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# An evaluating system for scientific mining of China's coal resources

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ABSTRACT

Coal as the basic energy in China plays a pivotal role in supporting national economic development and protecting national energy safety. The sustainable development of China's coal industry is still a hot topic both in practice and research. In terms of the lack of theoretical researches and practical applications of scientific coal mining evaluation, we built an evaluating system to assess the current development activities of coal enterprises. In the present work, to evaluate the scientific basis for coal mining systematically, effectively and objectively, the key indexes for assessing the level of scientific mining of coal resources were established using the document analysis method and the expert consultation method. The evaluating system consisting of 5 dimensions (informatization, productivity, safe mining, full cost and green mining), 18 criteria, and 56 assessment factors was constructed. Then, the weight values at all levels in the evaluating system were calculated using the analytical hierarchy process (AHP). Finally, an evaluating model for scientific mining could be constructed based on the comprehensive index assessment method. The application of this evaluating system of scientific mining could be used for finding the existing problems in the coal production process. Therefore, the coal enterprise managers and the government regulators could make the appropriate policies to enhance the scientific exploitation level of coal mines.

## 1. Introduction

Coal is the main source of energy in China. According to the *Statistical Communique of the People's Republic of China on the 2015 National Economic and Social Development*, China's coal consumption occupied 64.0% of the total energy consumption in 2015 (National Bureau of Statistics of China, 2016). As reported in the *Research on China's Medium-to-Long-Term Energy Development Strategy (2030, 2050), Energy Saving and Coal Volume*, the primary energy structure in China during the period from 2030 to 2050 will experience a significant adjustment, but coal will remain as the foundation of the energy system and will still account for nearly half of the market (Project Group of China's Medium-to-Long-Term Energy Development Strategy Research, 2011). Conclusively, in China, the coal plays an irreplaceable role in promoting economic growth and ensuring energy security in a substantially long period. Besides, China is the world's biggest coal producer and consumer (BP p.l.c., 2016). According to the latest data from *BP Statistical Review of World Energy* (BP p.l.c., 2016), 7861.1 million tonnes coal was produced worldwide in 2015, while China produced 3747 million tonnes, which accounts for 47.7%. As shown in Fig. 1, among the 7 primary coal producing countries, China produced more coal that the rest 6 countries combined. So, the sustainable development of China's coal industries is highly significant for the worldwide coal industry, which is a hot topic both in practice and research.

However, the current situation of the coal industry in China is not optimistic. Due to the relatively slowing growth of the national economy, the weak demand of the downstream industries, and the problems existing in the industry itself such as excess production capacity, high inventories and disordered development, many coal enterprises now operate at a loss, and the coal industry faces difficulties in development (Li et al., 2017a, 2017b; Song and Wang, 2016; Tang et al., n.d.). According to the latest data from the National Bureau of Statistics of China, the price of coal fell by 60% in recent four years and the gross profit of China's coal industries in 2015 is 4.41 billion yuan, which is the equivalent of 10% of the 2011 (Li, 2016).

Additionally, a series of problems such as environment pollution, ecological destruction and safety accidents are severely restricting the sustainable development of the coal industry (Li et al., 2017a, 2017b, 2015). How to achieve sustainable development of the coal industry and how to achieve scientific mining are questions that have attracted the intensive attention of many researchers. Experts and scholars, especially in the fields of mineral engineering and energy resource management, have conducted much research on scientific coal mining.

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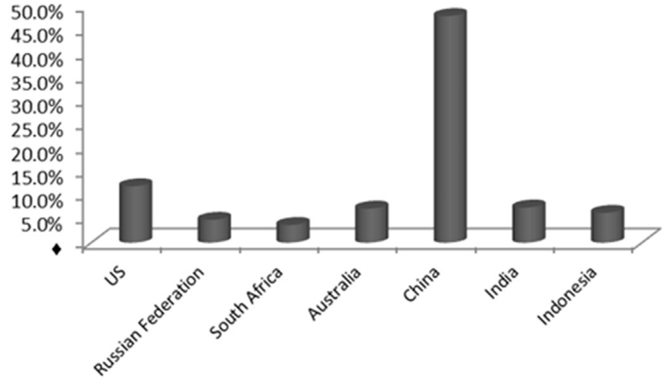


**Fig. 1.** Coal Production (BP statistical review of world energy 2016 workbook, 2016).

In China, "green mining" and "scientific mining" were put forward by Qian et al. (2008, 2003). According to his viewpoint, scientific mining mainly includes high-efficiency mechanized mining, green mining, safe mining, and increasing the resource recovery ratio (Qian et al., 2008).

As one of the basic connotation of scientific mining, ecological environmental protection in coal mine has attracted scholars' concern in recent years. Hu et al. (2015) developed an ecological restoration plan for abandoned underground coal mine site in Eastern China, using the Datong coal mine site in Huainan as a case study. Dai et al. (2014) have shown that coal resource exploitation in grasslands has more negative than positive effects on the well-being of herdsmen by studying the relationship between coal exploitation in grasslands and human well-being in Inner Mongolia, China. Also, some green industrial chains in the mining waste treatment was discussed and analyzed (Liu and Liu, 2010). Another primary aspect of scientific mining is informatization and intellectualization. Intelligent approach and intelligent optimization methods was utilized in the coal mining activities to predict the disaster, improve the production efficiency or monitor the production system (Cheng et al., 2015; Guo et al., 2010; Karacan, 2009; Rezaei et al., 2014; Xue et al., 2014).

From the perspective of the mining economy and energy management, Epstein et al. (2011) discussed the external costs of the life cycle of coal, including the stage of coal mining. Zheng et al. (2008) constructed a full cost system consisting of resource cost, security cost, environmental cost, development cost and production cost. Qian (2010) proposed that the scientific mining primarily includes five aspects, namely high-efficiency mining, green mining, safe mining, the increase of the mining ratio of resources, and economic mining. Furthermore, Qian and Xu (2011) refined the core contents of the scientific mining and constructed the technical framework, as shown in Fig. 2.

For the aspect of sustainable development of coal mining, based on the three key areas to realize sustainable mining (Laurence and Scoble, 2009), including the environment, economic and community, Laurence (2011) proposed that safety and resource efficiency must be addressed. In fact, mining never antagonized sustainability in all aspects. Rajaram et al. (2005) think that sustainable mining could be realized on the condition that balances economic, environmental and social considerations. Also, Zhang et al. (2016) presented that the exploitation of residual coal could delay China's coal depletion. That means, although the coal resources is exhaustible, people could realize sustainable mining in a certain period.

Abundant research has been conducted about the topics of sustainable mining, green mining and scientific mining, which provides the research basis for the scientific mining evaluation. Shen et al. (2015) developed a sustainable development framework for the mining industries' green supply chain management. Similarly, Azapagic (2004) developed a framework for sustainable mining indicators specifically for metallic, construction and industrial minerals. Marnika et al. (2015) focus on the mining activities in protected areas and proposed 36 sustainable mining indicators. Also, there are some research focused on the relationship between sustainable development and resources (minerals) mining, for instance, gold mining (Essah and Andrews, 2016; Ouoba, 2017), rare earth mining (Kamenopoulos et al., 2016a, 2016b), metal mining (Lèbre et al., 2016). Meanwhile, some research efforts have been made in the sustainable development of coal mining area or mining city (Lei et al., 2016; Wang et al., 2016; Zeng et al., 2016).

However, coal mining is different from the other minerals and natural resources, especially the mining method and exploitation process. When developing the evaluating system, we always focus on the evaluation of the mining process. Mining process is the core of the whole mining activities, while it differs greatly for different minerals. Those researches focusing on the generalized mining evaluation could provide some references but they could not be applied on the coal mining evaluation. In practice, although some coal enterprises have proposed slogans such as 'green mines' and 'digital mines' and have conducted a series of practical explorations, few studies regarding the applications of scientific mining in mine production and management have been performed. Although scientific mining is a guiding ideology of many coal enterprises in the scientific exploitation of coal resources, and also an important way to get rid of industry predicaments, it has still not been the assessment criterion for performance of coal enterprises, and it is difficult to promote systematically.

In terms of the lack of theoretical researches and practical applications of scientific coal mining, we built a evaluating system to assess the current development activities of coal enterprises, so as to reveal the existing problems in production processes. Compared to the existing research (e.g. Si et al., 2010; Yan et al., 2012; Zhang et al., 2012), we focus on the evaluation of scientific mining, aiming to realize the sustainable mining in aspects of environmental protection, improving production efficiency, increasing resources recovery and enhancing economic performance, not only focusing on one aspect of them. What's more, as the mining process is the core of the whole producing activities in coal mines and coal enterprises, main emphasis of our research has focused on the mining process. We decomposed evaluating targets into certain specific indexes that are strongly correlated with the mining process. These indexes could directly reflect the mining activities. That could make this evaluating system more practical and comprehensive. In addition, we added the level of information and green mining, which are emerging in recent years, and have not been arisen in other sustainable mining evaluation systems. By employing this evaluating system, the existing problems which damaged the scientific mining level could be found. This could help the coal enterprises' managers make the corresponding decision to enhance the coal mine's scientific development level and promote sustainable development.

## 2. Construction of the assessment system for scientific coal mining

### 2.1. Primary selection of the assessment indexes for scientific coal mining using the document analysis method

Using scientific mining (in Chinese), scientific coal mining (in Chinese), green coal mining (in Chinese), safe coal mining (in Chinese), high-efficiency coal mining (in Chinese), green mining, green exploitation, scientific mining and sustainable (sustainability) mining as retrieval key words, we performed literature retrieval from some retrieval platforms including CNKI, VIP, Engineering Village, Web of Science, Google scholar etc. After the primary screening, a total of 76 effective literatures were obtained for further analysis. The statistical analyses were conducted on the indexes proposed by each author to identify the frequencies of use and degrees of recognition of these assessment indexes for the level of scientific coal mining, and a total of 268 indexes were acquired. Moreover, the assessment subjects of these