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CALCULATION AND EVALUATION OF ECOSYSTEM COMPLEX CARRYING CAPACITY IN SEMI-ARID AREA OF China

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Abstract: The study of the urban ecological carrying capacity is an important part of the urban research field, which is of great significance for guiding urban social and economic activities and coordinating the relationship between the cities and the environment, and has more realistic significance for the cities which were restricted by natural regional environment. This study takes Chaoyang, a city located in the semi-arid area of Northwest Liaoning Province of China, as an example, by combining system analysis theory and mathematical methods, and by applying integrated urban sustainability calculation formulation together with using comprehensively qualitative to quantitative methods, to build a calculation model for complex urban ecosystem carrying capacity. The calculation results showed that the current complex carrying capacity of the ecosystem in Chaoyang City is higher than the value of its ecosystem pressure, and the ecological capacity is in a surplus state in this period. The current consumption of resources in Chaoyang City is less than the obtained amount, and the entire city is now in a position of sustainable development.

Keywords: semi-arid area, ecosystem carrying capacity, econometric model, Chaoyang City

I Introduction

City is a sophisticated and open natural-social-economic ecosystem. In the process of constant succession and upgrading, the materials and energy are exchanged with the outside world, and the waste is continuously transferred and digested. However, the external material input and waste transfer available to the urban ecosystems are still limited. If the speed of the input and transfer cannot meet the speed of the urban ecosystem's survival and development needs, it will produce a periodical eco-environmental stress. It will cause urban ecosystems to collapse when it accumulates to a certain limit and exceeds its capacity[1]. The development process of cities from primitive to higher levels essentially reflects the development process of human civilization itself. City is a complex and huge system, and it is the growth pole of regional development. The

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resource conditions that cities relying on for their existence and development, such as land, water, ecological environment, and electricity, are based on the cities' natural ecological environment and natural resource conditions.

The development of cities requires a strong ecological support system. The complex carrying capacity of the urban ecosystem is based on the ceaseless support of the urban ecological support system and driven by the development of the socio-economic system. The sustainable development of a city must be based on the continuous improvement of the urban ecosystem's complex carrying capacity[2]. How to maintain the normal operation of such a complex composite ecosystem is the primary problem to be solved in the construction of an eco-city, and it is also the main issue to be studied on the carrying capacity of the urban ecosystem. Therefore, the ultimate goal of the related researches on the carrying capacity of the urban ecosystems is to study the ecological processes and mechanisms of the natural-social-economic complex ecosystem, to explore the ecological construction countermeasures to improve its system structure and function, so as to regulate various unreasonable relationships within the urban ecosystem and improve the self-regulation abilities[3]. In this way, a virtuous cycle of the urban ecosystem could be achieved, a continuous symbiosis and coordinated development of the relationship between man and environment could be attained, the harmonious coexistence among social civilization, economic efficiency and ecological environment could be realized.

From this perspective, this paper measured the complex carrying capacity of the ecosystem of Chaoyang City, a typical city located in the semi-arid area of Northwest Liaoning Province of China, and conducted a series of scientific analysis and elaboration with the result providing the reference for guidance of the construction of the ecological city of Chaoyang in the future and determination of the maximum satisfaction of human desires under the premise of maintaining the healthy state of the urban ecosystem.

II Overview of the research area

Chaoyang City is located at the junction region of Liaoning Province, Inner Mongolia Autonomous Region and Hebei Province of China. Chaoyang has a long history and is rich in natural resources and bioaccumulation. The unique "Niuheliang Hongshan Culture" in Chaoyang has advanced the history of Chinese civilization by about 1500 years. Chaoyang is not only a small city with rich resources and beautiful natural scenery, but also the place where the first bird takes off and the first flower blooms on human history[4]. The name of Chaoyang is derived from the poem of Book of Songs which is the earliest collection of poetry in China that collected the poems from the early Western Zhou Dynasty to the middle of Spring and Autumn Period (11th century to 6th century). In terms of natural ecological environment and climate, the Chaoyang area belongs to the temperate and semi-arid monsoon climate zone in the northern hemisphere. The natural environment of Chaoyang is unique and the geological and geomorphological features of the mountainous area in the northwest of

Chaoyang are distinct. It is mountainous with less precipitation, which is a severe water shortage city. The per capita water resources in Chaoyang is only 235m^3, which is 10.6 percent of Chinese average. Moreover, the soil erosion and water loss in the territory is also serious, the flow changes and the sediment content are relatively large, especially in the high mountain valleys of the northwestern mountains, and the threat of soil erosion and water loss is greater, which belongs to a severely fragile ecological area and its ecological vulnerability is only 0.624. However, the diversity of Chaoyang's ecosystem is very prominent, and there are many rare and endangered species protected by Chinese government among its biological species[5]. In addition, Chaoyang is very rich in mineral resources and there are 53 different types of minerals and more than 830 mining sites have been found in Chaoyang area. Some minerals such as gold, molybdenum, manganese, and phosphorus bentonite are the dominant minerals in Liaoning Province in northeast China. Among all the advantageous minerals, bentonite reserves rank third in Asia, manganese reserves rank first in Northeast China, and gold mining ranks among China's eight major producing areas. Chaoyang hence not only has natural deficiencies from the natural ecological environment conditions, but also possess natural gifts with abundant natural products. Scientific calculation and evaluation of the city's ecological carrying capacity is conducive to optimizing the allocation of various urban resources and overall planning of the city; it is also conducive to rationally adjusting the industrial structure of the city simultaneously. In addition, the scientific calculation and evaluation of ecological carrying capacity are beneficial for cities to actively develop green economy, ecological industry engineering and low-carbon, circular economy, and further guarantee the sustainable development of urban economy and environment; it is also the theoretical basis and the foundation of urban ecological civilization construction, and has important theoretical and practical significance.

III Research Method

The carrying capacity of a biological species in an environment is the maximum population size of the species that the environment can sustain indefinitely, given the necessities available in the environment. In population biology, carrying capacity is defined as the environment's maximal load, although its effect on population dynamics may be approximated in a logistic model might ignores the possibility of overshoot which real systems may exhibit. However, the concept of ecosystem's carrying capacity in our research not only involves matters such as available supplies of food, water, raw materials, and/or other similar "resources". In addition, there are other factors that govern carrying capacity which may be less-instinctive or less-intuitive in nature also been taken into account, such as ever-increasing and ever-accumulating levels of wastes, damage, or eradication of essential components of any complex functioning system particularly the non-renewable resource depletion and increased consumption are considered simultaneously. Therefore, we define the carrying capacity as the existence of a certain threshold for the support of socio-economic activities by resources and the environment in a certain region under a certain period of time and specific environmental conditions. In modern society, many environmental problems in cities are caused by the intensity of human activities exceeding resources and environmental carrying capacity.

Technology can play a role in the dynamics of carrying capacity and while this can sometimes be positive such as the calculation of ecological carrying capacity. Many scholars have quantitatively calculated the carrying capacity based on different types of resources or regions. The main methods are relative carrying capacity calculation, calculation using linear programming mathematical models, calculation using applied system dynamics methods, and quantitative description and measurement using state space methods, etc. Although the contents and methods are different among all the researches on carrying capacity, they have the common feature that they all believe that carrying capacity is an important criterion for measuring the coordinated relationship between regional economy, resources and the environment, and it is defined by the ratio of the carrying capacity of the natural environment itself to acquired carrying capacity.

The composite carrying capacity of an urban ecosystem is the basic criterion for judging whether a city can develop healthily and stably or not. With the calculation of the ratio of the natural carrying capacity and the acquired carrying capacity of the ecosystem, we can more scientifically determine whether the city's natural ecosystem can continue to maintain stability or develop in a healthy direction, and whether the city will be sustainable in the near future.

The degree of sustainable development is a comprehensive indicator for judging sustainable development. In terms of quantitative description of sustainable development, there is still no uniformly accepted theory and calculation method in academic field. Qian Xuesen, one of the most famous Chinese scientist proposed a comprehensive integration method from qualitative analysis to quantitative analysis[6]. Afterwards, Chinese scholars Feng Yuguang and Wang Huadong tried to use the comprehensive integration method which proposed by Professor Qian Xuesen to innovatively construct a calculation formula for urban sustainability[7]. The formula is mainly used to quantitatively describe the sustainable degree of regional system development. The structural principle of the measurement model can be used as the main reference for the calculation of urban ecosystem composite carrying capacity. Therefore, this method is mainly adopted as calculation basis.

A. Ecosystem composite carrying capacity measurement model

According to the system structure and functional characteristics, the composite carrying capacity of an urban ecosystem can be divided into two parts: natural carrying capacity and acquired carrying capacity. Accordingly, its measurement model is divided into two parts: natural carrying capacity model and acquired carrying capacity model. The two models are coupled together in some relationship as follows:

a. Ecosystem natural carrying capacity measurement model

$$N = R \cdot \alpha_s^2 \cdot e^{\beta_s} \quad (1)$$

where：

$$R = (-\sum_{i=1}^{n} S_i \cdot \log_2 S_i) \times \sum_{i=1}^{n} S_i \cdot P_i \quad (1\text{-}1)$$

$$\alpha_s = \sum_{i=1}^{m} r_i / G \quad (1\text{-}2)$$

$$\beta_s = \frac{1}{k} \sum_{j=1}^{k} \lambda_j k_j \quad (1\text{-}3)$$

Where：N is ecosystem natural carrying capacity index; R is ecosystem restoration index； α_s is supply Index for urban resources；β_s is urban environmental capacity Index; r_i is supply amount of the type i resources；G is gross domestic product; S_i is percentage value of coverage area and total urban area of the type i resources; P_i is the elastic scores of the type i resources; λ_k is weights of environmental pollutants；K_j is discharge standards for type j environmental pollutants；k is the types of environmental pollutants.

b. Ecosystem Acquired Carrying Capacity Measurement Model

$$F = \mu \cdot \sigma \cdot Eco \quad (2)$$

where：

$$Eco = \frac{\Delta G / G}{\Delta POP / POP} \quad (2\text{-}1)$$

Where：F is acquired carrying capacity index of urban ecosystem; μ is technology index；σ is human resources Index; *Eco* is economic development capability index; $\Delta G/G$ is growth rate of GDP; $\Delta POP/POP$ is change rate of urban population size.

c. Coupling Model of Urban Ecosystem Composite Carrying Capacity

$$UECC = f(N, F) = r \cdot N \cdot e^F \quad (3)$$

Where: *UECC* is composite carrying capacity of urban ecosystem；r is characteristic factor in the system (Mainly refers to natural resources or science and technology, the value is 1 for non-resource cities.)

B. Ecosystem pressure econometric model

The carrying capacity of the urban ecosystem is always relatively to the pressure of the urban ecosystem. The source of this pressure origins from the rapid expansion of the urban population and the continuous strengthening of economic activities. Considering the complexity of the contribution of the "Driving Force-Pressure" composite component of the socio-economic system to the carrying capacity of the urban ecosystem, the pressure on the urban ecosystem is divided into internal pressure and external pressure (indirect pressure).

The internal pressure refers to the pressure of the socio-economic system on the ecological support system, which is mainly manifested by resource depletion and environmental pollution; the external pressure refers to the pressure of the urban complex ecosystem, which is mainly manifested in the requirements of population size, economic activity intensity and quality of life. In this paper, we constructed the urban ecosystem pressure index (UEPI) to characterize this kind of stress situation, through the increasing or decreasing trend of the ecosystem pressure index and the relationship between the urban ecosystem pressure index and the urban ecosystem carrying capacity (UECC) to judge whether the city can sustainable development. (Suppose their angle is represented by θ in a two-dimensional space coordinate system)

When the urban ecosystem itself can maintain a healthy state and the city's human living standards can reach a certain standard, the following three situations will appear:

a. When the angle is greater than zero, where $\theta > O^0$

It shows that the growth rate of the carrying capacity of urban ecosystem is greater than the growth rate of the pressure, which indicates that the carrying capacity of city's resources and the environment has not exceeded its threshold. The resources, environment and economic development are coordinated, urban ecosystems are developing in a healthy direction, the population size of the city can continue to expand, and the economic activities can be strengthened continuously.

b. When the angle is equal to zero, where $\theta = O^0$

It shows that the growth rate of the carrying capacity of urban ecosystem is equal to the growth rate of the pressure, which indicates that the carrying capacity of the city's resources and the environment has reached its threshold. The population size and the intensity of economic activity are moderate;

c. When the angle is less than zero, where $\theta < O^0$

It shows that the growth rate of the carrying capacity of urban ecosystem is less than the pressure growth rate of the pressure, which indicates that the carrying capacity of city's resources and environment exceeds its carrying capacity threshold. There will cause corresponding resource shortages and environmental problems eventually when this pattern lasts too long and the urban ecosystem will collapse at this moment. The full econometric model is as follows：

$$UEPI = \alpha_u^2 \cdot e^{\beta_u} \quad (4)$$

Where：

$$\begin{cases} \alpha_u = k_3 \sum_{i=1}^{m} (POP \cdot s_i + G \cdot \omega_i) / G & (4\text{-}1) \\ \beta_u = \frac{1}{k} \sum_{j=1}^{k} \lambda_j \left(POP \cdot w_j + G \cdot \psi_j \right) & (4\text{-}2) \end{cases}$$

Where, α is resource consumption index; β is environmental pollution index

(Here is mainly expressed by the equivalent pollution load ratio of pollutants); *POP* is Urban population size; S_i is the usage amount of the type *i* resources per capita；G is GDP(For the convenience of calculation, we will use the constant price in 2010);ω_i is the resource consumption per 10,000 yuan of GDP;λ_j is the weight of pollutants; w_j is the emissions of type *j* pollutants per capita;ψ_j is the pollutant emissions of per 10,000 yuan of GDP;k_3 is the constant; *k* is the type of pollutants.

IV Calculation of the complex carrying capacity of Chaoyang ecosystem

a. Calculation of urban ecosystem carrying capacity (UECC)

The composite carrying capacity model includes natural carrying capacity calculation (represented by *N*) and acquired carrying capacity calculation (represented by *F*).

1. Calculation of natural carrying capacity *N*

In this part, we will respectively calculate the recovery index *R*, the resource supply index α_s and the environmental capacity index β_s. All the values of *K* which appeared in the formula are constants are used to eliminate the dimension and have no numerical significance.

(1) Recovery index *R*

The recovery index is also called ecological elasticity index. According to the available data statistics, the ground cover in Chaoyang can be divided into seven categories, mainly including cultivated land, forest land, grassland, garden land, construction land, water surface and unused land. Constrained by the limited data sources, the data collected for this evaluation of the carrying capacity of Chaoyang is based only on the ground covered by Chaoyang in 2017 (Table 2).

Based on the research methods of Liu Jianjun who worked in the Institute of Geochemistry of the Chinese Academy of Sciences and also integrated the research results of Gao Jixi, we proposed the ecological elasticity index to analyze the stability and health of the Chaoyang ecosystem[8]. The higher the R value, the greater the ability of the ecosystem to maintain the structure and function of the system after being stressed by the ecosystem, and the healthier the ecosystem. The calculation formula of the ecological elasticity of Chaoyang is as follows:

$$R = D_i \times \sum_{i=1}^{n} S_i \times P_i$$

$$D_i = -\sum_{i=1}^{n} S_i \times \log_2 S_i$$

Where, *R* is ecological elasticity; D_i is Ecological Diversity Index(calculated using Shannon-Weiner index）；P_i is elasticity score of the type *i* ground cover; S_i is the proportion of ground cover area of type *i* to the total area. The ecological elasticity of different ground covers is classified and assigned scores according to the characteristics of the ecosystem in the research area and based on the opinions of some experts in the research field. The results are shown in Table 1.

Tab.1 The assignment and significance of landscape elasticity covered by different ground covers

Type of ground cover	Scores	Content and meaning
Waters	1.0	Extremely important; Maintaining ecosystem stability and health
Woodland	0.9	Extremely important; Maintaining ecosystem stability and health
Grassland	0.7	Very important; Maintaining ecosystem stability and health
Garden	0.6	Very important; Maintaining ecosystem stability and health
Arable land	0.4	More important; Excessive interference; Ecosystem elasticity decrease
Construction land	0.1	Important; Less contribution
Desert land	0	Important; Less contribution

Tab.2 The ground coverage and their respective proportions in total land area of Chaoyang in 2017

Type of coverage	Arable land	Garden	Woodland	Grassland	Construction land	Waters	Desert land
Aera (Ha)	476739.75	64827.95	633677.08	122742.63	106464.54	17378.95	68200.03
Proportion (%)	24.2%	3.3%	32.2%	6.2%	5.4%	0.9%	3.46%

Using the above elasticity scores and the statistical results of the ground covers of Chaoyang in 2017, calculating with formula (1-1), the calculated values of the Ecological Diversity Index and Ecological Recovery Index of Chaoyang in 2017 are as follows:

$$D_i = -\sum_{i=1}^{7} S_i \times \log_2 S_i = -(-0.167916\text{-}0.061162\text{-}0.227388\text{-}0.248718\text{-}0.526427\text{-}0.162405\text{-}0.495354) = 1.889374$$

$$R = D_i \times \sum_{i=1}^{n} S_i \times P_i = 1.889374 \times 0.4642 \approx 0.877$$

(2) Resource supply index α_s

According to the characteristics of ecosystem resources and environment system support capabilities and the analysis of material flow and energy flow characteristics of Chaoyang, the water resources, raw materials and energy are the essential resource elements for the production and life of urban ecosystem.

By selecting the available water resources, the supply of raw materials (primarily selected steel supply data), the supply of energy (primarily selected coal and electricity data) (List in Table 3) of Chaoyang in 2017, and the GDP data of the current year, calculating with formula (1-2). What needs to be explained here is that when the resource supply index was calculated, the supply value of various resources must be converted in advance according to the national energy conversion standard coefficient by combining the above data.

Regarding the coal consumption of steel, the current international advanced level of coal consumption during steelmaking is 0.7 to 0.9 tons of standard coal per 1 ton of steel. However, the current energy consumption per ton of steel in China is about 1.3 tons of standard coal, so the calculation is based on the consumption of 0.9 tons of standard coal per 1 ton of steel in this paper[9]. The converted value of the essential resource is as shown in Table 3:

Tab.3 Essential Resources Supply and Converted value of Chaoyang in 2017

Resource Type	Available Water Resources	Raw Materials	Energy	
		Steel	Raw Coal	Electricity
Resources Supply	41462.7×10^4 m^3	222.1×10^4 tons	206.89×10^4 tons	31.9×10^4 kWh
Conversion Coefficient	2.571	1.3	0.7143	3.6
Conversion of Supply (Tons of Standard Coal)	106600.6017	2887300	1477815.27 1148400	
Resource Supply Index	$\alpha_s=\sum_{i=1}^{m} r_i/G=1.6872$			

(3) Environmental capacity index β_s

According to the environmental quality status of Chaoyang in 2017, six typical indicators including chemical oxygen demand COD, ammonia nitrogen N-NH3, sulfur dioxide SO_2, and industrial dust environmental capacity were selected as the main indicators of environmental capacity calculation. According to the index value range of China's wastewater discharge standard GB18466-2005 and air pollution emission standard GB16297- 2004, after dividing the weight equally and calculating with formula (1-1-3), the calculated values of environmental capacity index of Chaoyang in 2017 can be obtained as follows:

$$\beta_s = \frac{1}{k}\sum_{j=1}^{k}\lambda_j k_j = 90.9375$$

Then the calculation result of natural carrying capacity also can be obtained after calculating with formula (1-1) ,by using the achieved results which were shown in Table 4.

$$N = R \cdot \alpha_s^2 \cdot e^{\beta_s}$$

Tab.4 Calculation results of Natural carrying capacity of Chaoyang in 2017

Calculated Index	R	α_s	β_s	N
Index Value	0.877	1.6872	90.9375	7.780135 10^{39}

2. Calculation of acquired carrying capacity *F*

In this part, we will respectively calculate the technology index μ , human resources index σ and economic capability index *Eco*.

(1) Technology Index μ

The technical index is mainly expressed by the ratio of the output value of high-tech industries to the total industrial output value (the constant price in 2010). According to the latest statistics of project construction and technological innovation in Chaoyang, the total industrial output value of Chaoyang was 77.5 billion yuan in 2017, and had got 10.46 billion yuan in high-tech new product output value with an increase of 24% year-on-year. Therefore, the Chaoyang Technology Index in 2017 is as follows:

$$\mu = 104.6 \div 775 = 0.135$$

(2) Human Resources Index σ

The human resource index refers to the proportion of labor force in the total population which represents the material level of the intellectual sub-bank in an urban ecological bank. The total population of Chaoyang in 2017 was about 3.402 million, and the labor force was about 1.7835 million. Therefore, the human resources index of Chaoyang in 2017 is as follows:

$$\sigma = 178.35 \div 340.2 = 0.524$$

(3) Economic Capability Index *Eco*

According to the statistical data of the Chaoyang Yearbook in 2017 and 2018, the gross national product (GNP) of Chaoyang in 2016 was 70.89 billion yuan and the total population was 3.044 million. However, the GNP of Chaoyang was 77.5 billion yuan and the total population was 3.402 million people in 2017. According to the economic capability index formula (2-1), after inserting the corresponding data of Chaoyang into the formula, the economic capacity index can be obtained as follows:

$$Eco = \frac{\Delta G / G}{\Delta POP / POP} = 7.9319$$

After inserting the calculation results of the technical index, human resource index and economic capacity index of Chaoyang into formula (2), the acquired carrying capacity of the urban ecosystem can be obtained as follows:

$$F = \mu \cdot \sigma \cdot Eco = 0.135 \times 0.524 \times 7.9319 = 0.5611$$

And the calculation results of each parameter are shown in Table 5.

Tab.5 Calculation results of the acquired ecosystem carrying capacity of Chaoyang in 2017

Index	μ	σ	Eco	F
Value	0.135	0.524	7.9319	0.5611

As Chaoyang is a non-resource type city, the characteristic factor of Chaoyang was set to 1 during the calculation process according to the coupled model of ecosystem composite carrying capacity, so the composite carrying capacity of Chaoyang in 2017 can be calculated as follows:

$$UECC = f(N,F) = r \cdot N \cdot e^{F} = 1 \times 7.780135 \times 10^{39} \times e^{0.5611} = 13.64 \times 10^{39}$$

b. Calculation of urban ecosystem pressure index (UEPI)

1. Resource consumption index α_u

The calculation of the resource supply index is based on the per capita water resource consumption, the comprehensive energy consumption of GDP (Here, coal and electricity were selected as the main energy calculate data which listed in Table 3), and the GDP value and population data of Chaoyang in 2017. However, what needs to be explained here is that Chaoyang has never counted the comprehensive energy consumption of GDP. Therefore, the comprehensive energy consumption of GDP of Chaoyang is the calculate result of comprehensive conversion based on energy consumption of GDP and the GDP of Liaoning province in 2017. In addition, the water resource consumption is converted according to the national energy conversion standard coefficient. According to the formula (4-1), after inserting the above corresponding data into the formula, the resource consumption index can be obtained as follows:

$$\alpha_u = \sum_{i=1}^{m} (POP \cdot s_i + G \cdot \omega_i) / G = 0.6421$$

Tab.6 Resource consumption of Chaoyang in 2017

Re-cources Tpye	Comprehensive energy consumption of GDP (Tons of standard coal per 10,000 yuan)	Water resources (Ten thousand cubic meters)
Value	0.0567	51861.5

2. Environmental pollution index β_u

The calculation of the environmental pollution index is based on the four major pollution load indexes which including chemical oxygen demand pollution load, ammonia nitrogen pollution load, sulfur dioxide pollution load and industrial dust pollution load. Moreover, the pollutant indexes should be divided into equal weights during the calculation. According to the *Statistical Yearbook* and the *Environmental Quality Report* of Chaoyang in 2017, the main pollutant discharge and the pollution index statistical values of Chaoyang in 2017 can be obtained and the pollutant load can be calculated separately thereafter. According to the formula (4-2), after inserting the above corresponding data into the formula, the environmental pollution load index can be obtained as follows:

$$\beta_u = \frac{1}{k}\sum_{j=1}^{k}\lambda_j\left(POP\cdot w_j + G\cdot\psi_j\right) = 92.3523$$

Tab.7 Major pollutants Emissions of Chaoyang in 2017 unit：ton

Pollutants	COD	N-NH_3	SO_2	Industrial Dust
Emissions	47250.28	3841.26	66525.92	41983.85

According to the formula (4), after inserting the resource consumption index value the and environmental pollution load index value into the formula, the urban ecosystem pressure index value of Chaoyang in 2017 can be obtained as follows:

$$UEPI = \alpha_u^2 \cdot e^{\beta_u} = 5.42\times10^{39}$$

The calculation results of the above steps are as shown in Table 8:

Tab.8 Calculation results of composite carrying capacity and ecosystem stress of Chaoyang

Facor / Time	UECC	UEPI	Carrying Capacity
2017	13.64 10^{39}	5.42 10^{39}	Positive Value

V Results and discussion

It can be seen from Table 8 that the urban ecosystem carrying capacity value (UECC) of Chaoyang in 2017 is higher than the urban ecosystem pressure index value (UEPI), which is a positive difference value. It shows that the coordinated development of resources, environment and economic system in this part of area is relatively better. The composite carrying capacity of the ecosystem is slightly higher than the pressure value of the ecosystem and is in the period of ecological surplus growth. The result of this evaluation is basically consistent with the evaluation results of the ecological suitability level and the current development stage of Chaoyang by the research group of ecological function zoning construction of Liaoning Environmental Protection Bureau. And this shows that the region's economic production mode is gradually changing to a green production mode.

It is possible to appropriately increase the number of enterprises, expand the scale of the enterprises, the scale of mineral resources mining and use the unique natural resources effectively of Chaoyang whenever against the background of the continued development of a coordinated development model of urban economic development and urban ecosystem support. So can promote the development of the urban economy and the continuous improvement of the living standards of local residents of Chaoyang. Meanwhile, it should also be noted that the area where Chaoyang is located is an underdeveloped area, and it is necessary to avoid focusing only on economic interests and falling into the misunderstanding of getting economic growth by scale production. The healthy development of the urban ecosystem should be maintained, and the reform of the economic system should be further deepened. On the basis of maintaining the existing production scale, rationally optimize the economic structure, effectively reduce environmental pollution, and improve resource utilization. For Chaoyang, efforts should be made to control the economic scale within the range of regional resources and environmental carrying capacity, and avoid the development road of "Treatment After Pollution". In this way, we can ensure a higher social living standard and economic development level and scale in Chaoyang, achieve coordinated development of resources, environment and economy to achieve the goal of building an ecological city as soon as possible. The calculation results of Chaoyang's ecosystem carrying capacity also show that the guarantee of the health and stability of a city requires the coordination and sustainable development of natural ecology, economic ecology, and social ecology. It is an important way to achieve ecological sustainable development by building an ecological city. From the perspective of a complex ecosystem, building an ecological city must take into account the coordinated development of various elements of the social, economic, and natural systems so as to achieve the best overall function.

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