INDUSTRIAL RESTRUCTURING AND OPTIMIZATION FOR SUSTAINABLE DEVELOPMENT OF RESOURCE CITIES BASED ON DYNAMIC SIMULATION PERSPECTIVE

Chen Peng*

University of Leicester, University Rd, Leicester LE1 7RH, UK

cc_academy@163.com

Wanlu Ji

University of Lancaster, Bailrigg, Lancaster LA1 4YW, UK

Reception: 01/05/2023 **Acceptance**: 18/06/2023 **Publication**: 08/07/2023

Suggested citation:

Peng, C. and Ji, W. (2023). **Industrial restructuring and optimization for sustainable development of resource cities based on dynamic simulation perspective**. *3C Tecnología. Glosas de innovación aplicada a la pyme, 12(2)*, 284-304. https://doi.org/10.17993/3ctecno.2023.v12n2e44.284-304

ABSTRACT

Resource cities are highly dependent on resource industries and have a single industrial structure, so how to adjust and optimize the industrial structure is of practical significance to the sustainable development of resource cities. This paper combines the principle of data envelopment analysis (DEA) and the principle of industrial layout optimization to evaluate and position the current situation of industrial structure in resource cities. Based on this study, the simulation dynamic simulation of the path optimization of sustainable industrial development is conducted through the study of the dynamics principle, and the realism and validity of the model are tested by combining it with the actual data to realize the prediction of sustainable industrial path development. The results show that: In the simulation dynamic simulation prediction, the scale of the resource industry in resource cities decreases by about 6%-8% in 2020, and its simulation prediction data and real data have high consistency, which verifies the effectiveness of industrial structure adjustment and optimization strategy. This paper studies the optimization and upgrading of industrial structure to promote the sustainable development of a resource-based city economy, narrow the gap between the economic development of east and west regions, promote urbanization, and improve inter- and intra-regional development imbalance.

KEYWORDS

Resource city; industrial structure; sustainable development; data envelopment analysis; dynamic simulation

INDEX

https://doi.org/10.17993/3ctecno.2023.v12n2e44.284-304

INTRODUCTION

Resource-based cities refer to those cities that gradually grow and emerge from the large-scale exploitation of natural resources, and their growth and development are inseparable from the exploitation of natural resources, and the basic characteristic of these cities is that the industrial structure is relatively homogeneous, and the resource industry is "one and only" [1-3]. With the exploitation of resources, some mineral resources are close to depletion, and the development process of "construction - prosperity - decline - extinction or transformation" is inevitably in front of single-type resource-based cities [4-5]. Therefore, the research on the development of resource-based cities is still a worldwide problem that has received much attention from scholars at home and abroad [6].

For the study of the industrial structure of resource-based cities, based on the degree of mineral resources processing and utilization in the regional context, the literature [7] proposed a five-stage theory of mining town development. The literature [8] then pioneered the study of resource-based cities, which focused on the demographic characteristics of resource-based cities, psychosocial issues, and architectural planning of towns. In a comprehensive analysis of resource industries and economics, literature [9] found that: labor salary differences trigger the phenomenon of shifting industrial focus, and the output value of each industry will influence the composition of employment. The literature [10] establishes a measure of economic development and industrialization through a study of the relationship between the growth rates of several industries in the manufacturing sector, which in turn enables the division of the industrialization process into four stages.

The energy crisis has promoted foreign scholars to conduct a lot of research and practice on industrial transformation and sustainable development of resource-based cities [11-13]. The literature [14] proposed a development model of LDC exploitation of mineral resources, i.e., the long-distance commuting model, and analyzed in some detail how regional and social development is affected by this model. The literature [15] studied the relationship between economic growth and natural resources positively, and the main variables they selected included economic system, investment, market openness, and natural resource abundance as indicators. The

https://doi.org/10.17993/3ctecno.2023.v12n2e44.284-304

literature [16] studied the impact of industrial transformation on the quality of life of a region in a resource city subject to sustainable development.

This paper firstly constructs the resource city resilience, economic resilience evaluation index system, urban economic resilience evaluation index system, comprehensive urban vulnerability index system, and sustainable development evaluation index system. Combined with the principle of data envelopment analysis (DEA) and the principle of industrial layout optimization to evaluate and position the current situation of industrial structure in resource cities. Secondly, through the study of the dynamics principle, the simulation and dynamic simulation of the path optimization of industrial sustainable development is carried out, and the realism and validity of the model are tested by combining it with actual data to realize the prediction of industrial sustainable path development. Finally, by comparing and analyzing the same and different characteristics of development among four resource-based cities with different natures, we propose targeted countermeasures and suggestions to improve the economic resilience of cities according to the characteristics of different cities.

1. ECONOMIC RESILIENCE ASSESSMENT SYSTEM AND MEASUREMENT METHOD FOR RESOURCE-BASED CITIES

1.1. CONSTRUCTION OF ECONOMIC RESILIENCE EVALUATION INDEX SYSTEM FOR RESOURCE CITIES

This paper collects relevant urban economic resilience evaluation indexes based on conceptual and theoretical mechanism research. Through a large amount of literature on urban resilience, economic resilience evaluation index system, urban economic resilience evaluation index system, comprehensive urban vulnerability index system, sustainable development evaluation index system, and other related research. Then, combined with the resources of resource-based cities, the characteristics of economic development conditions, etc., a comprehensive index system and assessment model of economic toughness evaluation of resource-based cities are established based on data availability, and the economic toughness of the four major coal cities are analyzed empirically, and the dynamic development characteristics and laws of the analysis results are summarized.

The city is a complex whole, and the system is affected by a variety of factors its economic system is also affected by the government's financial status, economic structure, innovation capacity, and other multi-purpose factors. Given this, based on the above index system and concerning the existing literature, a four-level comprehensive evaluation index system of urban economic resilience of the four major coal cities in Heilongjiang Province is constructed as shown in Table 1. The

https://doi.org/10.17993/3ctecno.2023.v12n2e44.284-304

system level is characterized by six subsystems: revenue and expenditure capacity, innovation environment, development vitality, stability, diversity, and openness system.

Table 1. Evaluation index system of economic resilience of resource-based cities

System layer	Evaluation Factor Layer	Evaluation Indicator Layer	Notes
A1 Income and Expenditure Capability System System	B1 Personal revenue and expenditure capacity	C1 GDP per capita Characterizing the urban economy	Indicates the city's economic strength and financial accumulation capacity
		C2 Disposable income per capita and fiscal burden	
	B2 Government revenue and expenditure capacity	C3 Local public revenue to GDP ratio	
		C4 Fiscal self-sufficiency rate	
A2 Innovation Environmental Systems System	B3 Science and technology innovation capacity	C5 Number of patent applications per 10,000 people	Reflecting the level of science and education, innovation capacity and economic development momentum
		C6 Science and technology expenditures/fiscal expenditures	
	B4 Social infrastructure environment	C7 Education expenditure/fiscal expenditure	
		C8 Number of doctors per 10,000 people	
A3 Development Vitality System	B5 Social Development Vitality	C9 Rate of increase in employed persons	Characterize the overall urban development trends
		C10 Rate of increase in total retail sales of consumer goods	
	B6 Ecological development vitality	C11 GDP growth rate	
		C12 Greening coverage rate of built-up areas	

1. Income and Expenditure Capacity System

Government public finance revenue and expenditure can effectively regulate the allocation of resources. Fiscal work is one of the important means to realize the macroeconomic control of each country and plays an important role in achieving the goals of economic development and the rational and optimal allocation of resources. The increase in fiscal strength can effectively regulate the internal contradictions of the people, and social distribution relations, maintain the stable development of the market mechanism and achieve social equity.

2. Innovative Environmental Systems

https://doi.org/10.17993/3ctecno.2023.v12n2e44.284-304

Innovation has a great impact on China's economy, which is reflected in promoting consumption, enhancing the competitiveness of foreign trade, and changing the mode of economic growth. A city or region with a strong innovation capacity can promote the high-quality development of the city or region. Vigorously promoting innovation capacity is conducive to the progress of science and technology and improving the vitality of urban economic development.

3. Development of a vitality system

The Vitality System is a system that characterizes the general trend of urban development. In addition, it can also be used to predict future fluctuations and development trends, so that we can prepare and make decisions in advance to face the crises and risks of urban development.

4. Stability System

The stability system is mainly reflected in harmonious and stable social and sustainable economic development, which is important for cities or regions to maintain stable development and absorb learning when they suffer from unknown risks and great disturbances. The increase in urbanization level, the improvement of the living environment, and the increase of people's life security level can promote the stable development of society.

5. Diversity System

Many regions and cities have thus experienced periods of economic recession, and in the face of periodic financial crises and risks, the economic development of resource-based cities has slowed down and their development levels have declined, the reason for this recession being an over-reliance on natural resources leading to a more homogeneous industrial structure.

6. Open System

The level of openness of a country or region is also the ability of foreign trade is one of the important factors in promoting economic development. The faster or slower economic growth and the ability of foreign trade both have a very close relationship, the stronger the level of foreign trade, the more developed the economy, the greater the influence, and the higher the level of economic resilience of the city.

The industrial development of small and medium-sized resource cities, especially small and medium-sized dependent resource cities, provides good reference, and the sustainable development route of 6 major systems in resource cities is shown in Figure 1.

https://doi.org/10.17993/3ctecno.2023.v12n2e44.284-304

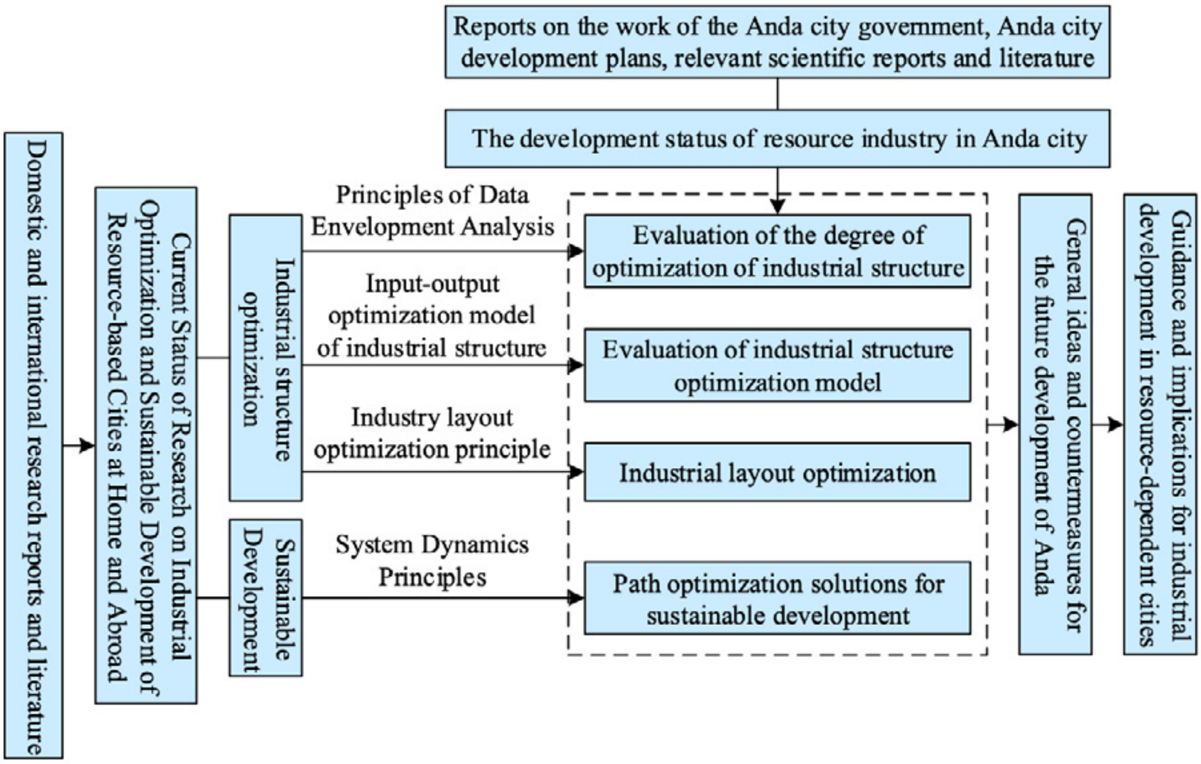

Figure 1. Industrial structure optimization and sustainable development road map

1.2. ECONOMIC RESILIENCE MEASUREMENT METHODS

1.2.1. SHANNON INDEX METHOD

Let the number of employees in a city be A, divided into n types of industries, and the number of employees in each type of industry be $A_i(1,2,3\ldots n)$, then we have:

$$\sum_{i=1}^{n} A_i = A \tag{1}$$

The ratio of the number of employees in each type of industry can be obtained as:

$$H = -\sum_{i=1}^{n} P_i \ln P_i = -\sum_{i=1}^{n}\left(A_i/\sum_{i=1}^{n} A^2\right)\ln\left(A_i/\sum_{i=1}^{n} A_i\right) \tag{2}$$

The information entropy of the industrial structure can be defined by the Shannon entropy formula:

$$P_i = A_i/A = A_i/\sum_{i=1}^{n} A_i, \sum_{i=1}^{n} P_i = 1 \tag{3}$$

https://doi.org/10.17993/3ctecno.2023.v12n2e44.284-304

Where: H is the industrial diversity index, P_i is the ratio of the number of industrial employees, A_i is the number of industrial employees, and A is the total number of employees.

1.2.2. ENTROPY METHOD

The entropy value method to determine the index weights mainly analyzes the degree of variation of the index. It is generally believed that the higher the entropy value, the smaller the degree of variation, the slower the change tends to be balanced, and vice versa. Therefore, this paper selects the entropy method to determine the weights, which can eliminate the influence of subjective assignments and reflect the information objectively, and the results are more scientific. The main steps are as follows:

1. The dimensionless treatment of indicators.

Eliminate the influence of indicators with positive and negative directions, enhance the comparability between different indicators, and eliminate the influence of outliers to some extent. The specific calculation formula and operation steps are:

Positive indicators:

$$X'_{ij} = \frac{X_{ij} - \min\left(X_{ij}\right)}{\max\left(X_{ij}\right) - \min\left(X_{ij}\right)} \tag{4}$$

Negative indicators :

$$X'_{ij} = \frac{\max\left(X_{ij}\right) - X_{ij}}{\max\left(X_{ij}\right) - \min\left(X_{ij}\right)} \tag{5}$$

Where: X_{ij} is the index data. $min(X_{ij})$ is the minimum value of the assessed index, $max(X_{ij})$ is the maximum value of the assessed index.

2. Calculate the entropy value of the index.

According to the information entropy theory, the entropy value of the index can be expressed as:

$$e_j = -k\sum_{i=1}^{m} y_{ij}\ln\left(y_{ij}\right) \tag{6}$$

Of these, $k = \dfrac{1}{\ln m}$, there are $0 \le e_j \le 1$.

https://doi.org/10.17993/3ctecno.2023.v12n2e44.284-304

3. Finally, the weights of each indicator are calculated:

$$W_j = \frac{1 - e_j}{\sum_{i=1}^{n} 1 - e_j} \quad (7)$$

1.2.3. MULTI-OBJECTIVE WEIGHTING FUNCTION METHOD

The level of urban economic resilience is the result of the combined effect of various indicators of each system, and the degree of urban economic resilience varies from system to system. The system is first quantified and finally, the urban economic resilience index is calculated. In this study, we use this method to calculate the urban economic resilience level of four major coal cities, first calculate the urban economic resilience index of each system, and then calculate the comprehensive urban economic resilience index. The calculation formula is as follows:

$$t = \sum_{i=1}^{m} ai \cdot \omega i, i = 1, \ldots, m \quad (8)$$

Where: t is the system resilience index, m is the number of indicators, a_i is the standard value of the i indicator in the factor layer, and i is the weight of the i indicator.

The city economic resilience index is calculated by the formula:

$$T = \sum_{j=1}^{n} t_j \cdot W_j, j = 1, \ldots, n \quad (9)$$

Where: T is the economic resilience index, t_j is the j system economic resilience index, and W_j is the j system weight of the system layer.

1.3. MULTI-OBJECTIVE LINEAR PATH PLANNING

Based on the inter-regional input-output table of province H in 2017, an optimization model is established, which should specifically contain a multi-objective optimization model using resource-output and economic objectives, since both objectives cannot be optimal at the same time. Therefore a satisfactory compromise between the two objectives can be solved using multi-objective linear programming. The dimensionless treatment should be carried out for different objective functions, while converting the multi-objective planning into single-objective planning, i.e., assigning a weight factor of 0.5 to the two objectives.

1. Objective function

 https://doi.org/10.17993/3ctecno.2023.v12n2e44.284-304

Objective function 1: The overall gain along the yellow area is the largest, that is, the sum of the value added of each industry in each city along the yellow area is the largest, the formula is as follows:

$$\max \sum_{r=1}^{m} = \sum_{i=1}^{n} v_i^r X_i^r \tag{10}$$

Where m is the number of cities, n is the number of industries in the city, v_i^r is the rate of value added in the r city i sector, X_i^r indicates the output of the r city i sector, in this paper $m = 8, n = 8$.

Objective function 2: The overall minimum water consumption along the yellow area, i.e., the minimum water consumption of each industry in each city along the yellow area, is given by the following formula:

$$\min \sum_{r=1}^{m} = \sum_{i=1}^{n} w_i^r X_i^r \tag{11}$$

Where w_i^r is the direct water use coefficient for the r city i sector and X_i^r indicates the output of the -city sector.

2. Binding Conditions

Constraint 1:Constraints on input-output models. The inter-municipal input-output model also provides a framework for describing the industrial relationships between different cities. The specific equations are as follows:

$$X_i^r = \sum_{s}^{m} \sum_{j}^{n} x_{ij}^{rs} + \sum_{s}^{m} y_i^{rs} \tag{12}$$

n is the number of industrial sectors, m is the number of cities, X_i^r is the output of sector i of city r, x_{ij}^{rs} represents the amount of intermediate inputs from sector i of city s to sector j of city r, and y_i^{rs} represents the final demand of sector i of city s. The above equation can be rewritten by introducing direct coefficients, which are structured as follows:

$$X_i^r = \sum_{s}^{m} \sum_{j}^{n} a_{ij}^{rs} x_j^r + \sum_{s}^{m} y_i^{rs} \tag{13}$$

where the direct coefficient a_{ij}^{rs} is expressed as the amount of input from the s city i sector needed to increase the unit output of the r city j sector, and X_j^r is the output of the r city j sector.

In the optimization model, it is ensured that the demand from the product in each department does not exceed the output, i.e. the constraints are as follows:

https://doi.org/10.17993/3ctecno.2023.v12n2e44.284-304

$$\sum_{s}^{m}\sum_{j}^{n} a_{ij}^{rs} = x_j^r + \sum_{s}^{m} y_i^{rs} \leq X_i^r \quad (14)$$

Constraint 2:Industrial structure constraint. To achieve the objective function while ensuring that the optimal output value of the high water use sector in the city is not 0, to meet the actual situation of the city, therefore, according to the previous study, a range of variation will be set for the output of the production and supply industry and the wholesale, retail and residential food industry. The formula is as follows:

$$X_i^r / \sum_{i=1}^{n} X_i^r \leq \bar{L}_i^r \quad (15)$$

Where X_i^r is the output of the r City i sector and $\overrightarrow{L}_i$ is the actual output ratio of the r City i sector.

Constraint 4:Baseline of agricultural production. From the analysis of water resources efficiency in the fourth sector, it can be seen that high water intensity in agriculture, i.e. the more water resources, the lower the economic efficiency, so there is a strong tendency for optimal agricultural production in the model to converge to zero. And Henan is a large grain province, which must take food security as a hard constraint. According to the change in agricultural output value in the past five years, the upper and lower limits of agricultural output in each city are determined, denoted as :

$$\underline{X}_i^r \leq X_i^r \leq \bar{X}_i^r \quad (16)$$

$\underline{X}^r$ is the lower bound of the output of the r city i sector and $\bar{X}_i^r$ is the upper ratio of the output

Constraint 5: Water use restrictions. To ensure that the water consumption for optimal production does not exceed the actual water consumption, the total actual water consumption is taken as the basis, specifically:

$$\sum_{i=1}^{n} w_i^r X_i^r \leq W^r \quad (17)$$

2. INDUSTRIAL RESTRUCTURING AND OPTIMIZATION OF RESOURCE CITIES

2.1. BUILDING CIRCULAR ECONOMY AND INDUSTRIAL CHAIN STRATEGY

Traditional value chains focus on value addition and profit, without much consideration for resource conservation. In the case of individual enterprises, there is

https://doi.org/10.17993/3ctecno.2023.v12n2e44.284-304

an interaction with the external environment from the development of their products to their final consumption. In the case of an industry, i.e. a sector, its development is not only constrained by the local resources and environment but also has an impact on the surrounding environment.

Therefore, to realize the coordination of industrial development with resources and environment. To achieve sustainable urban economic development, the circular economy strategy for industrial and even enterprise development should be studied from a strategic perspective. In terms of the relationship between individual enterprises and the environment, and thus from the aspect of clean production. As for the interrelationship between the industrial value chain composed of multiple enterprises and the natural environment, it should be studied from the perspective of system theory, how to be between enterprises. For example, between upstream and downstream enterprises in the industry, a large number of subsystems with resource conservation and ecological harmony are constructed, and each subsystem plays its function through the whole because it is in the same system. As an economic system as a whole, the purpose is to promote the rational and efficient allocation of resources, and this effective input and output is still sustainable, playing the maximum economic benefits of resources while minimizing damage to the environment, and even has the function of restoring the environment. The material flow cycle within the resource-based industry is shown in Figure 2.

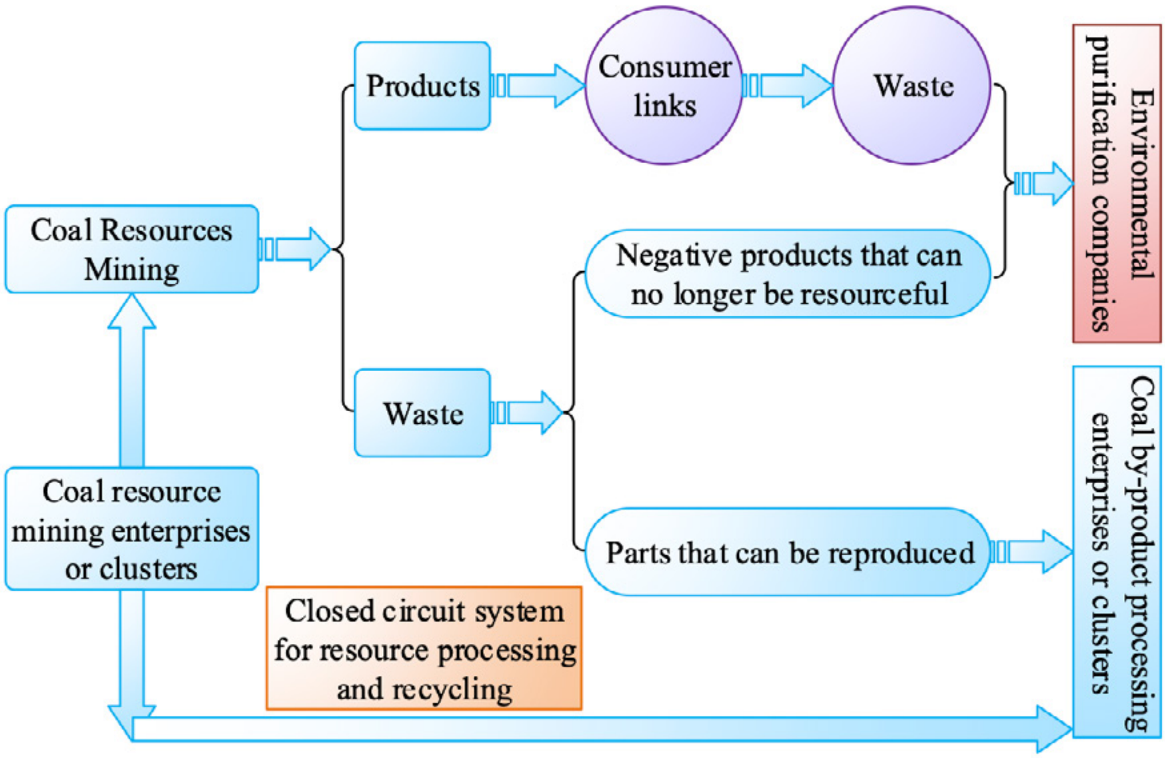

Figure 2. Roadmap for industrial structure optimization and sustainable development

To put the ecological and environmental elements, a scarce resource, into the industrial chain formed between upstream and downstream enterprises for allocation, so that the union of upstream and downstream enterprises into a circular production model. In other words, the waste produced by one enterprise becomes the raw material or resource input for another enterprise. In this way, different enterprises maintain their unique core competencies, and the industrial chain alliance formed between enterprises as a whole can realize the efficient allocation of resources and circular production, and achieve the most optimal economic benefits.

2.2. ADVANCED INDUSTRIAL STRUCTURE UNDER THE CONSTRAINTS OF MULTIPLE FACTORS

Demand structure, supply structure, and science and technology level are the key factors that dominate industrial upgrading. Demand and scientific and technological progress factors promote the development of advanced industrial structures, and the supply structure constitutes a rigid factor that restricts industrial upgrading within a certain period. At the same time, industrial policies and mechanisms in a certain period will have an impact on industrial upgrading.

Demand structure restricts the direction of industrial structure upgrading while promoting the development of advanced industrial structures. Demand factors bring the birth of new industries, the restructuring and upgrading of existing industries, and the elimination of some backward industries. The scale of demand brings the impetus for the development and expansion of the demanded industries, and promotes the process of industrial advancement, the specific driving process is shown in Figure 3.

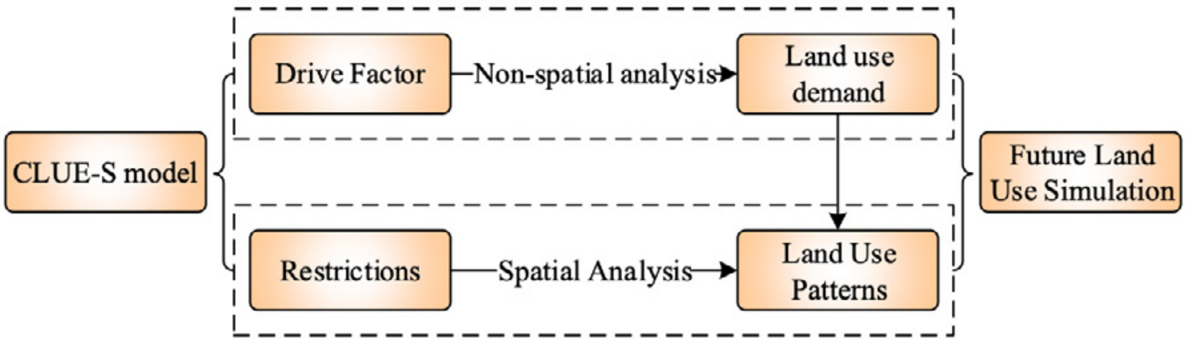

Figure 3. Industrial advanced CLUE-S cycle drive principle

Supply structure is a rigidifying factor for industrial development in a certain period and is a limiting factor for industrial upgrading. The supply structure of labor and resource-rich regions has the advantage of developing resource-based industries and labor-intensive industries. Once the industrial development forms a certain scale, it gradually becomes the leading industry of the region and dominates the development of urban industrialization and industrial upgrading will influence rigidification factors. If capital accumulation is insufficient or the human resources and technology level of the region is low and the introduction of capital and technology is difficult, even with the strong thrust of the demand factor, the development of new industries and the advanced industrial structure will be difficult.

https://doi.org/10.17993/3ctecno.2023.v12n2e44.284-304

2.3. INDUSTRIAL CLUSTER DEVELOPMENT UNDER AGGLOMERATION ECONOMY

An agglomeration economy is a gathering of diverse manufacturers, residents, and related organizational units in a certain spatial area such as a city. And to obtain economies of scale, external economic effects, and other effects of an economic model, agglomeration economic effect to promote the expansion and development of the scale of the industry. The agglomeration economic effect promotes the scale expansion and development of industries and makes them enjoy the external economic effect and the improvement of science and technology and management level brought by the agglomeration economic effect, and the agglomeration of industries promotes the acceleration of urbanization process and the expansion of city scale.

An industry cluster is a group of companies and institutions that are geographically close to each other and belong to the same industry and are interconnected with each other. For example, a group of competing and cooperating firms, specialized suppliers, service providers, financial institutions, manufacturers of related industries, and other related institutions in a given region, which are geographically concentrated and interrelated. A highly developed industrial cluster can improve the productivity and competitiveness of the overall industry and drive innovation through synergies in research and technology, complementary industries, and knowledge and human capital. This leads to increased competitiveness and economic wealth creation.

There is an inextricable link between industrial clusters and industrialization. Industrial clusters drive the population to cities, thus the proportion of the non-farm population increases and drives urbanization. The industrial cluster model points out that the transformation of industrial structure drives the industrialization process as shown in Figure 4.

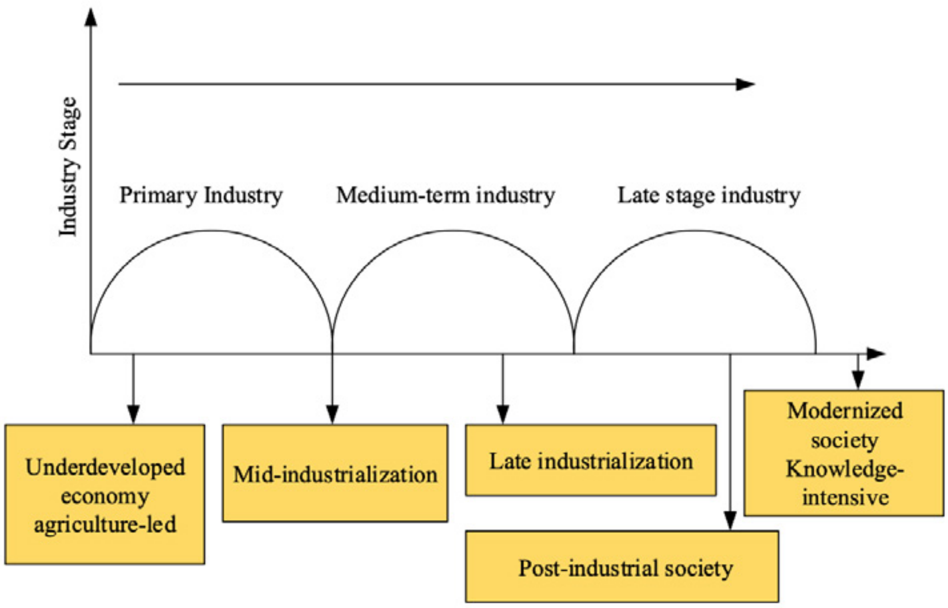

Figure 4. Structural transformation of industrial clusters drives industrialization

https://doi.org/10.17993/3ctecno.2023.v12n2e44.284-304

Industrial agglomeration is also a reasonable way for resource-based cities to realize industrial scale and brand development, promote industrial structure adjustment, and achieve efficient resource allocation and optimal urban development. Resource-based cities can rely on their own mineral resources and labor production factors and other resource advantages to develop large leading enterprises in line with regional characteristics. The formation of the production chain as a link to the internal division of labor refinement of enterprise clusters, to improve the internal production efficiency of the industry, gathering capital factors, labor factors, and science and technology, information, and talent factors to promote the development of industrial branding.

3. SIMULATION RESULTS AND ANALYSIS OF SUSTAINABLE ECONOMIC DEVELOPMENT DYNAMICS IN RESOURCE CITIES

3.1. ANALYSIS OF OVERALL DYNAMIC SIMULATION RESULTS OF ECONOMIC RESILIENCE IN RESOURCE CITIES

Unlike traditional linear prediction methods such as trend extrapolation and gray prediction, the multi-objective weighting function method has greater advantages for solving nonlinear system problems. In terms of accuracy, the multi-objective weighting function method continuously adjusts the weights by backpropagation and thus minimizes the error. The data in this paper are autoregressive and consistent with time series analysis, so the dynamic simulation model of the nonlinear multi-objective weighting function method is selected to more accurately reveal the development trend of economic resilience of the four major coal cities.

The overall error and deviation results of economic resilience of the four cities for 2018-2022 are calculated as shown in Table 2, and the deviation of each subsystem and the total system is small, and the subsystem error results are less than 0.12%, and the total system error is below 0.5%. The results pass the test and the calculation results can be used for the prediction and analysis of the economic toughness of the four major coal cities in Heilongjiang Province.

 https://doi.org/10.17993/3ctecno.2023.v12n2e44.284-304

Table 2. MAE (%) values and deviations of economic toughness for each system and total system

City	Jixi City	Hegang City	Shuangyashan City	Qitaihe City
Income and Expenditure Capacity System	2	2	0.02	80
Deviation	124	102	4	7
Innovation Environment System	2	4	0.07	8
Deviation	0.02	0.02	0.05	1
Development Dynamics System	1	3	0.03	4
Deviation	6	5	403	8
Stability System	1	12	4	182
Deviation	0.01	90	2	0.01
Diversity System	9	90	1	5
Deviation	0.1	0.01	0.04	1
Open System	7	0.02	1	0.01
Deviation	0.07	0.03	17	0.03
Total System	9	0.12	0.12	0.05
Degree of deviation	0.11	0.0004	2	143

In general, the four major coal cities 2018-2022 city economic resilience index Jixi and Qitaihe cities generally show a decreasing trend, and Hegang and Shuangyashan cities generally increase, but to a small extent. From the mean value of the change in economic resilience index of the four cities from 2018-2022, the mean value of Jixi city is the largest at 0.513, followed by Hegang city with a mean economic resilience index of 0.397, Shuangyashan city is the third at 0.134, and the smallest mean economic resilience index is Qitaihe city at 0.395.

Overall the average value of economic toughness of the four cities from 2018-2022 is presented as Jixi City > Hegang City > Shuangyashan City > Qitaihe City. It can be seen that the economic toughness level of the four major coal cities in the next five years Jixi City is still in the highest position, Qitaihe City has the lowest economic toughness level, Hegang City and Shuangyashan City will be in the middle level of economic toughness 0. From the fluctuation of the dynamic simulation of the four major coal cities' economic toughness index in 2018-2022, Qitaihe City has the largest decline in the next five years and is more volatile in each year, 2019 the predicted value is 0.325 in 2019 and 0.319 in 2022, a decline of 0.007. Jixi City declines only after Qitaihe City, and the economic toughness value will decline by

https://doi.org/10.17993/3ctecno.2023.v12n2e44.284-304

0.005 in the next five years. this paper simulates and verifies the household population and gross product of the four major resource cities as shown in Figures 5 and 6. From the simulation results, the simulated data and the real data have a high degree of consistency and meet the extrapolation requirements.

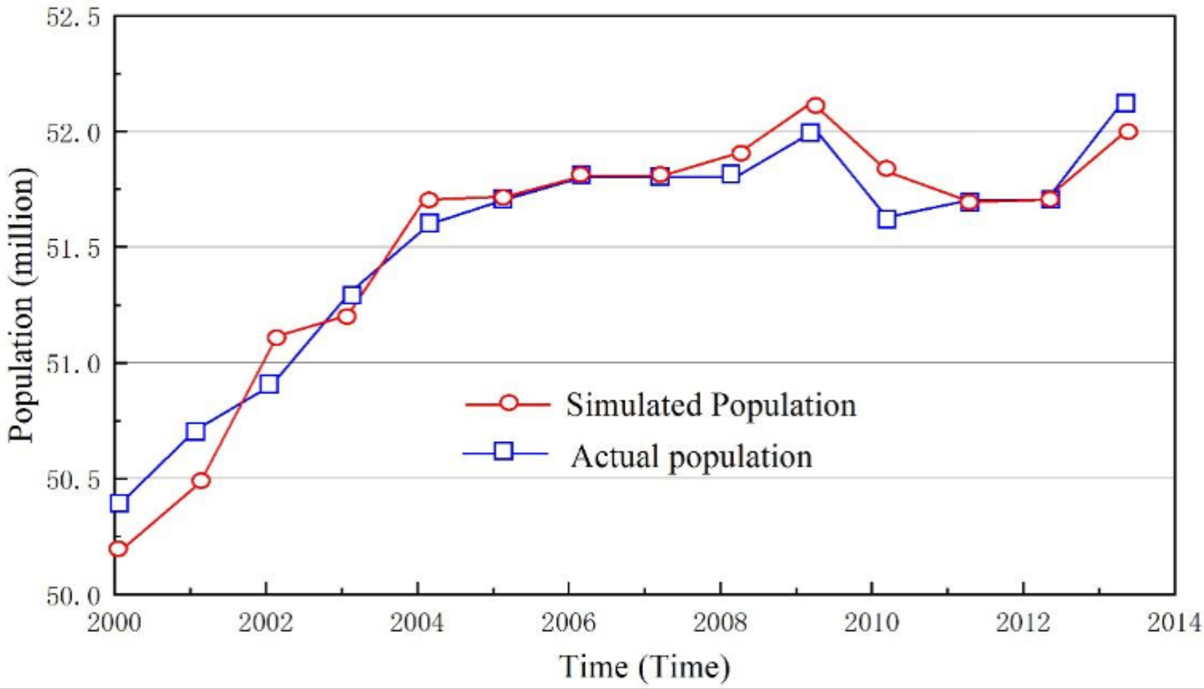

Figure 5. Simulated and actual values of household population, 2000-2013

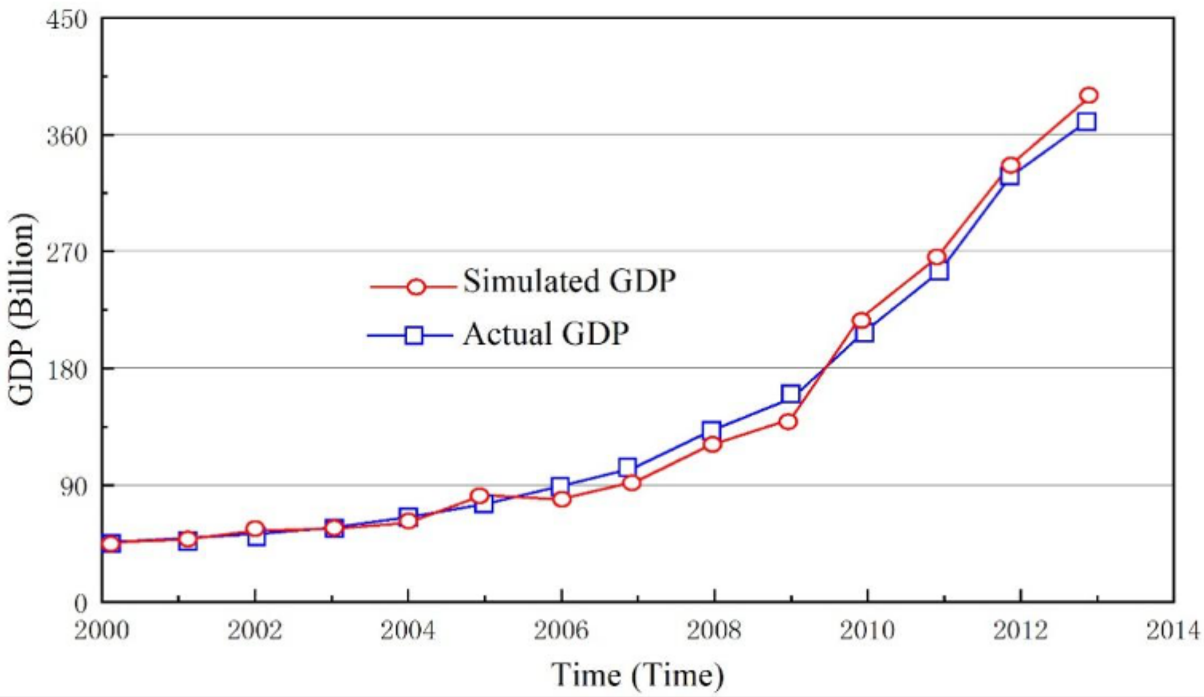

Figure 6. Simulated and Actual GDP for Resource Cities, 2000-2013

The economic resilience values of Hegang City and Shuangyashan City have increased, but the magnitude is small, and the overall Hegang City will only increase by 0.001, and the overall ups and downs in each year are not significant. Overall, the economic resilience of Jixi is still stronger than the other three cities in the next five years, but the development of various subsystems in Jixi is not coordinated, and the level of economic resilience decreases. The economic resilience value of Qitaihe is still the smallest among the four cities, and the economic resilience level also continues to decline. There is no significant change in Hegang and Qitaihe, which shows that the macro-control role and policy initiatives of the governments of the four cities are not significantly effective in the next five years. The depletion of resources, single economic structure, difficulties in industrial transformation, and large population outflow are still the shortcomings of the four cities' development.

3.2. COMPARATIVE ANALYSIS OF DYNAMIC SIMULATION RESULTS OF ECONOMIC RESILIENCE OF RESOURCE CITY SUBSYSTEMS

Table 3 shows the dynamic simulation comparison analysis of the six system economic resilience indices of the four major resource coal cities from 2019-2023. it can be seen that the overall trend of the four cities' income and expenditure capacity systems in the next five years shows both fluctuating upward and fluctuating downward trends. The average value of economic resilience of the revenue and expenditure capacity system is Jixi > Shuangyashan > Qitaihe > Hegang. It means that compared with the other three cities Jixi city has a better development level of economic toughness of income and expenditure capacity system. Overall, the degree of economic resilience of the income and expenditure capacity system in Jixi and Shuangyashan is better than in the other two cities in the future, but the level of income and expenditure capacity in Jixi and Hegang decreases in the next five years, and the level of their own income and expenditure capacity in Shuangyashan and Qitaihe improves.

Table 3. Comparison of dynamic simulations of economic resilience indices for the six systems

City	Income and Expenditure Capacity System	Innovation Environment System	Development Vitality System	Stability System	Diversity System	Openness System
Jixi	198	163	156	453	414	205
Hegang	106	203	136	143	142	263
Shuangyashan	192	263	264	264	113	165
Qitaihe	536	135	193	263	419	231
Average value	192	169	179	96	429	189

The mean value of economic resilience of the development vitality system is 0.096 in Jixi and 0.053 in Hegang, with the highest value and the lowest value in Shuangyashan. The overall mean value is Jixi City > Shuangyashan City > Qitaihe City > Hegang City. Overall, the economic resilience of the development vitality system in Jixi and Shuangyashan is high in the next five years, but the level of development vitality decreases. Hegang and Qitaihe are relatively low, but the development vitality level will have a good development trend in the next five years.

Both Jixi City and Shuangyashan City increased by 0.003, and Qitaihe City increased by a smaller amount. In terms of the mean value of economic resilience of the open system, it shows Jixi City> Hegang City> Qitaihe City> Shuangyashan City. In general, the economic toughness of the open system in Jixi and Hegang is higher in the next five years, but the level of the open system in Hegang is weakened.

4. CONCLUSION

In response to the problems of sustainable development and low and unreasonable industrial structure faced by resource-based cities. This paper combines the principles of data envelopment analysis (DEA) and industrial layout optimization to evaluate and position the current industrial structure of resource cities. The comprehensive economic resilience system of the city is divided into six systems: city economic revenue and expenditure capacity, innovation environment, development vitality, stability, diversity, and openness. This paper proposes effective countermeasures for the development planning and industrial development of resource cities. At the same time, it provides a good reference for the industrial restructuring and sustainable development of a large number of other domestic cities with dependent resources, and the specific conclusions are recognized as follows:

1. In terms of the average weights of the overall economic resilience subsystems of the four major coal cities, the main factors affecting economic resilience are the revenue and expenditure capacity, development vitality, and innovation environment systems. The diversity system has the least degree of influence. In terms of the weights of the influencing factors in the four cities, the main factors affecting Jixi city are openness, revenue and expenditure capacity, and stability system: Hegang city is mainly influenced by the stability system, innovation capacity system, and openness system. Shuangyashan City is influenced by a development vitality system, innovation environment system, and income and expenditure capacity system. The main factors affecting the economic resilience of Qitaihe City are income and expenditure capacity, openness, and development vitality system.

2. In terms of the weights of the influence factors of each system layer of the city, the income and expenditure capacity system mainly affects Qitaihe City, and the innovation environment system and the development vitality system affect Shuangyashan City. The stability system of Hegang is most influenced by it,

https://doi.org/10.17993/3ctecno.2023.v12n2e44.284-304

and both the diversity system and the openness system are most influenced by Jixi city.

REFERENCES

(1) Yu, X., Shan, L., & Wu, Y. (2021). Land Use Optimization in a Resource-Exhausted City Based on Simulation of the F-E-W Nexus. Land, 10.

(2) Li, J. (2020). Resource optimization scheduling and allocation for hierarchical distributed cloud service system in smart city. Future generation computer systems, 107(Jun.), 247-256.

(3) Pardo-Garcia, N., Simoes, S. G., Dias, L., et al. (2019). Sustainable and Resource Efficient Cities Platform – SureCity holistic simulation and optimization for smart cities. Journal of Cleaner Production, 215(APR.1), 701-711.

(4) Shu, M., Wu, S., Wu, T., et al. (2020). Efficient energy consumption system using heuristic renewable demand energy optimization in smart city. Computational Intelligence.

(5) Xia, Q. (2019). Research on the Eco-environment and Industrial Structure Optimization of Coal Resource City. China Ancient City.

(6) You, G., Pan, Q. (2011). Probe into Lupanshui City Frame Adjustment and Optimization of Coal Resource Exploitation and Utilization. Coal Geology of China.

(7) Li, S., Zhao, Y., Xiao, W., et al. (2021). Optimizing ecological security pattern in the coal resource-based city: A case study in Shuozhou City, China. Ecological Indicators, 130, 108026.

(8) Oldenhuizing, J., Kraker, J. D., Valkering, P. (2013). Design of a Quality-of-Life monitor to promote learning in a multi-actor network for sustainable urban development. Journal of Cleaner Production, 49(jun.), 74-84.

(9) Santos, T. M., Zaratan, M. L. (2017). Mineral resources accounting a technique for monitoring the Philippine mining industry for sustainable development. Journal of Asian Earth Science, 12(5), 142-158.

(10) David, P., & G. Wright. (2019). Increasing returns and the genesis of American resource abundance. Industrial and Corporate Change, 6, 203-245.

(11) Kaleka, A. (2012). Resources and capabilities driving competitive advantage in export markets: Guidelines for industrial exporters. Industrial Marketing Management, 31, 273-283.

(12) Grander, J. A., & Scott, M. (2018). The Simple Economics of Easter Island: A Ricardo Malthus Model of Renewable Resource Use. The American Economic Review, 88, 119-138.

(13) Carlaw, K. I., & Lipsey, R. G. (2012). Externalities, technological complementarities and sustained economic growth. Research Policy, 31, 1305-1315.

(14) Martin, R. (2018). Regional Economic Resilience, Hysteresis and Recessionary Shocks. Journal of Economic Geography, 12(1), 1-32.

(15) Zhong, Y., Ruan, G., Abozinadah, E., & Jiang, J. (2021). Least-squares method and deep learning in the identification and analysis of name-plates of power equipment. Applied Mathematics and Nonlinear Sciences.

(16) Martin, R. (2018). Regional economic resilience, hysteresis and recessionary shocks. Journal of Economic Geography, 12(12), 1-32.