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System Simulation Optimization of Resource and Environmental Effects of Circular Economy

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ABSTRACT

In order to study the system simulation optimization of resource and environment effects of circular economy, based on the theory of composite ecosystem, the dynamic model of composite ecosystem is established by using the method of system dynamics and software tools, and the development trend of future system status and main ecological risks are simulated by using the model. Based on the mechanism and characteristics of the ecosystem revealed by the dynamic model and the results of ecological security assessment, the countermeasures and measures for management and protection are put forward. The results show that GDP growth is very fast in the forecast, while net GDP growth lags far behind the GDP. This shows that the loss of environment and resources and natural disasters is also increasing in the process of rapid economic development. Therefore, this kind of economic development is at the cost of excessive pollution of the environment and consumption of resources. Economic development has become a threat to the pressure and security of the entire urban ecosystem. It is necessary to find ways of energy recycling and sustainable economic development.

INTRODUCTION

Resource conservation, environmental protection and economic development are three major themes facing the development of human society today. Energy sustainability is the foundation, environment sustainability is the condition, and economic sustainability is the ultimate goal. Based on this, the simulation model of energy-economy-environment system operation is established. Traditional economic development hardly takes into account the destructive effects of economic growth on the environment and ecosystem. It is based on the assumption that resources can be supplied without restriction (Edaibat et al. 2017). Therefore, economic activities guided by this kind of development cause a large consumption or even waste of resources and energy. Over the years, human beings have exploited various mineral resources predatorily, unilaterally emphasizing the scale and speed of economic development, neglecting many related factors such as ecological carrying capacity, separating the interaction of relevant factors in the ecosystem, causing climate deterioration and resource shortage, adversely affecting economic production, and ultimately endangering the human survival environment (Eker et al. 2017). The study of energy-economy-environment complex system needs not only natural science, engineering technology science and a lot of practical experience, but also the guidance of modern economic thoughts, theories and methods (King 2017, Sanatani 2017). The research on energy, economy and environment system also needs some theoretical foundation. The basic theories of analysis include sustainable development theory, energy economics theory, environmental value theory, system theory, econometrics theory and so on. These theories support the research work of this study from different levels and angles (Palomba et al. 2017). Developing circular economy is an important way to achieve clean and efficient production and sustainable development. On the basis of promoting energy saving and emission reduction, it creates new economic growth points for enterprises through extending the industrial chain, which has an obvious social, economic, resource and environmental effects (Teng et al. 2018).

Econometrics is an economic branch based on mathematical economics and mathematical statistics, which synthesizes the theoretical and empirical approaches to economic problems (Liu & Zhou 2017). The econometric research methods such as regression analysis, time series model, cointegration analysis and Granger causality test are adopted (Morgan et al. 2017). System dynamics is not only a subject of analysing and studying information feedback system, but also a new interdisciplinary subject of recognizing system problems and solving system problems. It is a branch of system science and management science. It is also a horizontal subject of communicating natural science and social science. Based on the research of circular economy, econometrics, environmental effects and system simulation optimization, Yancheng is taken as an example to carry out empirical research, and the future operation status of Yancheng energy-economy-environment system is simulated and predicted by using the established simulation model.

PAST RESEARCH

Circular economy model provides a strategic theoretical paradigm for sustainable development, which can fundamentally solve the contradiction and conflict between current economic development and natural environment. System dynamics model can reflect the interaction between structure, function and dynamic behaviour of complex systems, and is suitable for dealing with complex socio-economic and ecological environment problems with low precision. The focus of relevant research is different.

A study established the energy-saving and efficient waste heat cycle, nitrogen cycle, relaxation gas cycle, water cycle, waste residue recovery and product cycle by developing technologies such as methanol relaxation gas replacing coke oven gas, pressure swing adsorption hydrogen refining benzene, methanol air separation surplus nitrogen gas using dry quenching for power generation, waste water grading treatment, steam allocation cascade utilization, waste residue application coal blending system and so on, which realizes zero emission of "three wastes" and energy efficient cascade utilization in coal chemical production process.

A previous research (Guo et al. 2014) invents and provides a micro-grid control system, which includes micro-grid control cabinet, main control cabinet and measurement and control cabinet, as well as microgrid management module. Micro-grid control cabinet is electrically connected with power generation module and energy storage module respectively. It is used to receive and collect electric energy of one or more power generation modules and manage the storage and release of electric energy of energy storage module. The main control cabinet and the measurement and control cabinet are used to monitor the operation of the primary equipment of the whole micro-grid, analyse the operation of the micro-grid in real time, and obtain the optimization and adjustment strategy of the whole micro-grid and implement it quickly and automatically. Among them, the main control cabinet is electrically connected with the microgrid control cabinet, and the measurement and control cabinets are electrically connected with the main control cabinet. The microgrid management module is electrically connected with the microgrid control cabinet, the main control cabinet and the measurement and control cabinet respectively, which centrally controls and manages the microgrid control cabinet, the main control cabinet and the measurement and control cabinet. It is also responsible for the coordination of power generation module, energy storage module and external network. A new energy recycling system using the above microgrid control system is provided.

In view of the development goals and demands of smart grid in different periods, Han et al. (2012) proposed a dynamic evaluation method of smart grid based on system dynamics model. This method takes the investment of smart grid as the starting point and establishes the system dynamics model of the dynamic impact of smart technology on the construction effect of smart grid through investment. The model quantitatively analyses the causal feedback relationship between the two and gives the trend of the evaluation index of smart grid evolving with time. The rationality and validity of the dynamic evaluation method are verified by simulation analysis.

This paper discusses the basic principles and methods of carrying capacity of water and soil resources. At the same time, based on the characteristics of water and soil resources and economic development in arid areas of northwest China, a system model of carrying capacity of water and soil resources in arid areas of northwest China is established by applying the principle of system dynamics. Taking Hexi region of Gansu province as an example, the carrying capacity of water and soil resources is systematically analysed and studied. The countermeasures to improve the carrying capacity of soil and water resources in this area are put forward.

MATERIALS AND METHODS

Research object: Research object is Yancheng eco-natural environment system dynamics model.

Modelling method of system dynamics: The essence of the system dynamics method is a system of first order differential equations, which describes the dependence of the rate of change of each state variable on each state variable or specific input, as shown in Fig. 1. The modelling steps are as follows:

1. Research methods and modelling purposes are determined. Systematic analysis is carried out on the system characteristics of the object of study and the applicability of selecting the theory and method of system dynamics. Relevant data of the object of study and related data of system operation are collected, and the purpose of building the system dynamics model is clarified. The system boundary and system composition are determined. System events and their actual system behaviour patterns are analysed.
2. The boundary of the system is determined. The system structure is deeply analysed, and the key problems and main elements of the research object system, the hierarchy and subsystem structure of the research object system are clarified. The feedback system of the whole and subsystems of the system are defined as the main variable for describing the system.

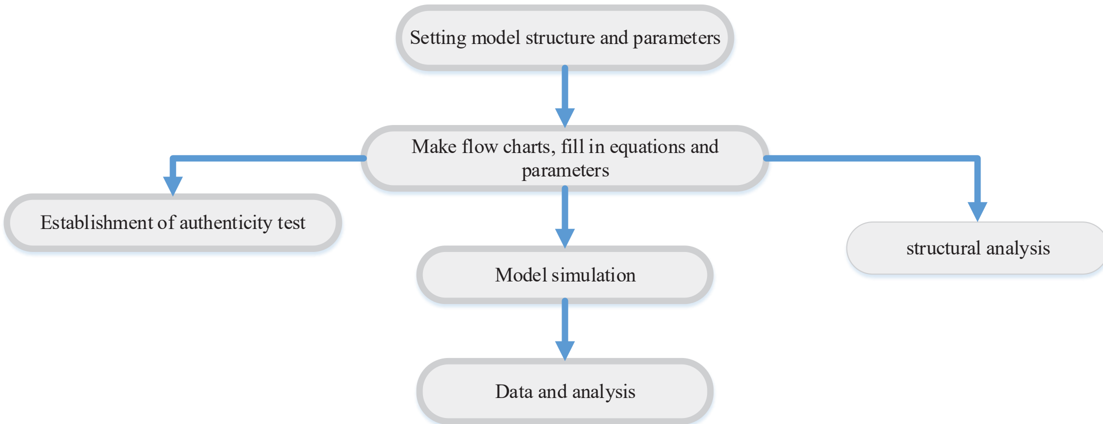

Fig. 1: Vensim' s general procedure for problem processing.

3. The causality and feedback loop of the system are determined. The causality among the elements in the system is analysed, and the critical feedback path of the system is identified. The main elements of each subsystem and their feedback relationship are determined, and the system variables, properties and variables are defined. According to the results of causality and feedback loop analysis, the causality diagram of the system is determined.
4. The system flow chart is designed, and the system dynamics model is constructed. A hypothetical design system flow chart is proposed. The relationship between system variables is analysed quantitatively. The equation of system variables is determined by means of mathematical analysis tools such as econometrics and statistics. The initial parameters of the system are set to check the accuracy of the unit of variables and the relationship between equations. In this step, a series of assumptions of system dynamics are expressed as a set of mathematical relations.
5. The validity of the model is tested. The validity test and sensitivity evaluation of the system dynamics model mentioned above are carried out. At the same time, more abundant information about the system operation and variables can be obtained, which lays a foundation for the next simulation of the system. In the process of model validity test, with the discovery of problems, the model can be modified in time.
6. The conclusion is drawn from the model checking simulation. With the help of system dynamic model, the system is simulated. The setting of system parameters is constantly changed with the purpose of modelling. Through repeated experiments, the behaviour mode of the system under different control conditions is analysed, and the most perfect system structure and behaviour mode are explored, so as to carry out relevant policy research on real activities.

System dynamics equation: Vensim software is used for simulation and prediction. The software is simple and convenient to use. It only needs to determine the quantitative relationship between variables in the equation editor of the software. It does not need to write another simulation program, and the establishment of equation and table function is simpler and more intuitive than other modelling software. In this study, the total population is regarded as the flow variable of population subsystem, and the population growth rate is the auxiliary variable. The net impact coefficient on population is the initial value and constant parameter value of the constant parameter flow level variable, which are based on the annual statistical value. The dynamic equation of energy-economy-environment system in Yancheng is as follows.

Population growth = natural population growth + mechanical population growth. Natural population growth depends on the birth rate and mortality rate of the population, which means natural population growth rate = birth rate - mortality rate.

Birth rate = 0.0124

Units: **undefined**

Birth population = total population * birth rate * family planning factor

Units: ten thousand people

mortality = 0.00643

Units: **undefined**

Death population = total population * mortality * eco-environmental impact factor

Units: ten thousand people

Energy consumption per unit GDP = total energy consumption/GDP

Units: Billion yuan

Per capita GDP = GDP/total population * 10,000

Units: yuan/person

Ecosystem model detection: The verification of the model follows two principles. Firstly, the model cannot exactly reproduce the "reality". It can only be required to reflect the problem to be understood in the record and to understand the impact of the hypothesis, and ultimately to show whether the hypothesis is correct. The solution can only be satisfactory, and the predicted future changes can only require the correctness of the trend of change. Secondly, effectiveness is a relative concept, which should be compared with other models and tested by practice. This study will select economic subsystems and population subsystems for historical testing. The starting time of verification is 2010, and the testing time is 7 years. Until 2017, the test variable is GDP. The initial values of GDP 1, GDP 2 and GDP 3 are based on 2010, and the constant parameters are set as RG1 = 0.033475, RG2 = 0.1701897, RG3 = 0.123381, which are the average values from 2010 to 2017.

RESULTS AND DISCUSSION

Total population and GDP test results: The relative error between the simulation value and the historical value of GDP and total population is not more than 0.1. The relative error test results are reasonable. The test results are shown in Table 1.

The results of the economic subsystem: The two main variables GDP and net GDP of the economic subsystem under the current development model are studied. The development trend in 2017-2030 is predicted, as shown in Fig. 2.

It can be seen from the Fig. 2 that the current economic growth rate will grow very fast in the next 13 years, but the growth rate of net GDP is far behind the GDP. That is to say, in the process of rapid economic development, the loss of environment and resources, as well as natural disasters, is also increasing. Therefore, this kind of economic development is at the cost of excessive pollution of the environment and consumption of resources. Economic development has become the pressure and security threat of the entire urban ecosystem.

Results of population subsystem: From Fig. 3, it can be seen that the system simulation value shows that the total population is increasing gradually. This trend of population growth is basically accompanied by economic growth, but because of the slow growth of net GDP, there is no population growth like the rapid growth of GDP. The population density of Yancheng is at a low level, so the population growth is inevitable in the process of ecological environment construction, social infrastructure and economic development.

CONCLUSIONS

In view of the characteristics of system dynamics method and complex ecosystem, it is feasible and operable to use system dynamics to analyse the dynamic trend of complex system in Yancheng district, and it has theoretical and practical value.

Table 1: Historical test results of GDP and total population.

	GDP			Total population		
Time	Historical value (billion yuan)	Simulation value (billion yuan)	Relative error	Historical value (billion yuan)	Simulation value (billion yuan)	Relative error
2010	54.12	53.98850	-0.08573	65.35	65,21	-
2011	57.81	60.39598	-0.04437	64.74	65,74618	-0.01587
2012	62.47	67.71382	-0.08372	64.03	66.12465	-0.03304
2013	70.11	76.07671	-0.08569	63.54	66.50668	-0.04667
2014	85.29	85.65031	-0.00412	63.26	66.89223	-0.05742
2015	95.73	96.61881	-0.00944	70.11	67.28192	0.04033
2016	108.24	109.1968	-0.00871	70.02	67.77689	0.03341
2017	122.81	123.6358	-0.00712	69.71	68.07815	0.02319

At the same time, using data analysis software to carry out linear regression quasi-sum test, it can be obtained that GDP: R = 0.99637, SD = 2.27796. P < 0.0001, total population: R = 0.71801, SD = 0.071172, P < 0.0001.

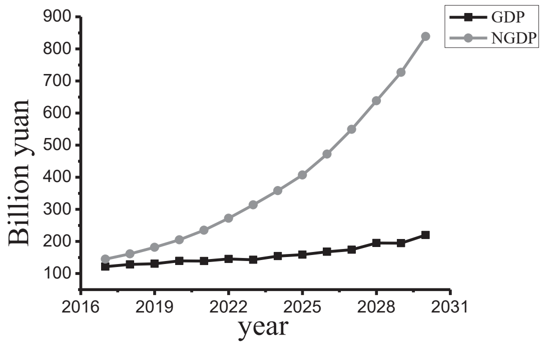

Fig. 2: A simulated chart of basic behaviour of GDP and net GDP.

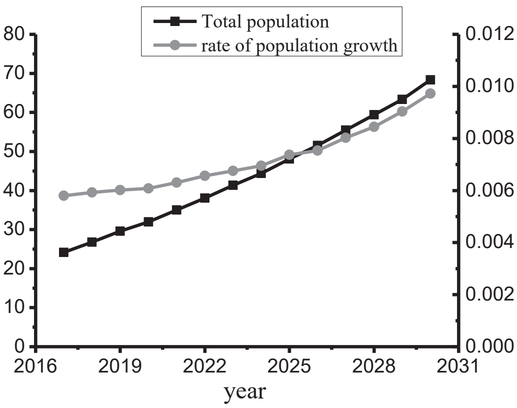

Fig. 3: Basic behaviour map of population and population increase (Population value is left ordinate and population growth rate is right ordinate).

Based on system analysis, the model established in this study can basically conform to and reflect the main mechanism of the system. Circular economy and environmental effects are composed of five subsystems: economic driving system, energy support system, environmental carrying system, social development system and policy control system. The five subsystems are coupled and constrained each other to form a simulation optimization system. With net GDP as the main reference variable, for economic development, the simulation results of each planning scheme are superior to the current trend. The main reason is that the planning scheme puts forward higher goals in infrastructure construction, environmental protection, energy saving and emission reduction, and ecological construction. Consequently, the loss of net GDP caused by natural disasters, environmental pollution and resource shortage is reduced.

In the 13 years after 2017, the rapid economic growth will be the main pressure of ecological security, and the resource problem will become the main restrictive factor of development, especially the energy problem. The rapid increase of environmental pollution emissions will greatly affect the quality of the ecological environment, and it is necessary to continue to look for ways of sustainable economic development of energy recycling.

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