ISSN: 2710-0588

Evaluation of the Transformation Effect of Coal Resource Depleted City in Jiaozuo City Based on the CRITIC-VIKOR Method

Shuting An

Henan Polytechnic University, Jiaozuo 454003, China

Abstract

This paper uses the CRITIC-VIKOR method to comprehensively evaluate Jiaozuo City, a typical coal resource depleted city, from four dimensions: environmental, economic, social and resource. By analyzing the relevant data from 2009 to 2023, this paper analyzes the transformation effects of each subsystem, aiming to provide theoretical basis and practical reference for the transformation and development of coal resource depleted cities.The results revealed that Jiaozuo achieved its lowest score of 0.36 in 2020, indicating a "relatively good" transformation status (Level IV) and the most effective transformation performance. Conversely, in 2012, it recorded the highest score of 0.82, corresponding to a "poor" transformation status (Level I) and the least effective performance. Socially, the best outcomes emerged around 2015, while economic improvements began in 2016. Environmental performance scores hovered around 0.5 with relatively stable fluctuations, peaking in 2014–2015. Resource-related transformation showed positive effects starting in 2020.Comparative analysis across dimensions revealed the following hierarchy: economic > social > environmental > resource.

Keywords

Coal resource depleted cities; transformation evaluation; CRITIC method; VIKOR method; Jiaozuo Market.

1. Introduction

China is a country with extremely abundant natural resources. Currently, according to the National Sustainable Development Plan for Resource-Based Cities (2013–2020) issued by the State Council in 2013, there are 262 resource-based cities in China, accounting for 38% of all cities in the country. These resource-based cities have made historic contributions to establishing an independent and complete industrial system and promoting national economic development in China[1]. However, the over exploitation and over utilization of natural resources have led to resource depletion, causing some resource-based cities to gradually become resource-exhausted cities. This transformation is accompanied by a series of social issues, including reduced employment opportunities, ecological degradation, environmental pollution, and slowed economic growth[2]. Therefore, it is urgent to target urban transformation directions, clarify dominant urban industries, accelerate the pace of urban transformation, and advance comprehensive urban transformation.

Resource-exhausted cities refer to those where mineral resource development has entered its late, final, or terminal stages, with cumulative production reaching over 70% of the recoverable reserves[3]. To achieve this goal promptly, the Chinese government has introduced numerous policies, such as the Several Opinions of the State Council on Promoting the Sustainable Development of Resource-Based Cities (Guo fa [2007] No. 38), the National Sustainable Development Plan for Resource-Based Cities (2013–2020) (Guo fa [2013] No. 45), and the Implementation Opinions on Supporting the Industrial Transformation and Upgrading of

ISSN: 2710-0588

Old Industrial Cities and Resource-Based Cities (Fagai Zhenxing Gui [2016] No. 1966), highlighting the government's emphasis on this issue. According to official documents released by China, a total of 69 resource-exhausted cities (counties and districts) have been identified, with coal-exhausted cities accounting for 53.6%, indicating that coal resources constitute the majority[4].

Many scholars both domestically and internationally have conducted research on this topic. For instance, Long Ruyin [5] et al. employed the dynamic evaluation method based on panel data—TOPSIS—to evaluate the green development levels of 30 coal resource-based cities in China. The results indicated that from 2012 to 2018, the overall green development level of these cities was relatively low, with variations across dimensions and regions. They also proposed corresponding policy recommendations for green development. Wang Xiaonan [6] et al. used the DEA model to evaluate the transformation efficiency of 41 resource-based cities in the Yellow River Basin and conducted panel regression analysis on influencing factors and their differences using a fixed-effects model. Their findings revealed that the transformation efficiency of resource-based cities in the Yellow River Basin was not ideal, with scale efficiency being the primary determinant of comprehensive efficiency, and differences in influencing factors among cities. Research by Zeng Xiangang and Duan Cunru [7] highlighted significant differences in green transformation performance across cities and the important impact of transformation path selection on transformation performance. Ye Changlong [8] selected 15 coal resource-exhausted cities as research subjects, constructed a three-dimensional indicator system encompassing economic development, social welfare, and ecological environment, and quantitatively assessed the transformation performance of these cities during the planning period of the National Sustainable Development Plan for Resource-Based Cities (2013–2020) (hereinafter referred to as the Plan) using the entropy method, cluster analysis, and obstacle factor model. He also analyzed the obstacle factors affecting urban transformation. Ji Chuning [9]et al. proposed a study on the transformation of coal resource-exhausted cities based on the integration of landscape and ecological functions, emphasizing the importance of ecological restoration and sustainable development.

This paper employs the CRITIC-VIKOR method to evaluate Jiaozuo City, a coal resource-exhausted city, from four dimensions: environment, economy, society, and resources. The aim is to contribute to the successful transformation and high-quality development of coal resource-exhausted cities in China.

2. Area of Study

According to official documents issued by the Chinese government, a total of 69 resource-exhausted cities (counties and districts) have been identified, among which coal-exhausted cities account for 53.6%, indicating that coal resources constitute the majority. Therefore, this paper selects coal-exhausted cities as the research subjects.

Jiaozuo City is located in the northwestern part of Henan Province, bordering Shanxi Province to the north with the Taihang Mountains and facing Zhengzhou and Luoyang across the Yellow River to the south. Jiaozuo City boasts a relatively wide variety of mineral resources with substantial reserves. Its coalfield extends 65 km from east to west, spanning from Xiuwu in the east to Boai in the west, and 20 km from north to south, bordering Wuzhi in the south. The proven coal reserves amount to 3.24 billion tons, primarily consisting of high-quality anthracite, which serves as an ideal raw material for the chemical and steel industries. From the onset of coal mining until the early 1990s, the value-added of industries related to coal accounted for over 90% of Jiaozuo's industrial added value. After years of exploitation, Jiaozuo's coal resources are nearing depletion, and in 2008, it was included in the list of "Typical Resource-Exhausted Cities in Central China." Additionally, the ecological environment deterioration

ISSN: 2710-0588

caused by resource exploitation has become increasingly severe. Hence, Jiaozuo City is chosen as the research area for this study.

3. Method

The transformation of coal resource-exhausted cities encompasses four main aspects: society, economy, ecological environment, and resources. However, these aspects are not isolated or parallel but are interconnected with one another[10]. With the acceleration of urbanization and robust economic growth, urban landscapes are rapidly changing. In the pursuit of higher-level economic development, excessive exploitation and utilization of natural resources often occur inadvertently, causing significant damage to the ecological environment. Issues such as air pollution, water pollution, and soil degradation are becoming increasingly severe, not only disrupting the ecological balance of nature but also posing severe challenges to the sustainable development of human society.

Faced with this situation, achieving coordinated development among the four aspects of society, economy, environment, and resources has become a crucial task of our era. This issue is particularly urgent and important during the transformation process of coal resource-exhausted cities. These cities have long relied on the coal industry to support their economic development. However, with the depletion of resources, traditional industries are facing decline, and economic growth is slowing down. Simultaneously, long-term mining activities have imposed a heavy burden on the ecological environment. Therefore, the transformation path for coal resource-exhausted cities must be a green, low-carbon, and sustainable one.

3.1. Construction of evaluation index system

Urban transformation contributes to the favorable development of cities. It helps coal cities break free from excessive dependence on coal resources, enabling a more complete and rational economic structure, fostering more stable social development, and creating a more comfortable and greener environment[11]. Therefore, this paper establishes an evaluation system encompassing four major aspects—society, economy, environment, and resources—to assess the transformation efficiency of Jiaozuo City. Drawing on previous research findings, 30 evaluation indicators have been designed. Of course, other indicators such as "economic growth rate," "total fixed asset investment in society," and "per capita public green space area" can also reflect the degree of urban transformation. However, considering data integrity and scientific rigor, the indicators presented in Table 1 have been selected for analysis.

3.2. Data sources

The data in the indicator system are sourced from the China City Statistical Yearbook, the China Urban Construction Statistical Yearbook, Jiaozuo City's urban statistical yearbooks, and the Statistical Bulletin on National Economic and Social Development spanning from 2009 to 2023. To ensure the accuracy and authenticity of the data, missing values for certain years or indicators were obtained through interpolation calculations. The proportion of missing data is less than 0.5%, which is minimal and insufficient to exert any significant influence.

3.3. CRITIC

The CRITIC method is a weighting approach proposed by Diakoulaki in 1995 to determine objective weights for evaluation criteria. It comprehensively measures and determines indicator weights based on the contrast intensity of evaluation indicators and the conflict among them[12]. Contrast intensity refers to the difference in the same indicator across different evaluation schemes, represented in the form of standard deviation. The greater the contrast intensity of an indicator, the higher its weight. Conflict is expressed through

ISSN: 2710-0588

correlation coefficients. A larger correlation coefficient indicates lower conflict and, consequently, a lower weight. The calculation method is as follows:

1. Data Standardization: Standardize the raw data to eliminate the influence of different units and ensure comparability among indicators. Standardization methods typically include processing for positive and negative indicators.

$$\text{Contrarian indicator: } y_{ij} = \frac{x_{max} - x_{ij}}{x_{max} - x_{min}}$$

$$\text{Positive indicators: } y_{ij} = \frac{x_{ij} - x_{min}}{x_{max} - x_{min}}$$

2. Calculate Standard Deviation (Contrast Intensity): The standard deviation is used to measure the volatility of an indicator. A larger standard deviation indicates greater volatility, more information, and thus a higher weight. The formula is as follows：

$$\partial_j = \sqrt{\frac{\sum_{i=1}^{n}\left(y_{ij} - \frac{1}{n}\sum_{i=1}^{n} y_{ij}\right)^2}{n-1}}$$

$$\text{Coefficient: } V_j = \frac{\partial_j}{\left(\frac{1}{n}\sum_{i=1}^{n} y_{ij}\right)}$$

3. Calculate Correlation Coefficient (Conflict): The correlation coefficient is used to measure the correlation between indicators. A larger correlation coefficient indicates lower conflict and, therefore, a lower weight. The formula is as follows:

$$B_j = \sum_{i=1}^{n}\left(1 - r_{ij}\right)$$, rijis the correlation coefficient

4. Calculate Weights:

$$W_j = \frac{\partial_j \times B_j}{\sum_{j=1}^{m} \partial_j \times B_j}$$

Based on the above steps, the weights of the indicators can be obtained, with the results presented as follows.

3.4. VIKOR method

The VIKOR method is a multi-attribute decision-making approach that determines the compromise solution for each alternative by identifying the positive ideal solution (optimal state) and the negative ideal solution (worst state). It ranks the priority order of evaluation objects by comparing the distances between each alternative and the ideal solutions[13]. The calculation method is as follows:

1.Standardized Results: Utilize the standardized results obtained as described above.

2.Determine Positive and Negative Ideal Solutions: These are set as the maximum and minimum values, respectively, from the standardized results.

3.Calculate Group Utility Value and Individual Regret Value:

$$S_i^+ = \sum_{j=1}^{m} \lambda_j \bullet \frac{f_j^+ - y_{ij}}{f_j^+ - f_j^-} \quad R_i^+ = \max_j \lambda_j \bullet \frac{f_j^+ - y_{ij}}{f_j^+ - f_j^-}$$

$$S_i^- = \sum_{j=1}^{m} \lambda_j \bullet \frac{y_{ij} - f_j^+}{f_j^+ - f_j^-} \quad R_i^- = \max_j \lambda_j \bullet \frac{y_{ij} - f_j^-}{f_j^+ - f_j^-}$$

ISSN: 2710-0588

4.Calculate the compromise

$$Q_i = \xi \frac{S_i - S_i^+}{S_i^+ - S_i^-} + (1-\xi)\frac{R_i - R_i^+}{R_i^+ - R_i^-}$$

Table 1. Evaluation index system

First-Level Indicator	Second-Level Indicator	Third-Level Indicator	Unit	Indicator Nature	Weight
Social	Social Security	Registered Urban Unemployment Rate	%	-	0.029
		Coverage Rate of Basic Pension Insurance for Urban Employees	%	+	0.026
		Coverage Rate of Basic Medical Insurance for Urban Employees	%	+	0.038
	Urban Development	Green Coverage Rate in Built-Up Areas	%	+	0.022
		Number of Students Enrolled in Higher Education Institutions	Person	+	0.024
		Tourism Revenue	100 million yuan	+	0.025
		Proportion of Science and Technology Expenditure in Total Fiscal Expenditure	%	+	0.029
		Proportion of Education Expenditure in Total Fiscal Expenditure	%	+	0.036
Economy	Economic Level	Per Capita GDP	Yuan/person	+	0.021
		GDP Growth Rate	%	+	0.032
		Urban Engel Coefficient	%	+	0.043
		Proportion of Total Fiscal Expenditure in GDP	%	+	0.026
	Industrial Structure	Proportion of Mining Employment in Total Employed Population	%	+	0.041
		Growth Rate of Coal Mining and Processing Industry	%	+	0.039
		Proportion of Secondary Industry in GDP	%	+	0.060
		Proportion of Tertiary Industry in GDP	%	+	0.031
Environment	Environmental Pollution	Industrial Sulfur Dioxide Emissions	Ton	-	0.030
		Industrial Smoke and Dust Emissions	Ton	-	0.028
		Industrial Wastewater Discharge	10,000 tons	-	0.024
	Environmental Governance	Number of Days with Good Air Quality	Day	+	0.057
		Harmless Treatment Rate of Domestic Waste	%	+	0.025
		Sewage Treatment Rate	%	+	0.023
		Treatment Rate of Industrial Sulfur Dioxide	%	+	0.033
		Removal Rate of Industrial Smoke and Dust	%	+	0.025
Resources	Resource Consumption	Increase in Energy Consumption per Unit of GDP	%	-	0.045
		Comprehensive Energy Consumption of Industrial Enterprises Above Designated Size | 10,000 tons of standard coal	10,000 tons of standard coal	-	0.025
		Per Capita Daily Domestic Water Consumption	Liter	-	0.028
	Resource Production and Utilization	Raw Coal Output	10,000 tons	-	0.023
		Total Gas Supply (Artificial and Natural Gas)	10,000 cubic meters	+	0.021
		Utilization Rate of Industrial Solid Waste	%	+	0.042

ISSN: 2710-0588

4. Analysis of Results

4.1. Evaluation of urban transformation effect

According to the above method, the transformation level results are obtained. These cities are divided into 6 tiers, as shown in the table below.

Table 2. Urban transformation evaluation result grade table

Urban transformation evaluation value	Evaluation level	State of transformation
0-0.2	V	Good
0.2-0.4	IV	Relatively Good
0.4-0.6	III	Fair
0.6-0.8	II	Minimal
0.8-1.0	I	Poor

4.2. Comprehensive evaluation results analysis

The transformation level of Jiaozuo City from 2009 to 2023 was evaluated using the aforementioned methods, with the results illustrated in the figure 1 below. Since the VIKOR method was employed to calculate the transformation performance scores for each city, and VIKOR considers the distance from the positive ideal solution, a higher performance score indicates poorer transformation outcomes. The results show that Jiaozuo City achieved the lowest score of 0.36 in 2020, with a transformation status classified as "better" and a transformation degree of Level IV, indicating the best transformation performance. This success can be attributed to Jiaozuo's integration of transformation and development into the core of its urban strategy. Through policy documents such as the 2020 Summary of Industrial Transformation and Upgrading Projects Citywide, the city clearly defined its transformation directions toward high-end, green, intelligent, and integrated development. The government took the lead in promoting the "Three Transformations" (intelligent, green, and technological upgrades), established special funds to support enterprise upgrades, and implemented a "Chief Service Officer" system to provide full lifecycle services to businesses[14]. For instance, in 2020, Jiaozuo prioritized 385 industrial transformation and upgrading projects with a total investment exceeding 100 billion yuan, forming a closed-loop chain of "policy guidance-project implementation-industrial upgrading."

Secondly, industrial upgrading played a crucial role. By diversifying its industrial layout to reduce resource dependence, Jiaozuo revitalized traditional sectors such as chemicals and food through technological innovations. For example, Hexing Chemical pioneered a global carbon black modification technology, making its high-performance conductive carbon black production and sales the world's largest; Zhongyuan Internal Combustion Engine built an intelligent manufacturing production line for cylinder liners, achieving full-process automation with an annual output of nearly 400,000 units[15]. Despite facing global pandemic impacts and economic downturn pressures in 2020, Jiaozuo achieved remarkable results in industrial transformation, urban governance, and technological innovation through these multifaceted efforts, laying a solid foundation for high-quality economic development.

In contrast, Jiaozuo recorded the highest transformation performance score of 0.82 in 2012, with a transformation status classified as "poor" and a transformation degree of Level I, indicating the worst transformation performance. Although Jiaozuo actively developed non-coal industries, manufacturing, and agro-food processing during its transformation, the constraints on economic expansion and barriers to upgrading development levels caused by coal resource depletion remained unresolved. In 2012, while the added value of coal mining and washing declined by 33.9% year-on-year, its share in the industrial sector remained high, significantly dragging down economic growth. Meanwhile, emerging industries such as

ISSN: 2710-0588

biotechnology, new materials, and new energy grew rapidly but remained small in scale, unable to fully offset the decline of traditional industries. Although Jiaozuo attempted to break free from resource dependence by developing tertiary industries like tourism and modern logistics, as well as cultivating strategic emerging industries, challenges persisted, including difficulties in upgrading traditional industries and the long incubation period for emerging sectors[16]. In 2012, the added value of six high-energy-consuming industries grew by 8.5%, 5.7 percentage points lower than the overall industrial growth rate, underscoring the urgency of transforming traditional industries.

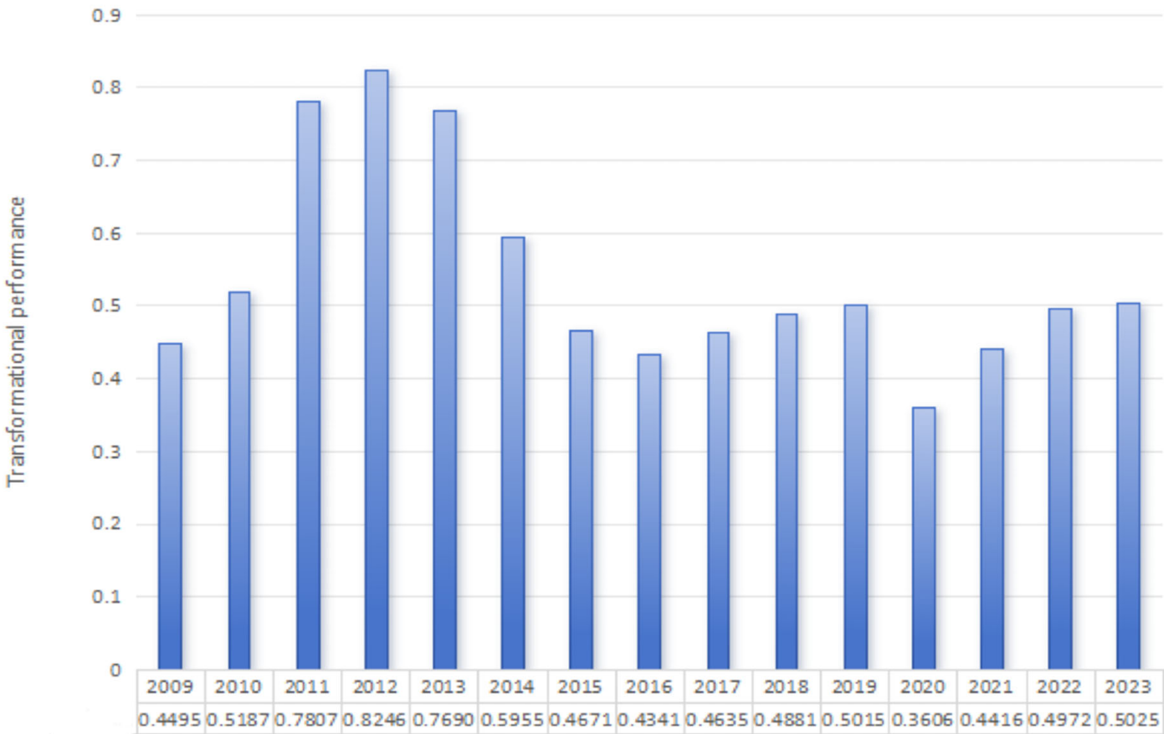

Figure 1. Transformation efficiency of Jiaozuo City

4.3. Evaluate the effect in each dimension

The data results in the figures illustrate the transformation effects of Jiaozuo City's four subsystems—economic, social, environmental, and resource—from 2009 to 2023, revealing varying performance levels across these dimensions for coal resource-depleted cities. The results are shown in the figures below.

Figure 2 depicts Jiaozuo's social transformation outcomes, indicating annual fluctuations with distinct stages of change. Social transformation represents a critical phase in urban development, particularly for resource-based cities like Jiaozuo, which face complex challenges due to long-term reliance on coal and other resources, including resource depletion, ecological damage, and an overly simplified industrial structure. Since 2009, Jiaozuo has embarked on a social transformation journey marked by four phases: initial progress, subsequent deterioration, temporary recovery, and renewed difficulties. Between 2009 and 2010, Jiaozuo actively responded to national policies for resource-based city transformation by promoting economic restructuring. This included upgrading traditional coal industries through advanced technologies and equipment to improve mining efficiency, safety, and environmental sustainability while reducing resource waste.

ISSN: 2710-0588

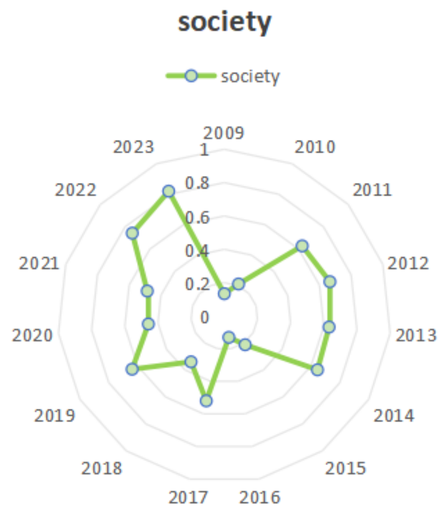

Figure 2. The efficiency of social transformation in Jiaozuo City

Figure 3 illustrates Jiaozuo's economic transformation outcomes, showing improvement starting in 2016 after a period of subpar performance during the early transformation stages. This reflects the delayed impact of industrial restructuring and the rise of emerging industries. Jiaozuo's economic transformation, initiated around 2010 when the Henan Provincial Government released the Overall Plan for Jiaozuo to Build a Demonstration City for Economic Transformation in the Central Plains Economic Zone, aimed to shift from resource dependency to a modern industrial system[17]. Initially, Jiaozuo's economy relied heavily on resource-based industries, particularly coal, which faced depletion and bottlenecks. Traditional sectors dominated, while emerging and high-tech industries remained underdeveloped, resulting in an irrational industrial structure, low economic openness, weak international competitiveness, and limited exports of technology-intensive and deep-processed products[18]. To address these issues, Jiaozuo implemented measures to optimize its industrial structure and promote upgrading, leading to significant changes over time.

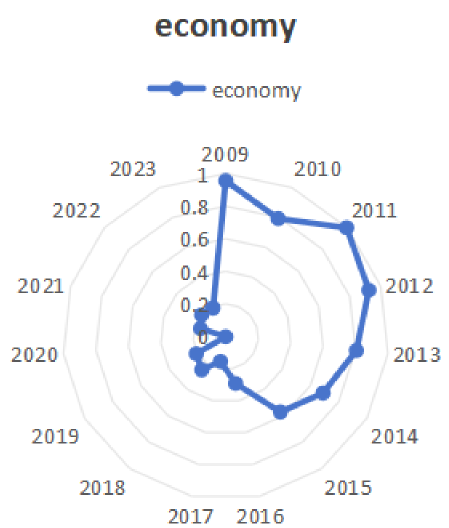

Figure 3. Jiaozuo City's economic transformation efficiency

Figure 4 presents Jiaozuo's environmental transformation outcomes, with performance scores fluctuating around 0.5 and peaking in 2014–2015 due to effective air pollution control measures, such as reducing coal consumption, upgrading coal-fired boilers with desulfurization systems, and shutting down small boilers[19]. These efforts lowered SO2 and PM2.5 concentrations, though PM2.5 levels remained high in autumn and winter 2015. From 2016 onward, further measures significantly reduced PM2.5 and SO2 concentrations, demonstrating the impact of these policies. Additionally, Jiaozuo's ecological quality improved around 2015, transitioning from a "critically safe" state (2008–2010) to steady enhancement, as evidenced by rising ecosystem quality indices from 2000 to 2020, indicating overall ecological recovery.

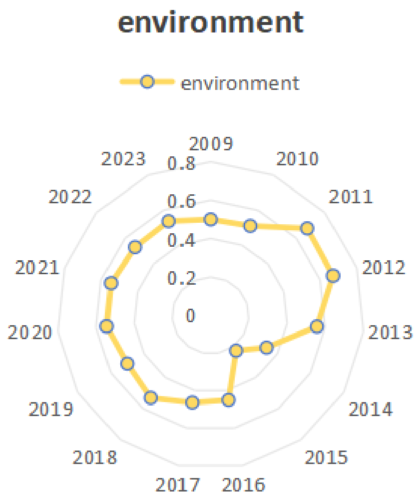

Figure 4. Jiaozuo City's environmental transformation efficiency

Figure 5 shows Jiaozuo's resource transformation outcomes, characterized by significant annual fluctuations but improvement since 2020. This progress stems from several factors: in January 2012, Jiaozuo was designated as a demonstration city for economic transformation in the Central Plains Economic Zone by the Henan Provincial Government, leveraging this opportunity to implement strategies for industrial strength, project-driven growth, openness, and technological innovation, fostering stable and rapid socioeconomic development. Jiaozuo supported the construction of industrial resource comprehensive utilization bases, incentivizing projects with investments exceeding 10 million yuan in resource recycling enterprises to enhance utilization efficiency. The city also encouraged green transformations using nationally promoted clean production technologies, improving resource efficiency and reducing pollution[20].

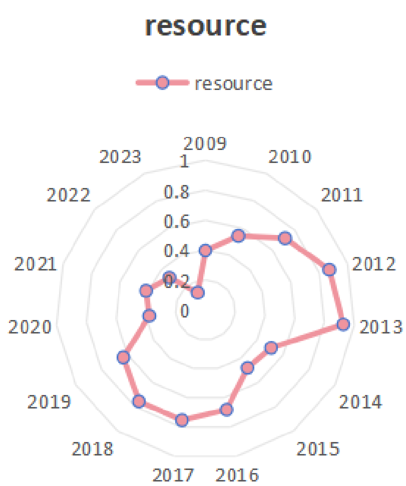

Figure 5. Jiaozuo City's resource transformation efficiency

ISSN: 2710-0588

Figure 6 compares transformation outcomes across all four dimensions, ranking them as economic > social > environmental > resource, with the economic sector demonstrating the strongest performance and vitality.

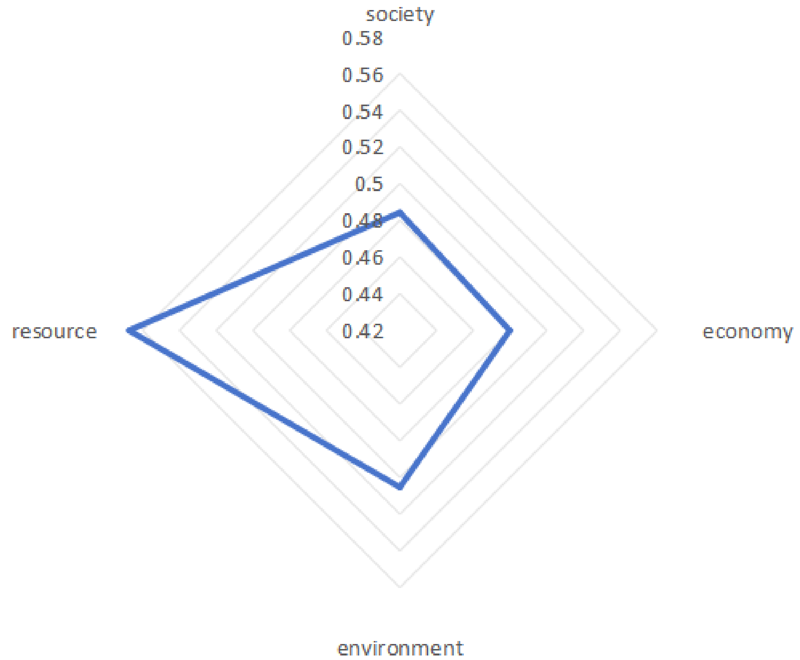

Figure 6. The transformation efficiency of Jiaozuo City at the social, economic, environmental and resource levels

Economic Dimension: Jiaozuo achieved remarkable results, with traditional industries upgrading through intelligent and green transformations—e.g., the chemical sector improving efficiency and reducing emissions via advanced technologies—while emerging industries, such as new energy battery materials, expanded rapidly, forming complete supply chains and attracting upstream and downstream enterprises. The service sector also thrived, with integrated cultural and tourism innovations boosting the popularity of attractions like Yuntai Mountain and Shennong Mountain, driving sustained growth in tourism revenue[21].

Social Dimension: Jiaozuo made steady progress by increasing education funding, building new schools, upgrading facilities, and improving teaching quality to cultivate talent. The healthcare system strengthened at the grassroots level, enhancing accessibility, while social security coverage expanded, with more residents enrolled in pension and unemployment insurance, improving living security.

Environmental Dimension: Jiaozuo took proactive measures, launching ecological restoration projects to rehabilitate mining areas and improving air and water quality through pollution controls, increasing days of good air quality and raising river water compliance rates, significantly optimizing the urban environment.

Resource Dimension: Jiaozuo advanced methodically by exploring efficient resource utilization pathways amid depletion, improving recovery rates, and promoting circular economy development. Despite challenges, the city progressed toward balancing resource exploitation with ecological protection.

Overall, Jiaozuo's coordinated development across dimensions, led by economic growth, lays a solid foundation for sustainable future development.

5. Discussion

As a typical resource-exhausted city, Jiaozuo has achieved remarkable results in its transformation and forged a distinctive path toward high-quality development.

Economic Transformation: In terms of industrial restructuring, Jiaozuo has promoted green and intelligent upgrades in traditional industries, revitalizing sectors such as chemicals and food processing through technological innovation. For instance, Hexing Chemical pioneered a global-first carbon black modification technology, securing the world's top position in product output and sales. Meanwhile, the city has vigorously cultivated emerging industries, with the new energy battery materials sector exceeding 56.7 billion yuan in scale. The new energy vehicle energy storage device manufacturing cluster was recognized as a national innovative industrial cluster, and strategic emerging industries demonstrated significant year-on-year growth in added value.

Social Transformation: Focusing on innovation-driven development, Jiaozuo prioritized innovation by implementing the "345" Innovation Initiative, integrating into the provincial "Two Cities, One Valley" system, and collaborating with institutions like the Henan Academy of Sciences to establish science and technology innovation platforms and accelerate the commercialization of research outcomes. In 2023, the city's R&D intensity reached 2.82%, with the fastest growth in R&D expenditure among large-scale industrial enterprises across the province.

Ecological and Environmental Transformation: Adhering to the "Two Mountains" philosophy (lucid waters and lush mountains are invaluable assets), Jiaozuo advanced ecological restoration and pollution control, earning recognition as a National Industrial Resource Comprehensive Utilization Base. It became the first city in the province to achieve full coverage of "Four Greens"—green factories, industrial parks, products, and supply chains.

Today, Jiaozuo has significantly increased the share of high-tech industries in its added value while drastically reducing the proportion of coal mining and other extractive sectors in its industrial structure, completing a remarkable transformation from a "black-dominated" to a "green-themed" economy.

6. Conclusion

This study employed the CRITIC-VIKOR method to evaluate Jiaozuo, a coal resource-exhausted city, across four dimensions—environment, economy, society, and resources. The results revealed that Jiaozuo achieved its lowest score of 0.36 in 2020, indicating a "relatively good" transformation status (Level IV) and the most effective transformation performance. Conversely, in 2012, it recorded the highest score of 0.82, corresponding to a "poor" transformation status (Level I) and the least effective performance.

An analysis of Jiaozuo’s transformation effects across economic, social, environmental, and resource subsystems from 2009 to 2023 demonstrated varying performance levels. Socially, the best outcomes emerged around 2015, while economic improvements began in 2016. Environmental performance scores hovered around 0.5 with relatively stable fluctuations, peaking in 2014–2015. Resource-related transformation showed positive effects starting in 2020.

Comparative analysis across dimensions revealed the following hierarchy: economic > social > environmental > resource. The economic dimension demonstrated the strongest performance, reflecting robust growth momentum, whereas the resource dimension lagged significantly, posing a critical constraint on Jiaozuo’s transformation.

Moving forward, Jiaozuo should deepen economic restructuring, strengthen social development initiatives, consolidate environmental governance achievements, and intensify

ISSN: 2710-0588

support for resource-based transformation to achieve balanced and sustainable development across all four dimensions.

References

[1] Wu Kang, Zhang Wenzhong, Zhang Pingyu, et al. High-Quality Development of China's Resource-Based Cities: Dilemmas and Breakthroughs [J]. Journal of Natural Resources, 2023, 38(01): 1-21.

[2] Research on the Planning Path for High-Quality Transformation and Development of Resource-Exhausted Cities [J].Urban architecture,2025,22(12):13-16+21.

[3] Research Group of the Institute of Macroeconomics, State Planning Commission. Definition and Classification of Resource-based Cities in our country[J]. Macroeconomic Research, 2002,24(11) : 37 - 39.

[4] YU Li' e, TONG Qianrui Analysis of Performance Evaluation and Obstacle Factor of Low-carbon Transformation in Coal Resource Depleted Cities. [J],2025,27(03):18-26.

[5] Ruyin L ,Haifeng L ,Meifen W , et al.Dynamic evaluation of the green development level of China's coal-resource-based cities using the TOPSIS method[J].Resources Policy,2021,74.

[6] Wang Xiaonan, Sun Wei. Transition Efficiency and Its Influencing Factors of Resource-Based Cities in the Yellow River Basin [J]. Progress in Geography, 2020, 39(10): 1643-1655.

[7] ZENG Xiangang, DUAN Cunru. Performance evaluation and differential analysis on green transformation of coal resource -exhausted cities in China [J]. China population, resources and environment, 2018, 28(7) : 127-135.

[8] YECL, YINJB, WANGZX, et al. Transformationperformanceandobstaclefactorsofcoalresource-exhaustedcities [J]. Journal of Shaanxi Normal University (Natural Science Edition),2023,51(6):84-96.

[9] JI C N HUANG J, HUANG G W, et al. Research on the transformation of coal exhausted cities based on the integration of landscape and ecological functions [J]. Journal of Henan Polytechnic University (Natural Science) ,2023,42(3):78-87.

[10] Zhu Li, Cao Mengying, Liu Ruijie. Evaluation of Energy Transformation and Identification of Obstacle Factors in Coal-Resource-Based Cities under the "Dual Carbon" Goals [J]. Environmental Science, 2024, 45(12): 6858-6869.

[11] Wang, Yang, et al. "End of rope or phoenix nirvana? Exploring the evolutionary paths of coal resource-based cities in China." Cities 154 (2024): 105382.

[12] Du X, Wang Y, Chen F. Evaluation of coal-resource-based cities transformation based on CRITIC-TOPSIS model[J]. Sustainable Cities and Society, 2024, 103: 105271.

[13] Zou Zonghua, Zhao Bin, Chen Jie, et al. Evaluation and Spatio-temporal Variation Characteristics of Water Resources Carrying Capacity in Nine Provinces and Regions along the Yellow River [J]. Journal of Earth Sciences and Environment, 2024, 46(3): 351-363.

[14] Tao Xiaoyan, Wu Zhanyong, Li Xiaofang, et al. Performance Measurement and Obstacle Factor Analysis of Transformation Development in Coal Resource-Exhausted Cities: A Case Study of Jiaozuo City [J]. Ecological Economy, 2022, 38(04): 94-100.

[15] Zeng Qi, Chang Menglin. Research on the Cultivation and Development of High-tech Enterprises in the Transformation of Resource-exhausted Cities: A Case Study of Jiaozuo City [J]. China Collective Economy, 2020, (06): 10-12.

[16] Liu Zhanyu, Sun Xialing. Research on Industrial Transformation and Upgrading of Resource-Exhausted Cities: A Case Study of Jiaozuo City [J]. China Collective Economy, 2017, (19):19-20.

[17] Bai Shuai, Cui Xufeng, Wu Jinhua, et al. Spatiotemporal Evolution and Prediction of Ecosystem Resilience in Resource-Based Cities: A Case Study of Jiaozuo City [J]. Ecological Science, 2025, 44(01): 88-99.

[18] Hu Meng. Research on the Development of Successive Industries in Resource-Based Cities [D]. Jilin University of Finance and Economics, 2019.

[19] Duan Kang. Research on Problems and Countermeasures of Ecological Transformation and Development in Resource-Based Cities [D]. Northwest A&F University, 2017.

ISSN: 2710-0588

[20] Zhao Yabo. Discussion on the Transformation of Resource-Based Cities: A Case Study of Jiaozuo City in Henan Province [J]. Journal of Capital Normal University (Natural Science Edition), 2013, 34(06): 59-64.

[21] Wang Xuejun, Hou Rui, Wang Ling. Research on the Evaluation System for Low-Carbon Transition of Resource-Based Cities Based on the TOPSIS Method: A Case Study of Jiaozuo City [J]. Ecological Economy, 2015, 31(11): 42-46.