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Computer Aided Simulation on Economic System Architecture

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Abstract. How to develop a circular economy to promote the long-term coordinated and healthy development of the population economy, resources and environment is an important task for China's economic development. This study used a computer-aided approach to build a regional economic system architecture model based on system dynamics. In the actual research, combined with the existing research results, the computer dynamics method was used to simulate and analyze the circular economy system. In addition, the system dynamics theory was used to model and simulate the circular economy system. The research shows that the model proposed in this paper has certain practical effects and can provide theoretical reference for subsequent related research.

Keywords: computer simulation; regional economy; economic architecture; system simulation
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1 INTRODUCTION

Opening to the outside world is not only the basic national policy of China, but also the source of power for the sustained and rapid development of China's economy and society. Accelerating the implementation of the free economic zone strategy is an important way and realistic choice for China to deepen reform and opening up in the new era. This is not only because the opening of the free economic zone is a partial, overall, safe and efficient opening, but also that the construction of a free economic zone can expand China's economic radiation range and international influence. Therefore, researching the development and evolution of the free economic zone and exploring the future development direction of China's free economic zone will benefit the implementation of the free economic zone strategy.

It is generally believed that the free economic zone plays an important role in promoting the overall development strategy and economic system reform of the national economy. However, through the study of the theory of regional economic unbalanced development, it can be seen that there are still different views on the impact of the establishment of a free economic zone on regional economic development. The American economist Beckers K F [1] proposed the "polarization-infiltration effect" theory. He used the "North" to define areas of economic growth, the "South" to define economically backward areas, and believed that the impact of North's growth on the South was mixed. Among them, the favorable effect of the North's increased investment in the South and the outward migration and per capita consumption levels in the South is called the “infiltration effect”. However, the adverse effects of the North's strong competitiveness on the suppression of economic activity in the South and the brain drain caused by immigration in the South are called "polarization effects." In the initial stage of economic development, the polarization effect plays a leading role and increases the economic gap between regions. However, when the economy develops to a certain maturity stage, this gap will gradually decrease with the long-term geographical penetration effect. Therefore, Hirschman's view is that the best way to develop regional economies is achieved through interregional non-equilibrium strategies. The central-periphery theory proposed by Barton P [2] expounds the process of regional economic growth from unrelated to unbalanced development to balanced development. He believes that any area is composed of two subsystems, the central area and the peripheral area. The central area is dominated by dense population, technology, capital concentration, strong innovation capability, and industrial development. However, the peripheral area is in a dependent position because of its lack of economic autonomy.

In the early stage of economic development, the mononuclear structure is the main form of expression. This spatial dual structure consisting of "central area – peripheral area" is very prominent. After entering the development stage of economic take-off, the original mononuclear structure was gradually replaced by multi-core structure [3]. Moreover, its spatial organization will also be integrated with the continuous development of the regional economy. This evolution process can be divided into the following four stages: regional low-level equilibrium development stage, regional polarization development stage, regional diffusion development stage, and regional high-level equilibrium development stage [4].

According to the dynamic system theory, Gilbert J proposes that the development of things is a process of continuous evolution and cyclic accumulation. He summarized this point of view into a cyclical cumulative causal principle and proposed the concepts of "diffusion effect" and "echo effect" in his representative work "Economic Theory and Underdeveloped Areas". He believes that the development of social economy is caused by a combination of factors including industry, income, production conditions, living standards, institutions and policies. Any change in any of these factors can be seen as an initial change that causes other factors to change accordingly. This becomes the second-level movement to strengthen the initial factors, and after repeated cycles and accumulations, the social economy will develop along the trajectory of the initial factors [5]. Such a cyclical cumulative causal movement will have both positive and negative effects: one is a favorable influence (that is, the diffusion effect), which means that various factors of production spread from the growth pole to the underdeveloped region, thereby narrowing the economic development gap between the two regions. The other is the adverse impact (that is, the echo effect), which refers to the return and accumulation of various factors of production to the growth pole, thereby expanding the economic development gap between the two regions. Moreover, the result always appears as an echo effect greater than a diffusion effect. The reason is that the gap between regions is always influenced by market mechanisms and tends to expand rather than shrink. Although this theory and Hirschman's '’polarization-infiltration effect' have the same effect, the views are quite different [6].

The product life cycle theory proposed by Barina G [7] believes that after the product enters the market, its life cycle has roughly experienced the three stages of "new product – maturity – standardization". When this theory is introduced and used to analyze the regional economic gradient transfer, it is believed that the economy has experienced four stages of innovation, development, maturity and decline in the development process. Therefore, the rise and fall of a regional economic development depends on the stage in which the leading industries in the region are located. When a region is dominated by the industrial structure sector in the recession phase, this region is a low-gradient region. However, when its industrial structure is dominated by the sector of innovation, the region can be seen as a high-gradient region. Generally speaking, the economic development of any country or region is at a certain stage of the gradient, but the level of the leading industrial sector is different. The important factor that determines the ability to achieve gradient transfer in a region is the level of innovation [8].

The regional production cycle theory proposed by Welkenhuysen K [9] believes that the development of the region has experienced the same evolution of life-like organisms as "young, mature and aging". In the younger period of regional industry, the region attracted a large amount of capital and talents due to its comparative advantage, and its competitiveness was significantly enhanced. During the maturity period, although the region is still in a dominant position, it has formed a competitive relationship with other regions as they have followed suit to establish a sub-district. In the aging phase, the original advantages of the region (such as cost and market advantage) are lost.

From the current research status of circular economy research, there are relatively few literatures on applying system dynamics to study the development trend of regional urban circular economy system. Based on the reference to other scholars' circular economy research, this paper applies the system dynamics method to explore the development of circular economy.

2 RESEARCH METHOD

(1) Causal relationship diagram

In order to visually describe the model structure, Causal Loop Diagram (CLD) is often used in the initial stage of the concept model to represent the system feedback loop structure. The causal relationship graph can more accurately express the hypothesis about the cause of the dynamic formation of the system and introduce and express the mental model of the individual or the team. The causal diagram consists mainly of causal arrows, causal chains, and feedback loops. The directed line segment connecting the causal elements is a causal arrow, the causal arrow has a positive and negative polarity, and the arrow indicates the cause, the arrow indicates the result, positive (+) indicates reinforcement, and negative (-) indicates attenuation. The causal chain can be obtained by depicting the relationship between system elements of recursive nature by causal arrows. The polarity of causal chain depends on the number of causal arrows in the system. If it is odd, it is negative causal chain, and vice versa is positive causal chain. The polarity of the feedback loop depends on the parity of the number of causal chains in the loop. If it is odd, the loop polarity is negative. If it is even, the loop polarity is positive [10].

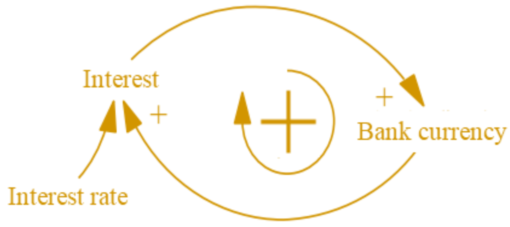

Figure 1: Example of a positive feedback loop.

Figure 1 shows a positive feedback loop using bank deposit currency as an example. Bank deposit currency generates interest over time. Under the premise of stable interest rates, the more money, the more interest. Moreover, the current year's principal and the next year's principal will continue to grow the bank's currency. Figure 2 is a negative feedback loop using the water level of the water cup as an example. When the water level difference is large, the drowning water should be more rapid. The higher the drowning rate, the faster the water level of the cup increases, and the smaller the water level difference, the closer the expected water level is [11].

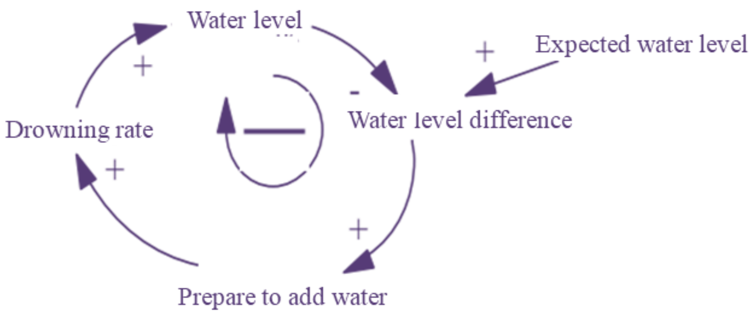

Figure 2: Example of negative feedback loop.

The socio-economic system is often a complex giant system. The hidden causal feedback loop is inherent in the causal relationship of each element in the social system. The dynamic behavior of the social system is determined by the positive feedback and negative feedback loops existing in the system itself. The positive and negative feedback loops are superimposed and combined to form a multiple feedback loop, as shown in Figure 3 [12].

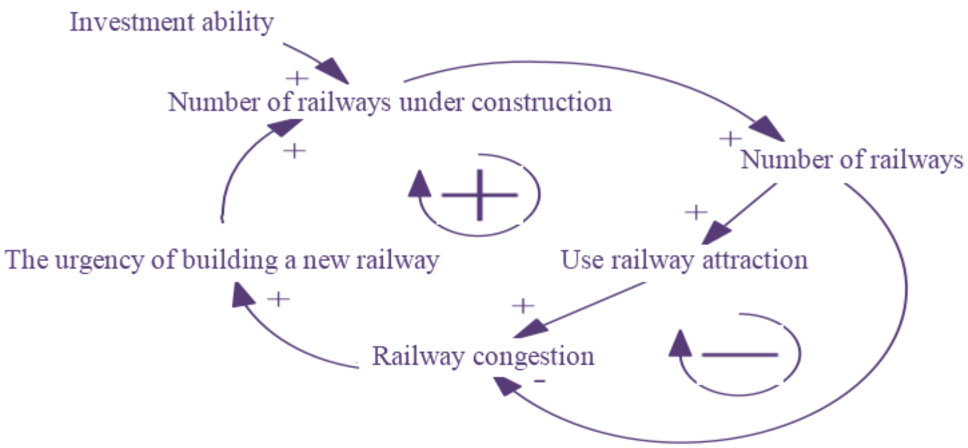

Figure 3: Re-feedback loop.

In Figure 3, there are two feedback loops, one positive feedback loop, the number of railways → the use of railway attraction → the degree of railway congestion → the urgency of building a new railway → the number of railways under construction → the number of railways. The other is a negative feedback loop, the number of railways → the degree of railway congestion → the urgency of building a new railway → the number of railways under construction → the number of railways. This system has a positive and negative feedback loop. When the regulation of the negative feedback loop is stronger than the self-reinforcement of the positive feedback loop, the system tends to be "stable", whereas the system exhibits "growth" or "recession" [13].

In the feedback loop, there will be an exponential or super-exponential increase in the positive feedback process, which will make the deviation of the variables in the loop increase, and also the characteristics of the system collapse. The negative feedback process has a function of finding, and the negative feedback structure tries to minimize the fluctuation of the system to reduce the gap with the expected level. The quality of feedback can only be judged by combining specific conditions, which makes sense.

(2) System equations and related variables

① Initial condition equation

The initial conditional equation is an equation that sets the initial value for a parameter or variable. The equation is as follows

$$\text{N} \quad N = C \tag{1}$$

In the formula, N is the initial conditional statement tag, and C is a constant [14].

② Rate variable and equation

Rate Variable is a variable that directly changes the value of accumulated variables. Its function is to transform the elements that affect the state of the system into actions that change the state of the system and reflect the speed of the input or output of the accumulated variables. The rate equation is used to control real logistics within the system. The output of the rate equation controls the increase and decrease of the horizontal variable and the physical flow between the horizontal variables. The equation is expressed as follows:

$$\text{R} \quad RA = RateS(t) = f_{(state\ v,ariable,\ constant)} = f\left[1v\ S(t), \mathrm{exo}(\mathrm{t}), \mathrm{aux}(\mathrm{t}), \mathrm{const}\right] \tag{2}$$

In the formula, R is the statement mark of the rate variable, $1v\ S(t)$ is the accumulated variable value at time t, $\mathrm{exo}(\mathrm{t})$, $\mathrm{aux}(\mathrm{t})$ are the exogenous variable and the auxiliary variable value respectively, and const is a constant [15].

③ Level Variable and equations

Level Variable, also known as the accumulation variable, is the variable that ultimately determines the behavior of the system, indicating that the feedback system contains a continuous, fluid-like accumulation process. Its value is quantitatively equal to the cumulative amount accumulated in the previous accumulation amount and time interval (DT).

The equation of state of the continuous form is as follows [16]:

$$1v\ S(t) = S(t_0) + \int_{t_0}^{t} RateS(t)dt = S(t_0) + \int_{t_0}^{t} \left[inflowS(t) - outflowS(t)\right]dt \tag{3}$$

In the formula, $1v\ S(t)$ is the cumulative value of the variable at time t, $inflowS(t)$ is the input rate, $outflowS(t)$ is the output rate, and $RateS(t)$ is the rate at which the accumulated variable changes.

The discrete formal equations are as follows:

$$L\ L.K = L.J + DT \times (RT.JK) \tag{4}$$

In the formula, L is the state variable statement mark, $L.K$ is the state value at time K, and DT is the time interval (J time to K time), $RT = Rate = inflow - outflow$.

④ Auxiliary variables and equations

Equation 2 above uses an expression to determine the rate equation, and the rate equation itself is complex. The auxiliary equations often take a detailed characterization of the rate equation by nesting multiple layers of functions. The variables in the auxiliary equation can be any combination of constant terms, state variables, rates, or other auxiliary variables. The structure of the auxiliary variable (Auxiliary Variable) and the algebraic equation should be meaningful and approximate to the mechanism of action of the real system [17].

⑤ Constants and equations

Constant is a time-invariant parameter in the system, which together with the stock determines the change in flow rate. The constant equation is to assign a value to a constant. Common expressions are as follows:

$$\mathrm{C} \quad Ci = Ni \tag{5}$$

In the formula, C is a constant statement tag, a Ci constant name, and a Ni constant value.

(3) Flow diagram

The flow diagram is a flow chart that are drawn using the unique characteristics of system dynamics that describe the various variables and their relationships, based on the causal feedback loop. Compared with the causality diagram, the flow graph is the basis for the quantitative model to collect data and is the basis for designing the system dynamic simulation. The flow graph and its representation symbol are shown in Figure 4.

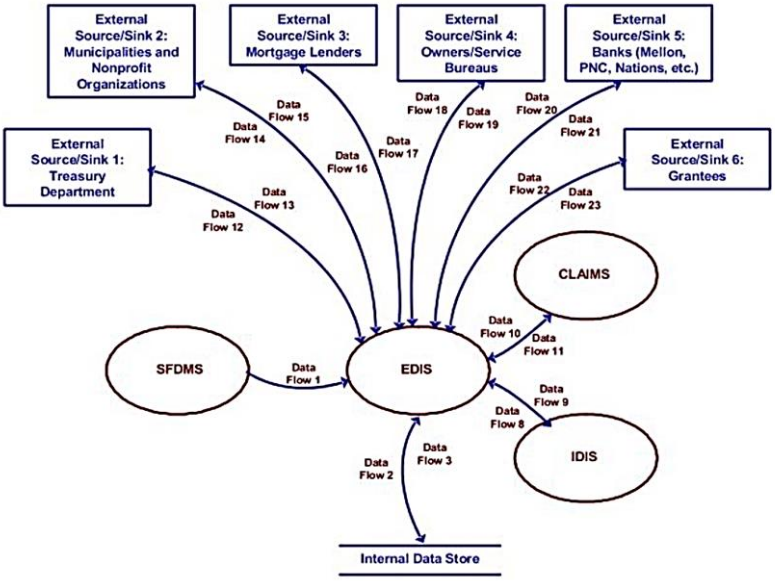

Figure 4: System flow diagram.

The cloud symbol in the above figure represents the source and sinks, representing the state of the input and output, and the boundary between the source and sink identification systems.

3 BASIC STEPS FOR MODELING AND SIMULATION

The basic steps of modeling of the system dynamics method include the following five parts.

(1) System analysis

The primary task of system analysis is to clarify the problem and analyze the cause of the problem. At the same time, it needs to clarify the problems to be solved, analyze the main contradictions and problems of the system, preliminarily delineate the boundaries of the system, and investigate and collect relevant system conditions and statistical data.

(2) Structural analysis of the system

On the basis of system analysis, according to the actual system, the structural level of the system and the sub-blocks are scientifically determined, and the main feedback mechanisms and feedback loops are deeply considered and analyzed, and the relationship between system variables and variables is defined, and the types of variables and main variables are determined.

(3) Establish a canonical model

The state, velocity, auxiliary variables, constants, etc. in the system are determined, the horizontal equation and the rate equation are established, and the control parameter values are determined by the trend extrapolation method, the linear regression method, the average value method, etc., and all N equations and C equations are assigned.

(4) Model simulation and policy analysis

Under the premise that the verification model is consistent with the historical data (the relative error of the two is not more than 10%), the system is adjusted by changing the relevant parameters in the model, and the future development of the system is predicted and compared. At the same time as the simulation, it is necessary to pay attention to the modification and improvement of the model, including the modification of the structure and parameters.

(5) Model testing and evaluation

Inspection and evaluation are carried out throughout the entire process of model construction and simulation, and a considerable portion is decentralized in the other steps described above.

A schematic diagram of the basic steps of system dynamics modeling is shown in Figure 5.

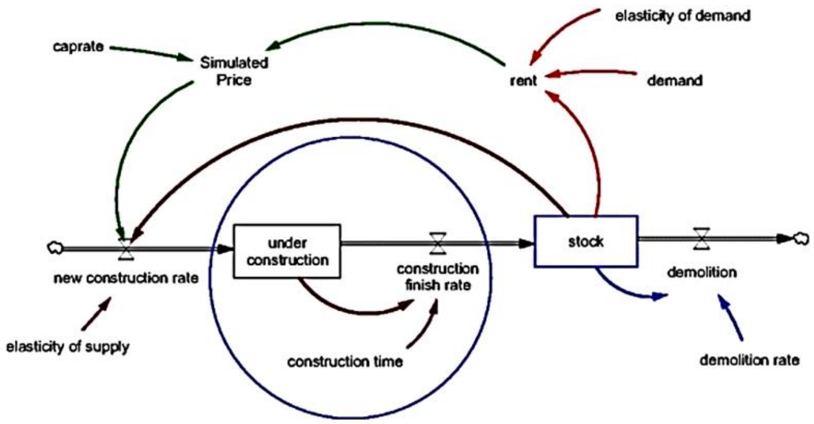

Figure 5: Schematic diagram of the basic steps of system dynamics modeling.

The system dynamics modeling steps are roughly the same. During the modeling process, the statistics and data of the problems related to the system should be collected and utilized to the greatest extent, and the decision-makers and relevant experts should be strengthened to contact and cooperate. In the simulation, the data is tested, and the relevant parameters are optimized to bring it closer to the real system.

Cybernetics is the science that studies the regulation and control laws of systems. Its basic concept is composed of information, feedback and control. The study of circular economy system is the continuous acceptance of human ecosystems to feedback the information that we change the system and then continuously adjust the behavior to within the threshold of ecological environment and self-regulation.

Information feedback has positive feedback and negative feedback. The feedback type that enhances the original information through the feedback of the new information is positive feedback, and vice versa is negative feedback. Negative feedback occurs more than positive feedback, both in nature and in human society. Efficient control of the system is achieved through feedback. The control information feedback diagram is shown in Figure 6.

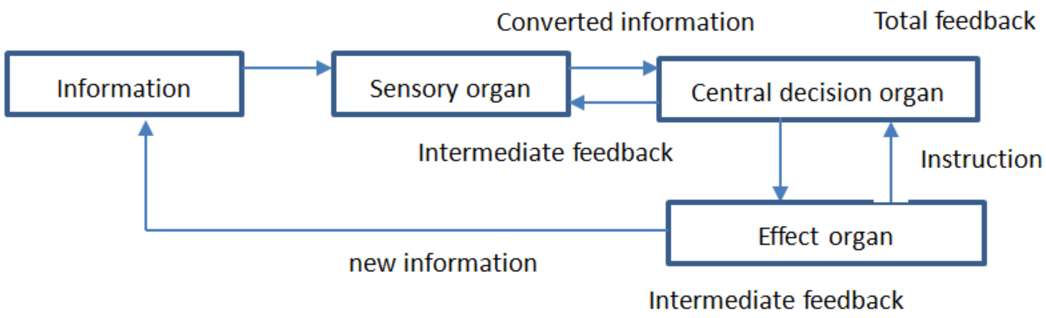

Figure 6: Information feedback diagram.

The cybernetic research object is the system. The necessary premise of the control methodology is to treat the object of analysis as a whole system. This mainly refers to a systematic thinking, rather than a holistic thinking of intuition, primitive, vague understanding or a quantitative thinking method to describe the linear causal relationship between phenomena. System thinking requires organically organizing research objects to form a system model based on the nature and structure of the system, studying the functions and behaviors of the system, focusing on analyzing the overall and comprehensive attributes of things and revealing their diverse connections, structures, and functions.

The circular economy is to use the principle of cybernetics to realize the circulation of ecological resources through information feedback and control adjustment within the system, to ensure the balance between ecological resources and intellectual resources, and to achieve system sustainability. The cluster evolution effect diagram is shown in Figure 7.

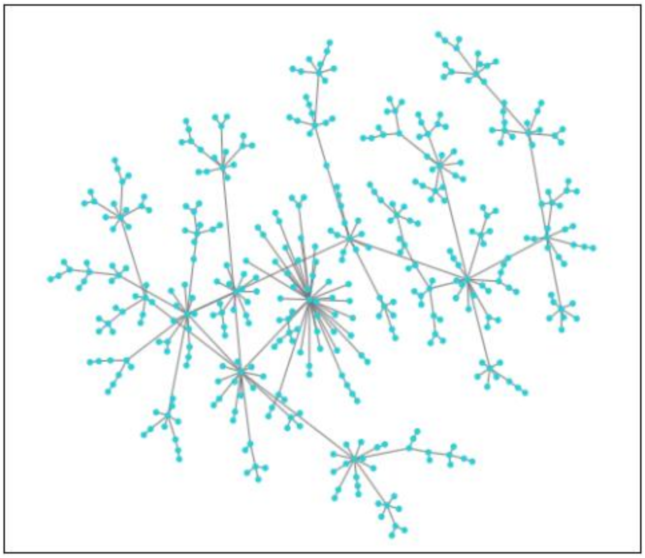

Figure 7: Cluster evolution rendering.

4 ANALYSIS AND DISCUSSION

System Dynamics (SD) is a systematic analysis of socio-economic issues proposed by Professor Jay. W. Forrester of the Massachusetts Institute of Technology (MIT) in 1956. In the early days, the law was mainly used for the management of industrial and commercial enterprises, and studied issues such as fluctuations in production employees, inventory problems in production and sales of enterprises, and instability in stock and market growth. Since then, the scope of application of system dynamics ideas and methods has continued to expand, reaching into all aspects of the real-world system. System dynamics is mainly used to study the socio-economic system, and it uses society as a nonlinear multiple information feedback system to conduct research. When using this kind of system model to study the socio-economic system, it has the advantages of low precision of data, complex real-world problem processing, combination of qualitative and quantitative, and simulation of system results.

(1) Goal-oriented

System dynamics modeling should first clarify the purpose and task of modeling, and the model without specific purpose is like a ship without sails. The whole process of modeling must always focus on the contradictions and problems faced by the objective system, the dynamic development process of contradictions and problems, the application of models and the implementation of policies.

(2) Combination of decomposition and synthesis

On the one hand, the study of system problems should consider the system problem from the overall point of view; on the other hand, the complexity of the system determines that it has a certain level. In the system structure analysis, the decomposition principle can be applied to carry out profound and meticulous research on subsystems of different levels.

(3) The model is the "laboratory" of the actual system

The model is an abstraction or imitation of the real-world part and is a certain section and side of the real world. Modeling should prevent the wrong tendency of modeling according to objective reality, and not pursue one-sided pursuit of the model, but insist on goal orientation. Efforts should be made to influence the key elements of the model to find intentional strategies and policies that can solve problems in the actual system.

(4) Whether the model is effective or not can only be tested in objective practice.

People's understanding of objective things is a spiraling ups and downs and cannot be achieved overnight. There is no absolutely correct model, only a phased, relatively effective model that meets the expected goals. Only by constantly testing and correcting the model in practice can the application of the model be more mature.

At present, domestic sustainable development research has been extended from partial interdisciplinary research to comprehensive composite concept research and is no longer limited to the ecological field itself. The research field is paying more attention to seeking economic, environmental and social interactions and coordinated sustainable development models with the support of technological progress and policy management. The research methods mainly include sustainable development models and evaluation index system construction.

The common goal of sustainable development theory and circular economy is to solve the problem of ecological resource constraints. In response to the increasingly severe environmental constraints, people have proposed solutions such as environmental friendliness, green technology, clean production, zero emissions, and waste recycling. From a systemic point of view, these solutions are inherently circular economy. Circular economy is an important carrier and concrete realization form for sustainable development. The development goals of circular economy are not only adapted to the requirements of sustainable development, but also the best way to solve sustainable development problems in the world today. The two have inherent unity.

System dynamics believes that the system structure determines the system behavior. In order to systematically understand and master the system behavior, it is necessary to study the structure of the system. After clarifying the purpose of the problem to be studied and initially delineating the system boundaries, it is necessary to focus on the structural study of the system. The structure of the system dynamics model mainly includes the feedback loop and mechanism of the system, system levels and sub-blocks and variables.

5 CONCLUSION

Regional economic simulation based on complex network research is aimed at being close to the real system network model. This paper compared the previous research results of industrial cluster evolution, selected the system dynamics model which can reflect the characteristics of real network structure as a reference, and improved and developed an evolutionary model of directed and weighted networks. In the case of computer aided, the system dynamics method was used to simulate and analyze the circular economy system, and the system dynamics theory was used to model and simulate the circular economy system. At the same time, the circular economy system was decomposed into four parts: population subsystem, economic subsystem, resource subsystem and environmental subsystem, and representative indicators were selected. In addition, under the guidance of the relevant plans for the development of circular economy, the representative policy parameters of each subsystem were reasonably adjusted, and the trend of the development and change of the corresponding level variables before and after the adjustment of each parameter was analyzed. Through the research, we can see that the algorithm has certain effects, and it can be combined with the model to carry out verification analysis in subsequent related research.

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