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Evaluation of the derivative environment in coal mine safety production systems: Case study in China

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ABSTRACT

The derivative environment can be separated into five elements: the production condition, job security condition, management regulation, organizational interaction, and culture diffusion. Through field research at three large state-owned coal mining groups in China, all elements of the derivative environment are evaluated in five grey classes from the perspective of reality, expectation, and ideality by using the mixed center-point triangular whitenization weight function method. The results indicate that the derivative environment sends out inferior signals on the whole. From the reality perspective, the production condition is in the “poor” grey class, while the elements of job security condition, management regulation, and organization interaction are in the “pass” grey class. Culture diffusion is located in the “good” grey class. From the expectation perspective, management regulation shows a positive trend, among which the operation pattern, awards and penalty system, and basic safety management system is highlighted the most, while organization interaction shows a negative trend, with caring features prominent therein. From the ideality perspective, there is a deviating phenomenon in key derivative sub-elements such as facility level, working time, labor intensity, wages, feedback of basic rights, organizational respect, and communication, which are far beyond an ideal level. The results are of great reference value, improving the level of the derivative environment and promoting the balance between the industrial development and safety control of coal mines.

1. Introduction

Coal is the basic energy source in China. However, the projected development of the coal industry is poor due to the impact of new energy sources, limits on carbon emission (Wang and Song, 2014; Wang et al., 2015) and the increasing enthusiasm about clean coal and environmental protection (Yu and Wei, 2012). These factors are retarding the growth of the coal industry, which is characterized by high carbon emissions and high risks. In addition, recently adopted government policy to reduce coal production capacity and the number of personnel in the coal industry is expected to decrease production by 500 million tons and redeploy 1.3 million personnel (The State Council of China, 2015). Consequently, the security of many coal mines is at severe risk. Many coal mine enterprises are experiencing difficulties in operation; the debt of coal mines is increasing year by year; and gas, water and fire hazards are occurring more frequently. Furthermore, coal workers' incomes are declining constantly, and increasingly, coal workers are having lower expectations for a guaranteed future career. The organizational environment of coal enterprises is deteriorating day by day, and expressions of opposition, suspicion and disappointment between employees and employers are widespread, prompting insecure behaviors that result in accidents. In the first half of 2016, major accidents in Chinese coal mines showed a rising trend, with five major accidents and 64 deaths. There were four more accidents and 43 more deaths than as occurred in the same period of the previous year, highlighting that safe coal production is being severely threatened (SAWS, 2016).

According to accident causation theory, accidents can be caused by four elements: people, machines, the environment, and management (Greenwood and Woods, 1919). As the environment is a significant factor in preventing coal mine accidents, it has aroused wide concern among scholars. For example, Yin et al. (2000) classified and summarized the effects and influencing characteristics of

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coal mine environmental geological disasters based on the source of the mine disasters (water, fire, gas, roof, and coal dust). Xu et al. (2009) conducted a risk analysis and evaluation of the environmental elements from the viewpoint of the natural safety conditions of the mines (the geological condition of the coal mine, coal seam occurrence, and gas conditions). Chen et al. (2014) and Liu and Li (2014) conducted safety analyses and evaluations of the temperature, dust, lightning, and air conditions in the working environment and proposed effective prevention methods. These studies show that the research on mine environmental factors has focused more on the natural environment and the workplace than on other influences (Yin et al., 2000; Zhang and Hao, 2016). However, focusing on the environment has a restricting effect that remodels the whole system and people's behaviors (Bronfenbrenner, 1981; Neal and Neal, 2013), so connotations with regard to the coal mine environment should involve not only the hard environment of production (natural environment and workplace) but also the soft environment. Chen (2008) proposed that coal mine production systems need the people and the environment working together and that the environment can be categorized into the natural environment and the derivative environment. The natural environment refers to those natural characteristics that are determined by the natural geological conditions of the coal mine, not by people, and they should have an effect on the production process, whereas the derivative environment means the design of the coal mining process and the input elements, which are all determined by people, during the process of production. In contrast to the natural environment, the derivative environment is artificial and can be controlled. The machines, the management, and the workplace environment, which are referred to in accident causation theory, should be included in the derivative environment. The establishment and safeguarding of the derivative environment can promote a steady condition of safety in a coal mine production system and the mine workers can become more adaptable and reliable by changing the derivative conditions, so the derivative environment is particularly important (Chen, 2008; Chen and Qi, 2013).

However, specific elements of the derivative environment have not been clearly pointed out in the current literature. In this study, the relevant elements concerning coal mine safety were integrated based on the connotation of the derivative environment, and the derivative environment was reduced to the five elements: the production condition, development condition, management regulation, organizational interaction, and culture diffusion. Research on the production condition has mainly focused on the facility (Chugh and Patwardhan, 2004; Zhou and Zhao, 2016) and the workplace (Petrović et al., 2014; Tello and Grau, 2015). However, the working time and labor intensity should also be included in the production condition due to the fact that both are required basically by enterprises. Research on the job security condition has been mainly directed towards the individual career orientation (Campbell and Holland, 1972; Eddy et al., 2015) and wages (Zhu and Chai, 2009). There has been relatively less research on Chinese professional development and professional stability based on human engagement in Chinese coal mines. When it comes to management regulation, the relevant research has been mainly focused on basic management systems, supervision systems, organization management, and emergency management (Hua and Fu, 2011; Song et al., 2013; Chen et al., 2015; Liu and Li, 2014). The operation pattern of enterprise management (Liu and Liu, 2010) should also be included in the management regulation as it provides guidelines for coal management. In addition, organization management, the most significant aspect of management, is usually studied as a part of coal mine management regulation, but it is separated from other aspects in this paper because the interaction between an organization and employees is a key factor influencing harmonious production in a coal mine. Nowadays, the phenomenon of employee opposition and petitioning has become more common, indicating that this factor has become significant in hindering production and operation (Eisenberger et al., 2010; Kurtessis et al., 2015). Specifically speaking, organization fairness, organization respect and communication are key factors in organizational study (Yildirim, 2014; Nix and Wolfe, 2016). The research on culture has included safety training and the safety culture climate (Nævestad, 2010; Fugas et al., 2012; Lu and Chen, 2015). Based on the review of the studies set out above and research experience, the secondary indicators of the derivative environment were subdivided as follows: the production condition (workplace, facility level, working time, and labor intensity); the job security condition (post promotion, work stability, and wages); management regulation (operation pattern, supervision system, basic safety management system, awards and penalty system, and emergency system); organizational interaction (organizational respect, organizational justice, feedback of basic rights, communication, and caring features); and culture diffusion (safety climate, construction of enterprise culture, and safety training).

The establishment of derivative elements follows the connotation of the derivative environment of mine production systems, but it is worth thinking about whether the condition of the derivative environment of current mine enterprises has reached the optimal standard and whether it is favorable to the operation of mine production systems. The derivative elements need more evaluation and the condition of each element can be ascertained so as to provide a reference for the improvement of mine safety production systems. This evaluation of derivative elements differs from previous safety evaluations. Safety evaluations aim to determine dangerous conditions in production systems in order to take measures to prevent accidents in time. The derivative environment gives priority to the merit ranking of derivative elements and is similar to “environmental efficiency” (Song and Guan, 2014), which aims to change and optimize the derivative environment in order to adapt to the whole safety production system. A lot of research has been conducted by Chinese and international scholars on evaluation methods. The main methods include fault tree analysis (FTA) (Ou et al., 2007; Komal, 2015), safety checklists (SCL) (Cao et al., 2012), probability assessment (Zhang and Wu, 2011), analytic hierarchy process (AHP), and fuzzy comprehensive evaluation (FCE) (Chang, 1996; Liu et al., 2007b). Fault tree analysis is conductive to fault analysis and the safety checklist does well in inspection and analysis, but neither of them is applicable to the evaluation of the derivative environment. Although probability assessment has been in use, it still lacks a theoretical basis and practicability. AHP and FCE are most commonly used, but they have problems with ensuring weight and membership and produce deviations if they are used alone. Grey clustering is a special clustering method that can divide observable indicators and observed objects into several classes that can be defined by category according to a grey incidence matrix or a grey number whitening weight function, which applies to objects in a system lacking enough data and information (Liu et al., 2007a; Lin and Liu, 2006). It is impossible to obtain all of the information needed for each coal mine by survey because of the mines' wide distribution, so only a few samples can be chosen randomly to make a effective and comprehensive evaluation, which is why it is suitable for the evaluation of a derivative environment. Accordingly, this study adopts the mixed central-point triangle whitening weight function to make evaluations of grey levels and judge at which level each element lies in order to instruct mine production, improve inferior elements, strengthen superior elements, and finally achieve “target-style safety.” The word “targeted” originally appeared in the medical field and refers to actions