perspective of transport equipment system, the load capacity of protecting facilities and facility maintenance is large, with the path coefficients being 0.60 and 0.53 respectively, therefore, the provision of protecting facilities and equipment maintenance shall be intensified. In terms of workplace environment, the transportation path and environment have relatively larger impact, whose path coefficients are 0.69 and 0.56 respectively. Therefore, it is necessary to reasonably design the transportation path to constantly improve the workplace environment. As for the organization management system, safety culture, safety training, safety system and safety supervision are influential, whose path coefficients are 0.75, 0.65, 0.62 and 0.61 respectively, therefore, the enterprises shall enhance safety culture construction, strengthen personnel safety training, improve safety rules and regulations and intensify safety supervision and inspection. As to the quality of staff, the sense of security and teamwork of staff, workload, physical condition and operation level all have a fairly large impact, with the path coefficients being 0.69, 0.65, 0.65, 0.60 and 0.60 respectively. Therefore, the staff training shall be intensified to elevate their sense of security and teamwork, and enhance their operational level. They shall be assigned work appropriately to avoid fatigue working.

(4) From the dimension of near-misses in coal mine transportation, the path coefficients of near-miss reporting, near-miss analysis and near-miss handling of the near-miss in coal transportation are 0.65, 0.66 and 0.60 respectively. The standard and system for near-miss treatment scheme shall be strengthened to ensure prompt and effective treatment of the near-misses.

6. Control measures for near-miss factors in coal mine transportation

Combing with existing researches, the coal mine should establish the management mechanism for the near-misses in coal mine transportation. Starting with the organization and management system, the coal mine shall enhance the construction of near-miss management system and security culture construction, implement standard operation procedure, and carry out security training to promote the overall improvement of coal mine transportation equipment, operating environment system and quality of staff, thus fully controlling the near-misses in coal mine transportation and improving the transportation security management level.

(1) Establish and perfect the management system for near-misses in coal mine transportation

Design well-rounded management system for the near-misses in coal mine transportation; formulate a set of complete process including reporting, treatment, analysis and event tracking, simplify the reporting procedures for near-misses in coal transportation and establish multiple ways of reporting; set up database for the near-misses in coal transportation to form the near-miss knowledge sharing platform and make the near-miss treatment generalized, routinized, thus sufficiently preventing the occurrence of near-misses in coal transportation.

(2) Strengthen enterprises' safety management system and safety culture construction

Enterprises shall improve the safety management system, improve the management system and safety production rules and regulations to ensure that there are rules to follow and abide by, the responsibilities are clear, and rewards and punishments are appropriate. Meanwhile, enterprises shall create sound safety culture and atmosphere, which are beneficial to improve the staff's sense of security, and reduce their unsafe behaviours. It is very important to the coal mine safety management. Enterprises shall carry out a variety of security cultural activities, create sound security atmosphere, and enhance the employee’s sense of security. The security propaganda shall be intensified to improve the staff's sense of security, thus making the security culture sink deep in the hearts of staff.

(3) Carry out a variety of safety trainings and education to improve the quality of staff

Carry out various regular or occasional production safety training, such as experiential training. Taking advantage of practical training and virtual reality training to make staff feel intuitively and improve their operational level. The means of family affection influence, and accident case study could intensify the worker's awareness of accident hazards, improve their sense of security responsibilities and consciously do their jobs safely. For those who have unsafe behaviours, they will be educated to make correction. The methods of psychological assistance and working time adjustment will be adopted as well. Comprehensive education shall be offered to staff to improve their safety awareness.

(4) Increase investment, improve the level of mining Mechanization and increase the monitoring and controlling efforts

Increase the mining mechanization technology investment, improve the level of coal mining mechanization, and eliminate backward mining technology; improve the mine monitoring and control system to increase the scope of monitoring, improve the monitoring accuracy and improve the overall monitoring

and control level, so that it can monitor various safety indexes of the mine more comprehensively and more accurately; designate persons to be responsible for the daily maintenance of the monitoring facilities and equipment; establish standing book for the monitoring facilities and equipment, to conduct regular calibration and maintenance of the monitoring facilities to ensure safe and smooth coal transportation.

Acknowledgments

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