Research on the Evaluation Model and Suggestions of Coal Resources Mining Level in China

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Abstract. As the basic energy resource of China, coal is a reliable energy supply provided for the national economy and social development. But with the adjustment of economy and energy structure, the coal industry now is facing some prominent issues such as overcapacity, low production efficiency, high pressure of production safety and environmental protection. According to the characteristics of coal industry, the evaluation model and indicators system of coal mining level based on four dimensions of production safety, production efficiency, resource recovery and environmental protection were established, and the weight of each indicator was determined. Considering the indicator values of America's coal industry to be the standard, coal mining level of China, America, Australia and the Inner Mongolia Autonomous Region of China were evaluated and analysed comparatively. Based on the analysis of the development environment of China's coal industry under the new situation, five suggestions for improving the level of coal resources exploitation and promoting the green and sustainable development of China coal industry were put forward.

1. Introduction

Coal is the main energy in China. Since the past two decades, China's coal industry has made significant progress, with the level of production safety, resource recovery rate and mining mechanization increased significantly, which has provided a reliable energy supply for the rapid development of the national economy [1]. However, due to the changes of China's economic environment, slow growth of energy demand and other factors, some prominent contradictions have significantly restricted the healthy development of the coal industry.

The first is excess overcapacity. Affected by the transformation of economic growth from high speed to high quality and the influence of energy structure adjustment from coal dominated to clean and low carbon energy, coal demand has reached the peak platform. It would still be the primary task for coal industry to eliminate backward capacity in the coming period.

The second is low productivity efficiency. There are about 4 million coal mine workers in China, and the annual coal production per capita is less than 1000 tons, while compared with that in America and Australia is more than 10 thousand tons, it still has a long way [2].

The third is poor green coal resources. Among the 1.53 trillion tons proven reserves, only about one third are green coal resources in accordance with the principle of "safety, technology, environment and economy". The coal resources with high quality and easily mining conditions are not abundant.

Under this background, it is of great significance to promote the coal industry structure adjustment and upgrading through establishing coal mining level evaluation model and to put some relevant suggestion by benchmarking with the developed coal production countries.

2. Evaluation model of coal mining level

2.1. Evaluation model

The coal resources are nonrenewable, and mining activities are usually involved with lots of risks and closely related to the environment [3]. Therefore, the evaluation model of coal resources mining level is established on term of production safety, production efficiency, resource recovery and environmental protection. The model could be abstracted as formula (1):

$$L = f(u_1, u_2, u_3, u_4) \tag{1}$$

Where, L is the coal resource mining level; u1 is indicator of safety; u2 is indicator of efficiency; u3 is indicator of recovery; u4 is indicator of environment.

2.2. Evaluation indicators system

It is reported that the indicators system should be established with the principles of representativeness, independence and quantification [4]. According to principles above and characteristics of coal industry, evaluation indicators system of coal mining level with three gradations has been established. The logical framework of the system and specific indicators are shown in Table1.

Table 1. Evaluation Indicators of Coal Mining Level.

Target layer	Feature layer	Indicator layer
Coal mining level	Mining safety	Death rate per million tons
	Mining efficiency	Mining mechanization level
		Coal mining efficiency
	Resource recovery	Coal resources recovery
	Environmental protection	Mining area rehabilitation

2.3. Evaluation method

Table 2. Weight of Each Indicator.

Indicators		Weight
Mining safety	Death rate per million tons	0.2
Mining efficiency	Mining mechanization level (%)	0.2
	Coal mining efficiency(tons annual)	0.2
Resource recovery	Coal resources recovery (%)	0.2
Environmental protection	Mining area rehabilitation (%)	0.2

In view of the indicators involved in the evaluation system are comprehensive indexes, which reflect the coal mining level from different aspects, and the importance of each indicator is basically the same from the survey feedback among coal industry's experts. According to this peculiarity, when making evaluation, the actual value of each indicator should be compared with the reference value one by one to determine the corresponding evaluation score, which could improve the feasibility of evaluation

process, and reflect the real and specific level of every indicator, and finally the coal mining evaluation score would be computed by the score of each indicator multiplied by the corresponding weight. The weight of each indicator is shown in Table 2.

Among the five specific indicators, the death rate per million tons is a negative indicator with the smaller value the better evaluation. While the rest four are positive indicators with the bigger the better. For positive indicators, the evaluation score could be computed by formula (2):

$$S = \begin{cases} A/R \times 100, & A < R \\ 100 & , \ A \geq R \end{cases} \tag{2}$$

For negative indicator, the evaluation score could be computed by formula (3):

$$S = \begin{cases} R/A \times 100, & A > R \\ 100 & , \ A \leq R \end{cases} \tag{3}$$

Where, S is the evaluation score of single indicator, A is the actual value of each indicator, and R is the reference value of each indicator.

Based on the score of each indicator, the evaluation score of coal mining level could be computed by formula (4):

$$L = \sum_1^5 S_i \times P_i \tag{4}$$

Where, L is the evaluation score of coal mining level, Si is the evaluation score of No. i indicator, Pi is the weight of No. i indicator.

2.4. Evaluation standard

The purpose of establishing the evaluation model is to analyze the coal mining level of China and compare it with that of the developed countries such as America and Australia. Therefore, in the process of evaluation, the actual values of indicators in America coal industry are chosen as the reference value, given that the evaluation score of America coal mining level is 100 points.

3. Evaluation of China coal mining level

Table 3. Comparison of Coal Mining Indicators

Indicators	Average in China	Inner Mongolia	Average in America	Average in Australia
Death rate per million tons	0.255	0.027	0.04	0.005
Mining mechanization level (%)	80	100	100	100
Coal mining efficiency (tons annual)	1000	6500	12000	13800
Coal resources recovery (%)	60	85	79	75
Mining area rehabilitation (%)	70	90	100	100

Through the investigation of domestic major coal producing provinces and the developed coal producing countries represented by America and Australia, the main data of coal resources mining indicators were

systematically sorted out. Combined with the model above, coal mining level of America, Australia, China and the Inner Mongolia Autonomous Region of China have been evaluated. The actual value of each indicator was shown in Table 3, the evaluation results of overall mining level as well as each indicator were shown in Table 4.

Table 4. Evaluation Results of Coal Mining Level

Score of indicators	Average in China	Inner Mongolia	Average in America	Average in Australia
Death rate per million tons	16	100	100	100
Mining mechanization level	80	100	100	100
Coal mining efficiency	8	54	100	100
Coal resources recovery	76	100	100	95
Mining area rehabilitation	70	90	100	100
Score of coal mining level	50	89	100	99

From the data and evaluation results of coal mining, it is concluded that:

(1) Compared with the developed countries such as America and Australia, the coal mining level in China was relatively low from the overall country, especially in the aspects of coal mining mechanization, coal production efficiency, million tons' mortality and environmental protection.

(2) As to the Inner Mongolia Autonomous Region, China's largest coal producing province, dominated by large coal enterprises, the mining mechanization, production efficiency and resource recovery of which were relatively high, and the coal mining level was in the leading position of China. Except for the little lack of environmental protection, there are little difference from that of America and Australia on the overall coal mining level [5, 6].

(3) The above results also illustrated that the coal mining's development level in different regions and different scale enterprises in China existed the unbalanced condition.

4. Development environment of coal industry in China

After the rapid development of golden decade (2002-2011) and deep adjustment of economic structure during the past few years, the development environment of coal industry in China has undergone fundamental changes.

Firstly, China has entered into the decisive period of building a moderately prosperous society in all respects. The report of 19th CPC National Congress has clearly declared that energy production and consumption revolution should be promoted to construct a beautiful China, by building a clean, low carbon, safe and efficient energy system, and reforming the ecological civilization system. This general requirement would surely compress coal demand fundamentally, which means that coal market oversupply will be a long-term trend.

Secondly, it was reported that in the past the domestic coal market was constrained by the transportation channel, but now the bottleneck of coal transportation from north to south and from west to east has been broken. Railway transportation becomes abundant, which has provided the condition for the eastern and southern regions to reduce capacity [7, 8]. Meanwhile, as the transportation cost

decreased, it would further improve the competitiveness of coal production in the western area. So coal industry in the whole country would face fiercer competition.

Thirdly, China's coal market will always be impacted by imported coal for quite a long time in the future. The cutting down of China's domestic production capacity would likely to cause the rebound of domestic coal price, when international coal from Australia, Indonesia and other countries flooding to China would once again impact the domestic market. The foreign coal is always a "Damocles Sword" hanging on Chinese coal market.

The above situation will force China's coal industry to consider the future development with a new pattern and perspective, especially more emphasis should be put on green and sustainable development.

5. Suggestions on the development of China's coal industry

Based on the analysis above, the suggestions on the development of China's coal industry were put forward as follows:

(1) China should seize the opportunity of supply-side reform and optimize the layout of coal industry. According to the requirements of pushing forward the economic quality transformation, coal supply-side reform should be further carried out considering of the characteristics of coal resources in different regions, thus to optimize the spatial layout of coal industry. Coal reserves in Shanxi, Shaanxi, Inner Mongolia, Gansu and Ningxia provinces are mainly green resources, with the potential coal production reaching 3 billion tons/year. Coal mining industry should continue to concentrate on this area before 2050, and the comprehensive energy base status of this region should be further highlighted. In Northeast and Southern China, the geological conditions of coal resource are complex with poor mining conditions. In East China, due to a long history of mining, easy mining resources in the shallow ground were exhausted and the remaining resources in the deep are affected by the threat of disasters, so mining in these areas should be restricted, and the exploiting scale and production capacity should be cut down in the next few years. And in the long term, coal mining in the East would be dropped out before 2050. Xinjiang is rich in coal resources with relatively good mining conditions, but due to the distance from the mainland market, coal mining in this area should mainly be positioned to meet the needs of the region itself in a longer period. While Qinghai should limit the coal development to protect the ecological environment.

(2) China should promote coal production overcapacity disposal with overall consideration and achieve the balance between coal supply and demand. In accordance with the government arrangement, the coal industry should eliminate backward capacity gradually, optimize existing capacity and expand capacity of high quality and realize the dynamic balance between supply and demand. The focus of overcapacity disposal should be distinguished among different coal production areas. For Northeast, East and Southeast China, coal mines with backward capacity (non-mechanized mining), insecure mining conditions and serious loss should be eliminated [9]. In Shanxi, Shaanxi, Inner Mongolia, Gansu and Ningxia provinces, the key point of overcapacity reduction is to propone and suspend some mines under construction, and shut down then reform some mines by technology; In Xinjiang and Qinghai provinces, coal capacity should mainly meet the region's demand, by proponing and suspending some mines under construction, and shutting down then reforming some mines by technology. According to the characteristics of coal resources and coal production in different regions, shutting down, restructuring and reforming coal mines should be taken to reduce overcapacity, optimize coal supply structure and realize the dynamic balance of supply and demand.

(3) China should pursue the integration of coal industry chain and strengthen the coal industrial convergence. China should focus on the construction of national energy base in Shanxi, Shaanxi, Inner Mongolia and Ningxia provinces, support the recombination between enterprises from the industries of coal, power, coal-chemical and transportation in accordance with market principles, and form several large energy groups of hundred million tons' capacity. All this will further improve the industry concentration and the production efficiency, increase market controlling and competition ability, and thus to lead the healthy and efficient development of the coal industry.

(4) China should improve the protection and conservation of coal resources and promote the sustainable development of energy. Resource conservation is the basic national policy. As coal is nonrenewable resource, in order to improve the exploration concentration and production efficiency, large coalfields should be given priority to big and dominant enterprises. As to the special scarce coal, extremely thick coal seams in Xinjiang, and coal under rivers, buildings and railways in Eastern China, measures of temporary mining prohibition or protective mining should be implemented, so as to strengthen the protection and conservation of coal resources and realize the sustainable development of energy.

(5) China should carry out the ecological civilization construction in mining area and promote green development. The concept that clean water and green mountains are just golden and silver should be established and practiced thoroughly, to strengthen ecological protection and restoration. New mining technology and process such as underground filling, water preserving mining, simultaneous extraction of coal and gas and distributed underground reservoir could be employed to minimize the damage to the ecological environment, retain clean water and green mountains and reconstruct ecosystem in mining areas by governance, reclamation and restoration measures [10].

6. Conclusion

Based on the research above, the following conclusions can be drawn:

(1) The coal industry in China now is facing overcapacity, low production efficiency, high pressure of production safety and environmental protection and other prominent issues. It is of great strategic significance to establish the evaluation model and indicators system to analyze the coal mining level, which is favorable for structure adjustment and the coal industry upgrading.

(2) Through establishing evaluation model and indicators system, coal mining level of America, Australia, China and the Inner Mongolia Autonomous Region of China were systematically evaluated and analyzed. The coal mining level in China is relatively low on the perspective of the whole country compared with America and Australia. However, mining level of the Inner Mongolia Autonomous Region was just little different from that of America.

(3) The development environment of coal industry in China has undergone profound changes. Measures should be taken to realize the green and sustainable development of coal industry, which involves seizing the opportunity of supply-side reform and optimizing the layout of coal industry, promoting the coal production overcapacity disposal with overall consideration and achieving balance between coal supply and demand, pursuing the integration of coal industry chain and strengthening the coal industrial convergence, improving the protection and conservation of coal resources and promoting the sustainable development of energy, and carrying out the ecological civilization construction in mining area and promoting green development.

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