Model Construction of Influencing Factors for the Sustainable Development of Resource-Based Cities Based on Gray Correlation Analysis

Yan Wang[1], Haiying Liu[1], and Lina Fu[1,2](✉)

[1] Ordos Institute of Technology, Ordos, Inner Mongolia, China
fulina324@163.com
[2] Tianjin Normal University, Tianjin, China

Abstract. Sustainable development of resource-based cities are an important part of implementing green development. This paper constructs the indicator system of influencing factors of sustainable development of three aspects of the economy, society and environment, uses gray correlation analysis method and entropy method to analyze the correlation degree of the indicator system, and obtains the ranking of the importance of each indicator, with an effort to construct a more universal analysis model of influencing factors of sustainable development of resource-based cities. Taking Ordos City as an example for empirical analysis, the conclusion has to be in conformity with the actual situation of sustainable development in Ordos City, and verifies the applicability of the model.

Keywords: resource-based city · sustainable · grey relational analysis · evaluation indicators · Ordos city

1 Introduction

China's economy has been transitional from a phase of rapid growth to a stage of high-quality development. This is a pivotal stage for transforming our growth model, improving economic structure, and fostering new drivers of growth. General Secretary Xi Jinping emphasized that it is necessary to make significant strides to accelerate the transformation of economic development mode and promote high-quality economic development. In 2013, the State Council issued the *National Sustainable Development Plan for Resource-based Cities (2013–2020)*, which present the goal of resource-based transformation and development, that is, the achievement of the sustainable development of resource-based cities. Via constructing the sustainable development indicator system of resource-based cities, using the gray correlation analysis method and entropy value method, this paper finds out the main influencing factors of the sustainable development of resource-based cities based on the correlation analysis of the indicators, and takes Ordos as an example to verify the model.

A. Luqman et al. (Eds.): PMIS 2022, AHCS 6, pp. 56–64, 2023.
https://doi.org/10.2991/978-94-6463-016-9_8

2 Research Methods

2.1 Construction of Rating Indicator System

With the purpose of achieving sustainable development, combined with the targeted requirements of economic development, industrial transformation, energy conservation and environmental protection of the sustainable development of resource-based cities proposed in the National Sustainable Development Plan for Resource-based Cities (2013–2020), 15 indicators were selected from three aspects of economy, society and environment. Combined with the basic principles of purpose, comprehensiveness, representativeness, data availability and simplification, etc., the evaluation indicators constructed in this paper are reproduced in Table 1.

2.2 Basic Assumptions and Data Processing

The evaluation of the influencing factors for the sustainable development of resource-based cities can be supposed as the problem of ranking the correlation degree of different indicators, and the ranking represents the importance of the indicator. Gray correlation analysis of the numerical changes of various indicators in different regions in recent years can measure the most important influencing factors of sustainable development in

Table 1. Weighted value and weight of sustainable development in resource-based cities

Target layer	System layer	Criteria layer	Indicator layer
Transformation of Resource-based Cities	Economic development	Economic situation	GDP per capita (yuan/person) GDP growth rate (%)
		Industrial structure	Employment proportion of manufacturing industry (%)
			The proportion of tertiary industry output value in total output value (%)
			Urban registered unemployment rate (%)
		Living standards	Per capita disposable income of residents (yuan/person)
			Total retail sales of consumer goods per capita (yuan)
	Social development	Culture, health and education	Resident insured medical insurance ratio (%)
			Culture, education, health and science expenses as a percentage of fiscal expenditure (%)
		Urban construction	Green coverage rate in built-up areas (m^2)
			Per capita road area (m^2)
	Environmental protection	Environmental governance	Comprehensive utilization rate of industrial solid waste (%)
			Sewage treatment rate (%)
		Energy consumption	10,000-yuan GDP water consumption (cubic meters/10,000 yuan)
			10,000-yuan GDP energy consumption (tons of standard coal/10,000 yuan)

the region. The indicator set consisting of m evaluation indicators is assumed $U = \{u_1, u^2, \ldots, u_m\}$, and each indicator set takes the annual value of the indicator as a variable, with n variables, i.e., the variable set $V = \{v_1, v_2, \ldots, v_n\}$. If the element (u_i, v_j) is recorded as a_{ij}, the indicator evaluation matrix composed of $m \times n$ elements is $A = [a_{ij}]_{m\times n}$.

Indicators goes through consistent and dimensionless treatment. Since only the urban registered unemployment rate, 10,000 yuan of GDP water consumption and 10,000 yuan of GDP energy consumption are very small indicators. The countdown method is used to deal with them consistently.

The indicator dimension is handled by the extreme difference transformation method. The formula is as following:

$$a_j^* = \max_{1\le i\le n}\{a_{ij}\} + 0.001 \tag{1}$$

$$a_j^0 = \min_{1\le i\le n}\{a_{ij}\} - 0.001 \tag{2}$$

$$x_{ij} = \frac{a_{ij} - a_j^0}{a_j^* - a_j^0} \tag{3}$$

Where, *aij* represents the value of the *j*-th indicator in the *i*-th year, and represents the maximum and minimum values of the j-th indicator, *xij* represents the processed indicator variable, $j = 1, 2\ldots m$ is the number of indicators, $j = 1,2\ldots m$ is the value of the indicator in the *i*-th year. The indicator evaluation matrix is $X = [xij]m\times n$.

$$X = \begin{bmatrix} 0.558 & 0.804 & 1.000 & 0.000 \\ 1.000 & 0.661 & 0.321 & 0.000 \\ 0.924 & 0.963 & 1.000 & 0.000 \\ 0.000 & 0.500 & 1.000 & 0.138 \\ 0.978 & 0.022 & 0.384 & 0.668 \\ 0.335 & 0.312 & 0.000 & 1.000 \\ 0.000 & 0.480 & 1.000 & 0.124 \\ 0.000 & 0.008 & 1.000 & 0.919 \\ 0.486 & 0.000 & 1.000 & 0.487 \\ 0.000 & 0.743 & 1.000 & 0.470 \\ 0.000 & 0.685 & 1.000 & 0.770 \\ 0.705 & 0.565 & 0.000 & 1.000 \\ 0.000 & 0.234 & 0.551 & 1.000 \\ 0.091 & 0.481 & 0.776 & 0.909 \\ 0.760 & 0.998 & 0.973 & 0.002 \end{bmatrix}$$

2.3 Equations Determination of Weight

After a large number of papers were looked up and expert consultation was referred, via solving the weight of indicators, it is believed that the economic, environmental

and social indicators in the sustainable development of resource-based cities are in the same important position in theory, so the solution of indicator weight adopts the entropy method. The entropy method holds that in the evaluation indicator system, the indicator with greater value difference can better reflect the gap of the evaluated unit. Armed with this concept, this paper selects the entropy method to determine the indicator weight, with a focus on the variability of the indicators.

The formula is as following:

$$e_j = -\frac{1}{\ln m}\sum_{j=1}^{m} p_{ij}\ln p_{ij} \tag{4}$$

$$d_j = 1 - e_j \tag{5}$$

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \tag{6}$$

Where e_j denotes the entropy value of the j-th indicator, p_{ij} means the proportion of the i-th year indicator value of the j-th indicator, d_j is the weight of the indicator, and d_j is normalized to obtain the weight value w_j of the j-th indicator.

2.4 Comprehensive Evaluation Model Based on Grey Correlation Analysis

Grey correlation analysis is a data-to-data mapping method for analyzing and processing random quantity of gray systems. Firstly, the national average value of each indicator for the current year is selected as the optimal value, and the optimal relative indicator set $U_0 = (x_{01,}\ x_{02,\ \ldots,}\ x_{0n})$ is constructed, so the gray correlation coefficient between the x_{ij} of the annual evaluation indicator U_i and the evaluation indicator U_{0j} of the relatively optimal sample is constructed.

$$\xi_{ij} = \frac{\min\limits_{1\le i\le n}\min\limits_{1\le j\le n}\left|x_{0j} - x_{ij}\right| + \rho\min\limits_{1\le i\le m}\min\limits_{1\le j\le n}\left|x_{0j} - x_{ij}\right|}{\left|x_{0j} - x_{ij}\right| + \rho\min\limits_{1\le i\le m}\min\limits_{1\le j\le n}\left|x_{0j} - x_{ij}\right|} \tag{7}$$

In the formula: ρ is the resolution coefficient, and $0 \le \rho \le 1$, here ρ takes 0.5.

The above analysis shows that the gray correlation coefficient matrix of m × n indicators is $R = (\xi_{i,j})$ m × n. Thus, the weighted correlation vector between each indicator U_i and the optimal relative indicator sample U_0 is:

$$R^T = \xi w = \left\{R_1\ R_2\ \ldots\ R_m\right\} \tag{8}$$

According to the ranking of the correlation degree R_i on the indicators, R_i value is larger, indicating a great impact, while a smaller value indicates a small impact.

3 Empirical Analysis

3.1 Determination Evaluation Matrix

Taking the resource-based city of Ordos as an example for empirical analysis, the data of each indicator from 2013 to 2019 in Ordos City were collected as the original data set, and the data consistency and dimensionless processing of each indicator were carried out to obtain the evaluation matrix X.

3.2 Determination of the Weight

Based on the entropy method, the weight value is determined:

Target layer	System layer	Criteria layer	Indicator layer	Weight (w)
Transformation of Resource-based Cities	Economic development	Economic situation	GDP per capita (yuan/person)	0.070
			GDP growth rate (%)	0.066
		Industrial structure	Employment proportion of manufacturing industry (%)	0.071
			The proportion of tertiary industry output value in total output value (%)	0.060
			Urban registered unemployment rate (%)	0.072
	Social development	Living standards	Per capita disposable income of residents (yuan/person)	0.063
			Total retail sales of per capita consumption(yuan)	0.059
		Culture, health and education	Resident insured medical insurance ratio (%)	0.052
			Culture, education, health and science expenses as a percentage of fiscal expenditure (%)	0.068

(*continued*)

(*continued*)

Target layer	System layer	Criteria layer	Indicator layer	Weight (w)
	Environmental protection	Urban construction	Green coverage rate in built-up areas (m^2)	0.069
			Per capita road area ()	0.070
		Environmental governance	Comprehensive utilization rate of industrial solid waste (%)	0.070
			Sewage treatment rate (%)	0.064

3.3 Grey Correlation Assessment of Influencing Factors for the Sustainable Development in Ordos City

Calculated by the formula, the correlation coefficient matrix of the sustainable development factors of Ordos City to the reference series is:

$$\xi_{ij} = \begin{pmatrix} 0.531 & 0.718 & 1.000 & 0.333 \\ 1.000 & 0.596 & 0.424 & 0.333 \\ 0.869 & 0.932 & 0.999 & 0.333 \\ 0.333 & 0.500 & 1.000 & 0.367 \\ 0.958 & 0.338 & 0.751 & 0.601 \\ 0.429 & 0.421 & 0.333 & 1.000 \\ 0.333 & 0.490 & 1.000 & 0.363 \\ 0.333 & 0.335 & 1.000 & 0.860 \\ 0.493 & 0.333 & 1.000 & 0.494 \\ 0.333 & 0.661 & 1.000 & 0.486 \\ 0.333 & 0.613 & 1.000 & 0.685 \\ 0.629 & 0.535 & 0.333 & 1.000 \\ 0.333 & 0.395 & 0.527 & 1.000 \\ 0.355 & 0.491 & 0.691 & 0.846 \\ 0.676 & 0.996 & 0.949 & 0.334 \end{pmatrix}$$

According to the formula (8), the correlation coefficient is weighted, and the weighted correlation vector of R is:

$$R = \xi w = \begin{pmatrix} 0.045 \\ 0.039 \\ 0.055 \\ 0.033 \\ 0.048 \\ 0.035 \\ 0.032 \\ 0.033 \\ 0.039 \\ 0.043 \\ 0.046 \\ 0.043 \\ 0.036 \\ 0.045 \\ 0.052 \end{pmatrix}$$

The results of ranking the indicators are as follows:

Target layer	System layer	Criteria layer	Indicator layer	Weight (w)	R_{in}
Transformation of Resource-based Cities	Economic development	Economic situation	GDP per capita (yuan/person)	0.070	0.045
			GDP growth rate (%) Proportion of	0.066	0.039
		Industrial structure	manufacturing industry employed (%)	0.071	0.055
			The proportion of tertiary industry output value in total output value (%)	0.060	0.033
	Social development	Living standards	Urban registered unemployment rate (%)	0.072	0.048

(*continued*)

(*continued*)

Target layer	System layer	Criteria layer	Indicator layer	Weight (w)	R_{in}
			Per capita disposable income of residents (yuan/person) Total retail sales of per capita consumption (yuan)	0.063	0.035
			Total retail sales of per capita consumption (yuan)	0.059	0.032

Through the calculation of R, the top three factors influencing the sustainable development of Ordos City are the proportion of manufacturing industry, the energy consumption of 10,000 yuan of GDP (tons of standard coal/10,000 yuan), the registered unemployment rate in cities and towns, and the constraints of economic development. The most influential factor is the further optimization of the industrial structure. The sustainable development of society must continue to enhance the living security of residents. The most critical problem to be solved by environmentally sustainable development is the energy conservation and utilization. The conclusion is in line with the actual progress of Ordos City, which proves that the model is realistic and feasible.

4 Conclusion

This paper tests the validity of the comprehensive evaluation model established by the gray correlation method, and analyzes the factors influencing the sustainable development of resource-based cities. It should be pointed out that: (1) the weight of each indicator in this paper only examines the sensitivity of the indicator. (2) This paper regards the indicators with high correlation as the main influencing factors or constraints of the sustainable development of the region in the near future. An indicator with a small correlation is considered to have entered a development bottleneck, and more favorable stimuli is needed to drive the further development of this indicator.

Acknowledgment. Fund Project: 2019 Natural Science Foundation Project of Inner Mongolia Autonomous Region: Research on the Mode and Path of Effective Supply of Irrigation and Water Conservancy in Arid and Semi-arid Areas from the Perspective of Multi-center Governance-Taking Inner Mongolia as an Example, No. 2019MS07005; 2021 Social Science Fund Project of Inner Mongolia Autonomous Region: Research on the Transformation and Upgrading Path of Mining Economy in Yellow River Basin of Inner Mongolia, No. 21M35; 2021 Industrial Innovation Talent Team Project of Ecological Restoration and High-quality Development of Cultural Tourism Industry of Ordos City.

References

1. Ordos Municipal Bureau of Statistics (2016) Ordos statistical yearbook. China Statistics Press, Beijing
2. Ordos Municipal Bureau of Statistics (2018) Ordos statistical yearbook. China Statistics Press, Beijing
3. Ordos Municipal Bureau of Statistics (2020) Ordos statistical yearbook. China Statistics Press, Beijing
4. National Bureau of Statistics (2009) China statistical yearbook. China Statistics Press, Beijing
5. SiSK, Sun X (2021) Mathematical modeling algorithms and applications. National Defense Industry Press, Beijing