

Evaluation of Green Development Level of a Coal Enterprise Based on the Entropy Weight–TOPSIS Model and Obstacle Degree Model

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Abstract: To evaluate the green development level of a coal enterprise and identify its major obstacle factors, this study selected a coal enterprise as a case study, collected relevant data from 2021 to 2025, and constructed an evaluation index system with four dimensions: economic development, resource and energy utilization, environmental friendliness, and green innovation and environmental governance. The entropy weight–TOPSIS model was employed to measure the green development level of the enterprise, and the obstacle degree model was used to identify the major obstacle factors. The results showed that the overall green development level of the enterprise first increased, then declined, and subsequently recovered during the study period, with the relative closeness ranging from 0.34 to 0.55. The “environmental friendliness” dimension and the “green innovation and environmental governance” dimension had relatively large impacts on the evaluation results. The major obstacle factors exhibited distinct stage-specific characteristics. From 2021 to 2022, the main obstacle factors were environmental protection investment, ecological management, and resource utilization. From 2023 to 2025, the major obstacle factors gradually shifted toward operational efficiency, pollution control, and resource utilization.

Keywords: coal enterprise; green development; entropy weight–TOPSIS; obstacle degree model

1 Introduction

With the advancement of China's dual-carbon strategy and the promotion of green development, resource-based enterprises, particularly coal enterprises, are facing increasingly prominent pressure to undergo green transformation[1]. The coal industry is characterized by high energy consumption and high emissions[2]. Under increasingly stringent environmental constraints, scientifically evaluating the green development level of enterprises and identifying the key factors constraining their green transformation have become important issues in enterprise management practice[3]. Therefore, constructing a green development evaluation index system, comprehensively evaluating the level of green development, and identifying the major obstacle factors are of practical significance for promoting the green development of coal enterprises.

Existing studies have examined green development from different perspectives. Yang et al.[4] employed the entropy weight method, TOPSIS, and the coupling coordination degree model to measure the high-quality development level of China's coal industry from 2000 to 2019. They found that the overall high-quality development level of the coal industry had generally improved, but industrial scale and development quality had not improved synchronously, and the major driving factors and constraints varied across different stages. Liu et al.[5] used the analytic hierarchy process to construct a green development evaluation system for metal mines, and taking Jiangsu Province as an example, identified four development modes. The results showed that the construction effectiveness of the comprehensive mode was relatively significant. Ren et al.[6] used principal component analysis to measure the green development level of the mining industry in 31 provinces, autonomous regions, and municipalities in China. The results showed that the eastern region had a generally higher green development level than the western region, and five typical development patterns were identified through cluster analysis. Luo et al.[7] employed a projection pursuit model and a coupling coordination degree model to analyze the green development level of China's mining industry from 2011 to 2023. The results revealed an overall improving trend, with environmental friendliness as the main influencing factor, while the

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coordination among the subsystems gradually reached a moderate level. Li et al.[8] introduced a sub-index dynamic time warping weighted clustering method based on panel data, classified the green development of the mining industry across provinces into four patterns, and suggested differentiated countermeasures for the problems associated with each pattern. Xu et al.[9] used the fuzzy analytic hierarchy process to construct an evaluation system for energy-saving and emission-reduction potential, taking Wuyang Coal Mine in Shanxi Province as a case study. The main constraints were identified in terms of resource recovery, equipment energy consumption, production processes, and energy management. Overall, existing studies have developed a variety of methods for evaluating green development. However, most of these studies have mainly focused on the regional level, while relatively limited attention has been paid to the evaluation of green development at the enterprise level, particularly for coal enterprises. In addition, prior research has focused more on measuring the overall level of green development, with insufficient attention paid to the specific obstacles associated with different indicators during the green transformation of enterprises. Therefore, it is necessary to construct an enterprise-level green development evaluation system that better reflects the characteristics of the coal industry and to further identify the key factors constraining its green development.

Green development involves multiple dimensions, including economic development, resources, environment, and innovation. A single indicator cannot fully reflect the green development level of an enterprise, while subjective weighting methods may be affected by human factors. The entropy weight–TOPSIS method determines indicator weights according to the degree of dispersion in the indicator data and measures the comprehensive development level based on the proximity of the evaluation object to the positive and negative ideal solutions. This approach can reduce the influence of subjective weighting on the evaluation results to some extent. Building on this method, the obstacle degree model is introduced to further identify the major factors constraining the green development of enterprises. In this study, the entropy weight–TOPSIS method and the obstacle degree model are combined to evaluate the green development level of a coal enterprise and further identify its major obstacle factors, thereby providing a reference for the green transformation and green management of coal enterprises.

2 Index System Construction and Data Sources

Based on relevant studies[10-12] and considering the characteristics of green development in coal enterprises, this study follows the principles of scientificity, systematicity, operability, and representativeness. Twelve indicators are selected from four dimensions: economic development; resource and energy utilization; environmental friendliness; and green innovation and environmental governance. An evaluation index system for the green development of the enterprise is thus constructed, as shown in Table 1. The economic development dimension reflects the operating efficiency and growth capacity of the enterprise; the resource and energy utilization dimension reflects the levels of energy consumption and resource recycling; the environmental friendliness dimension measures pollutant emissions

Table 1. Evaluation index system and weights for the green development of the enterprise

Target	Subsystem	Indicator	Attribute	Information entropy	Weight
Enterprise green development level	Economic development	Labor productivity (10,000 CNY/person)	+	0.82	0.07
		Operating revenue growth rate (%)	+	0.60	0.15
	Resource and energy utilization	Comprehensive energy consumption per 10,000 CNY of operating revenue (tce/10,000 CNY)	–	0.85	0.06
		Comprehensive utilization rate of mine water (%)	+	0.76	0.09
		Comprehensive utilization rate of coal gangue (%)	+	0.79	0.08
	Environmental friendliness	Wastewater discharge per 10,000 CNY of operating revenue (t/10,000 CNY)	–	0.75	0.09
		Waste gas emission per 10,000 CNY of operating revenue (m ³ /10,000 CNY)	–	0.82	0.07
		General industrial solid waste generation per 10,000 CNY of operating revenue (t/10,000 CNY)	–	0.83	0.07
		Area of mine geological environmental remediation (ha)	+	0.78	0.09
	Green innovation and environmental governance	R&D investment intensity (%)	+	0.83	0.07
		Proportion of R&D personnel (%)		+	0.82
		Environmental protection investment intensity (%)	+	0.73	0.10

and ecological management; and the green innovation and environmental governance dimension reflects the levels of investment in green innovation and environmental governance. The data were mainly obtained from the enterprise's annual reports and internal statistical records for 2021–2025. For indicators showing abnormal fluctuations in certain years, the actual operating conditions were examined to verify the data, and corrections were made accordingly to improve the reliability of the evaluation results.

3 Research Methods

3.1 Entropy Weight Method

The entropy weight method is an objective weighting method based on the degree of variation in indicator data. The greater the variability of an indicator, the more useful information it contains and the greater its influence on the comprehensive evaluation results; consequently, its corresponding weight is higher. This method can reduce the influence of subjective factors on the determination of indicator weights to a certain extent. In this study, the evaluation matrix contains data for 5 evaluation years and 12 indicators. First, the original data are standardized. Positive and negative indicators are standardized separately using Equations (1) and (2), respectively.

$$x'_{ij} = \frac{x_{ij} - x_{\min}}{x_{\max} - x_{\min}} \quad (1)$$

$$x'_{ij} = \frac{x_{\max} - x_{ij}}{x_{\max} - x_{\min}} \quad (2)$$

where x'_{ij} is the standardized indicator value, $i=1,2,\dots,m$; $j=1,2,\dots,n$. After standardization, the value range of each indicator is $[0,1]$. After completing the standardization of the indicators, the indicator proportion p_{ij} , information entropy e_j , information utility value d_j , and indicator weight w_j are calculated, and the calculation formulas are shown in Equations (3)–(6):

$$p_{ij} = \frac{x'_{ij}}{\sum_{i=1}^m x'_{ij}} \quad (3)$$

$$e_j = -\frac{1}{\ln m} \sum_{i=1}^m p_{ij} \ln(p_{ij}) \quad (4)$$

$$d_j = 1 - e_j \quad (5)$$

$$w_j = \frac{d_j}{\sum_{j=1}^n d_j} \quad (6)$$

where m is the number of samples. Through the above steps, the objective weights of each evaluation indicator are determined, providing a weight basis for the subsequent TOPSIS model to measure the comprehensive green development level of the enterprise.

3.2 TOPSIS Model

The TOPSIS model measures the overall green development level of the evaluation object by calculating the distances between each evaluation object and the positive and negative ideal solutions. First, the weighted standardized matrix $Z_{ij} = \{w_j \cdot x'_{ij}\}$ is constructed. Then, the positive ideal solution and the negative ideal solution are determined. Subsequently, the Euclidean distances between each evaluation object and the positive and negative ideal solutions are calculated, and the relative closeness is obtained. The specific calculation formulas are shown in Equations (7)–(9).

$$D^+ = \sqrt{\sum_{j=1}^n (Z_{ij} - Z_j^+)^2} \quad (7)$$

$$D^- = \sqrt{\sum_{j=1}^n (Z_{ij} - Z_j^-)^2} \quad (8)$$

$$C_i = \frac{D^-}{D^+ + D^-} \quad (9)$$

where $Z_j^+ = \max Z_{ij}, i=1,2,\dots,n$; $Z_j^- = \min Z_{ij}, i=1,2,\dots,n$. The closer C_i is to 1, the closer the evaluation object is to the

positive ideal solution, and the higher its green development level.

3.3 Obstacle Degree Model

The entropy weight–TOPSIS model can measure the green development level of an enterprise in different years, but it cannot further identify the specific obstacle factors affecting this level. Therefore, on the basis of the comprehensive evaluation, this study introduces the obstacle degree model to measure the obstacle degree of each evaluation indicator. First, the deviation degree I_{ij} and factor contribution F_j of each indicator are calculated, where $I_{ij}=1-x'_{ij}$ and $F_j=w_j$. On this basis, the obstacle degree of each indicator is obtained. The specific calculation formula is shown in Equation (10). The greater the obstacle degree, the stronger the constraint imposed by the indicator on the green development level of the enterprise.

$$H_{ij} = \frac{I_{ij} \cdot F_j}{\sum (I_{ij} \cdot F_j)} \times 100\% \quad (10)$$

4 Case Analysis

The case enterprise is a large-scale energy enterprise primarily engaged in the coal industry. In recent years, the enterprise has continuously promoted green mining and intelligent mine construction, strengthened efforts in energy conservation and consumption reduction, and increased investment in innovation. This study selected relevant data from 2021 to 2025 to evaluate and analyze the green development level of the enterprise and its major obstacle factors.

4.1 Analysis of the Comprehensive Green Development Level

Based on the entropy weight method, weights were assigned to the green development evaluation indicators of the enterprise, and the results are shown in Table 1. Overall, the weights of the indicators varied to some extent from 2021 to 2025. Among the four dimensions, the environmental friendliness dimension had the highest weight, accounting for 31.4%, indicating that the indicators in this dimension varied considerably during the study period and thus had a relatively large impact on the comprehensive evaluation results. Specifically, wastewater discharge per CNY 10,000 of operating revenue and the area of mine geological environmental remediation showed an overall upward trend from 2021 to 2024 and then declined in 2025. In 2025, wastewater discharge per CNY 10,000 of operating revenue decreased significantly, indicating that the amount of wastewater discharged per unit of operating revenue declined, which may be related to improvements in wastewater recycling and other factors. The area of mine geological environmental remediation also decreased in 2025, which may be related to the implementation schedule of remediation projects and changes in the production area. In the economic development dimension, the weight of the operating revenue growth rate was the highest, which was mainly related to the large variation in this indicator during the study period. In 2023, the operating revenue growth rate decreased significantly, reflecting fluctuations in the scale or operating conditions of the enterprise. The entropy values of labor productivity, the proportion of R&D personnel, and R&D investment intensity were relatively high, indicating that the variation in these indicators during the study period was relatively small and their overall fluctuations were limited.

Based on the calculation results of the entropy weight–TOPSIS model, as shown in Figure 1, the green development level of the enterprise generally exhibited an initial increase, followed by a decline and subsequent recovery during 2021–2025. In 2022, the relative closeness increased, mainly due to the increase in the operating revenue growth rate, the improvement in labor productivity, and the increase in environmental protection investment. In 2023, the relative closeness decreased significantly, mainly due to the decline in the operating revenue growth rate, the decline in R&D investment intensity, and changes in indicators related to energy consumption, wastewater discharge, waste gas emissions, and general industrial solid waste generation. From 2024 to 2025, the green development level of the enterprise continued to increase, driven by the continuous improvement in environmental protection investment intensity, the recovery of R&D investment intensity, the decline in wastewater discharge per CNY 10,000 of operating revenue, and the improvement in the comprehensive utilization rate of coal gangue. However, changes in indicators within the economic development dimension still constrained further improvement in the overall level to some extent.

4.2 Analysis of the Obstacle Degree of Enterprise Green Development

The main results of the obstacle degree analysis for the enterprise from 2021 to 2025 are shown in Table 2. Based on the obstacle degree results, the major obstacle factors for the green development of the enterprise varied across years, showing distinct stage-specific characteristics. From 2021 to 2022, the major obstacle factors were

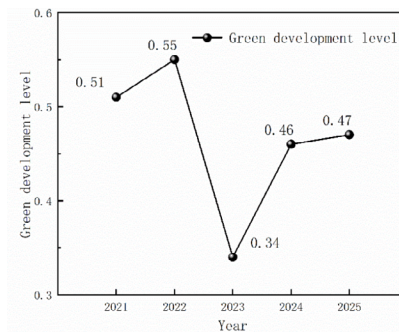


Fig. 1. Green development level of the enterprise from 2021 to 2025

environmental protection investment, ecological management, and the utilization of mine water resources. From 2023 to 2024, the operating revenue growth rate, wastewater discharge, and comprehensive resource utilization gradually became the major obstacle factors. In 2025, the major obstacle factors were the operating revenue growth rate, labor productivity, and the generation of general industrial solid waste. These results indicate that, as environmental protection investment and some resource utilization indicators gradually improved, the constraints on green development shifted from environmental governance toward operational efficiency, labor productivity, and solid waste control. Therefore, subsequent green transformation should not only focus on environmental protection investment but also further improve operational efficiency, strengthen efforts in energy conservation and consumption reduction, and enhance the source control of solid waste to promote continuous improvement in the green development level.

Table 2. Major obstacle factors and obstacle degrees in each year

Year	First obstacle factor	Obstacle degree	Second obstacle factor	Obstacle degree	Third obstacle factor	Obstacle degree
2021	Environmental protection investment intensity	0.23	Area of mine geological environmental remediation	0.19	Operating revenue growth rate	0.16
2022	Comprehensive utilization rate of mine water	0.2	Environmental protection investment intensity	0.2	Area of mine geological environmental remediation	0.15
2023	Operating revenue growth rate	0.33	Wastewater discharge per 10,000 CNY of operating revenue	0.18	Comprehensive utilization rate of mine water	0.17
2024	Operating revenue growth rate	0.3	Wastewater discharge per 10,000 CNY of operating revenue	0.21	Comprehensive utilization rate of coal gangue	0.18
2025	Operating revenue growth rate	0.34	Labor productivity	0.16	General industrial solid waste generation	0.15

5 Conclusion

This study took a coal enterprise as the research object and employed the entropy weight–TOPSIS model and the obstacle degree model to evaluate and analyze its green development level and major obstacle factors from 2021 to 2025. The main conclusions are as follows:

(1) In terms of indicator weights, the environmental friendliness dimension had the highest weight of 0.32, while the green innovation and environmental governance dimension had a weight of 0.24. Together, these two dimensions accounted for more than 50% of the total weight. From the perspective of individual indicators, the weights of several indicators were relatively high, including the operating revenue growth rate, environmental protection investment intensity, comprehensive utilization rate of mine water, and wastewater discharge per CNY 10,000 of operating revenue. This indicates that economic operating conditions, resource utilization, and environmental governance had relatively large effects on the green development evaluation of the enterprise.

(2) In terms of the overall green development level, the relative closeness of the enterprise ranged from 0.34 to 0.55 during 2021–2025, showing an initial increase, followed by a decline and subsequent recovery. Although environmental governance and resource utilization indicators improved to some extent, operational efficiency, energy consumption, and pollutant control remained major constraints on further improvement in the green development level.

(3) The major obstacle factors varied across different stages. From 2021 to 2022, the obstacle degrees of environmental protection investment intensity, the area of mine geological environmental remediation, and the comprehensive utilization rate of mine water were relatively high, indicating that green development was mainly constrained by environmental governance investment and resource utilization. From 2023 to 2025, the operating revenue growth rate became one of the major obstacle factors, while labor productivity and the generation of general industrial solid waste also posed relatively high obstacle degrees. The major constraints on green development gradually shifted from environmental governance investment toward operational efficiency, pollution control, and resource utilization.

Based on the above conclusions, the green transformation of enterprises should not rely solely on increasing environmental protection investment, but should also pursue coordinated improvements in source reduction, energy conservation and consumption reduction, and operational efficiency. The green development of enterprises depends on multiple factors, including operational efficiency, resource utilization, environmental governance, and green innovation, rather than on increased investment in environmental governance alone. Therefore, subsequent green transformation should adopt differentiated management strategies based on the major obstacle factors at different stages, thereby achieving coordinated improvements in economic and environmental benefits.

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