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Intelligent Algorithm Support Strategies for the Development of the Blue Carbon Industry in Macau and Zhuhai from a Multi-dimensional Perspective

Yidong Ren[1,*]
[1] School of Finance and Trade, Zhuhai College of Science and Technology, Zhuhai, Guangdong, 519090, China

Corresponding authors: (e-mail: amonthofsundays9@163.com).

Abstract Blue carbon economy, as an emerging form of marine economy, has significant ecological value by protecting and restoring marine ecosystems to improve the carbon sink function. Macao and Zhuhai are positioned as new growth poles on the west bank of the Pearl River Estuary in the Guangdong-Hong Kong-Macao Greater Bay Area Development Plan by virtue of their geographical advantages. Exploring the optimization path of creating a blue carbon industry cluster in the Macao-Zhuhai pole is of great significance to promote the synergistic development of the two regions and the high-quality development of the marine economy. Based on the system dynamics method, this study explores the optimization path of creating a blue carbon industry cluster in the Macau-Zhuhai Pole. By constructing a system dynamics model of the blue carbon industry cluster in the Macao-Zhuhai Pole, the interaction relationship between key factors such as government investment, technological innovation, the construction level of the Macao-Zhuhai Pole and blue carbon production was analyzed, and model validity tests and sensitivity analyses were carried out. The results show that: fiscal expenditure, raw material cost and fixed asset investment are more sensitive to the impact of blue carbon processing industry cluster development, and by 2030 under the high-speed development scenario, the size of blue carbon processing industry cluster in the AZZ Pole can reach 901.301 billion yuan, which is 48.3% higher than that of the base scenario; under the growth rate scenario of fixed asset investment, the size of cluster development can reach 680.122 billion yuan, which is 14.98% higher than that of the base scenario; labor cost is more important to the development of blue carbon processing industry than the base scenario. 14.98%; labor cost has a relatively small impact on the development of industrial clusters. Based on the simulation results, optimization paths such as low-carbon transformation of high-carbon industrial clusters, transformation of industrial parks to low-carbon industrial parks, development of modern service industrial parks, creation of strategic emerging industrial parks, and construction of low-carbon industrial chains are proposed. The study has an important reference value for promoting the healthy and sustainable development of blue carbon industrial clusters in the AZZ Pole, and promoting the high-quality development of regional economy and ecological environmental protection.

Index Terms Blue carbon industry cluster, system dynamics, Macau-Zhuhai Pole, optimization path, sensitivity analysis, low carbon transformation

I. Introduction

Inrecent years, the proportion of China's gross domestic product (GDP) accounted for by the ocean has been maintained at about 8%, and the ocean economy has become an important engine to promote the high-quality development of social economy [1]. Blue carbon economy, as an emerging form of marine economy, refers to the economic activity of protecting and restoring marine ecosystems, improving their carbon sink function, reducing the concentration of carbon dioxide in the atmosphere, and providing corresponding ecological products and services [2].

In 2009, the concept of blue carbon was first proposed in the report titled 'Blue Carbon: The Role of Healthy Oceans in Carbon Sequestration', jointly released by the United Nations Environment Programme and other international organizations. The report indicated that approximately 55% of the carbon captured through photosynthesis by global natural ecosystems each year is captured and stored by marine organisms within marine ecosystems. This portion of 'carbon' is referred to as 'blue carbon', or marine carbon sinks. It was found that the leaves of mangrove forests store organic carbon in the plant body by absorbing atmospheric CO_2, which is converted into organic carbon, and the plant residues and root system decompose in the sediment and store organic carbon in the soil for a long period of time, which has the characteristics of a strong carbon sink capacity and a long period of carbon storage, etc. Salt-marsh plants are capable of storing a large amount of carbon in the soil through their root system and leaves, and seagrasses are also capable of absorbing CO2 from seawater and storing it in the seabed sediments [3]-[5]. Although the biomass of coastal zone plants such as mangrove forests, salt marsh wetlands and seagrass beds in China is only 0.05% of that of terrestrial plants, their carbon burial rates per unit area are as high as (242.2±25.9), (226±39), and (138±38) g C/m²/year, respectively, such that their annual carbon sequestration is roughly equivalent to that of terrestrial plants [6]-[8]. Therefore, the protection and restoration of blue carbon ecosystems in coastal zones play an extremely important role in increasing carbon sinks and mitigating the effects of climate change [9]. In order to cope with global climate change and achieve the goal of carbon neutrality, the blue carbon economy is moving from ecological protection to the modernization of the marine economy industry, giving rise to a variety of industrial forms [10].

Macao and Zhuhai are adjacent to each other, and their superior geographic location provides natural advantages and convenience for exchanges and cooperation between the two places.The Outline of the Plan for the Development of the Guangdong-Hong Kong-Macao Greater Bay Area (GD-HK-MA-GBA), which was released in February 2019, explicitly proposes to "give full play to the leading and driving role of the strong alliance of Hong Kong-Shenzhen, Guangzhou-Foshan, and Macao-Zhuhai (Macao-Zhuhai)," with the aim of promoting the Macao The aim is to promote the synergistic development of Macao and Zhuhai, and to create a new growth pole on the west bank of the Pearl River Estuary. The construction of the Macao-Zhuhai Cooperation Zone has become an emerging strategic platform to promote the moderate and diversified development of Macao's economy and to promote the optimization and upgrading of Zhuhai's industrial structure, which not only provides strong national policy support and powerful guidance for the deepening of Macao-Zhuhai and Macao-Zhuhai cooperation, but also marks the cooperation between Macao and Macao-Zhuhai moving towards a brand-new stage of development that is more forward-looking and systematic [11]-[13]. And Zhuhai and Macao have the superior geographic location of large-scale international carbon trading pilot respectively, which provides a new venue for the optimization of blue carbon industry clusters.

In recent years, the proportion of China's gross domestic product (GDP) accounted for by the ocean has remained at about 8%, and the ocean economy has become an important engine for promoting high-quality socio-economic development. As an emerging form of marine economy, blue carbon economy improves the carbon sink function of marine ecosystems by protecting and restoring them, reduces the concentration of carbon dioxide in the atmosphere and provides corresponding ecological products and services.In 2009, international organizations such as the United Nations Environment Programme (UNEP) proposed the concept of blue carbon sink for the first time, pointing out that about 55% of the world's naturally captured carbon is fixed and stored by marine organisms. Studies have shown that coastal plant ecosystems such as mangrove forests, salt marshes and seagrass beds have significant carbon sink capacity, with carbon burial rates per unit area as high as 242.2±25.9, 226±39 and 138±38 g C/m²/year, respectively, and the annual carbon sequestration is comparable to that of terrestrial plants despite the fact that the biomass is only 0.05% of that of terrestrial plants. In response to climate change and to achieve the goal of carbon neutrality, the blue carbon economy is moving from ecological protection to a modernized industry of the marine economy, giving rise to a variety of industrial forms. The geographical proximity of Macao and Zhuhai provides a natural advantage for exchanges and cooperation between the two places, and the Outline of the Plan for the Development of the Guangdong-Hong Kong-Macao Greater Bay Area, released in 2019, explicitly proposes to play the role of "the leading role of the Macao-Zhuhai strong alliance", aiming at turning Macao-Zhuhai into a new growth pole on the west bank of the Pearl River Estuary. The construction of Macao-Zhuhai Cooperation Zone not only provides national policy support for the two places, but also marks a new stage of cooperation towards a more forward-looking and systematic development. Meanwhile, Zhuhai and Macao have the geographical advantage of large-scale international carbon trading pilot, which provides a new venue for the optimization of blue carbon industry clusters. This study adopts a system dynamics approach to construct a blue carbon industry cluster model for the Macau-Zhuhai pole, and systematically analyzes the complex relationships among the elements within the cluster. Firstly, we identify the key influencing factors and analyze the causal relationship between them to establish a system dynamics model; then we test the validity of the model to ensure the accuracy of the simulation results; through sensitivity analysis, we compare the impacts of changes in factors such as fiscal expenditures, investment in fixed assets, labor costs, and raw material costs on the development of the industrial clusters in different scenarios; finally, based on the simulation results, we analyze the impacts of changes in factors such as the low-carbonization of high-carbon industrial clusters, the transformation of industrial parks into low-carbon industrial clusters, and the transformation of industrial parks into low-carbon industrial clusters. Finally, based on the simulation results, it proposes the optimization path for the creation of blue carbon industrial clusters in the Macao-Zhuhai Pole in terms of the transformation of high-carbon industrial clusters, the transformation of industrial parks to low-carbon industrial parks, the development of modern service industrial parks, the creation of strategic emerging industrial parks, and the construction of low-carbon industrial chains. This study is of great theoretical and practical significance for promoting the healthy and sustainable development of blue carbon industrial clusters in the Macao-Zhuhai Pole, the high-quality development of the regional economy and ecological environmental protection.

II. Construction of system dynamics model based on blue carbon industry cluster

II. A. Basic concepts of system dynamics

II. A. 1) Overview of system dynamics

System dynamics [14], [15] (SD) is a cross-cutting and comprehensive discipline based on system theory, integrating feedback control theory and information theory, and using computer simulation and modeling technology as a means. System dynamics is based on a given goal, the organic combination of multiple interdependent factors into an overall decision-making system, can solve highly nonlinear, high-order, multivariate, multiple feedback and other complex and variable large system problems, not only to grasp the trend of the development of things on a macro level, but also to analyze the interactions between the microscopic elements within the system.

II. A. 2) Systems and Feedback in System Dynamics

1) System

System dynamics considers a system to be an aggregate of many elements that are organically linked together by mutual distinction and interaction, while having a certain function. From the point of view of system dynamics, a system contains three parts: matter, information and motion.

The most basic structure of a system is a first-order feedback loop. First-order feedback loops are loops that couple the state, rate, and information of the system, which correspond to the three components of the system: units, motion, and information. Together, these interacting feedback loops form a complex system.

2) Feedback

Feedback can be directly linked from the output of a unit, sub-block or system to its corresponding input, or it can be realized by other units, sub-blocks or other systems.

3) System state space description

The system dynamics used to analyze and study the system is basically a multivariable system. The following is a mathematical model of the state space of a system, starting from the concepts of state and state space.

(1) State

The state of a dynamical system is the smallest set of variables that completely describes the time-domain behavior of the system.

Let $x_1(t), x_2(t), \cdots, x_m(t)$ be a set of state variables of the system, then its corresponding state vector is: $X(t) = [x_1(t), x_2(t), \cdots, x_m(t)]^T$.

(2) State space

The Euclidean space consisting of $x_1(t), x_2(t), \cdots, x_m(t)$ as the axes is called the state space, and when the number of axes is a finite number, this state space is finite dimensional.

(3) Mathematical modeling of the state space of a system

In general, the system contains state variables $x_1, x_2, \cdots, x_m$, control variables $u_1, u_2, \cdots, u_r$, and output variables $y_1 y_2, \cdots y_h$. The system of equations consisting of m first-order differential equations is described:

$$X_i = f_i(x_1, x_2, \cdots, x_m; u_1, u_2, \cdots, u_r; t) \quad (i = 1, 2, \cdots, m) \tag{1}$$

Its output characteristics can be expressed as:

$$Y_i = g_j(x_1, x_2, \cdots, x_m; u_1, u_2, \cdots, u_r; t) \quad (j = 1, 2, \cdots, h) \tag{2}$$

The above two equations form a complete description of the system in state space, and the state vector X, the control vector U and the output vector Y are introduced to simplify the expression:

$$X = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_m \end{bmatrix} \quad U = \begin{bmatrix} u_1 \\ u_2 \\ \vdots \\ u_r \end{bmatrix} \quad Y = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_h \end{bmatrix} \tag{3}$$

The vector functions corresponding to the functions in Eqs. (1) and (2) are also introduced: $f(X,U,t)$ and $g(X,U,t)$ Thus the original state equation can be rewritten as:

$$X = f(X,U,t), X \in R^m, U \in R^r \tag{4}$$

The original output equation can be rewritten as:

$$Y = g(X,U,t), Y \in R^h \tag{5}$$

where R denotes the Euclidean space and the vectors X are m-dimensional; U is r-dimensional; and Y is h-dimensional.

If the system is linear, the vector functions f and g will have a linear relationship, and the equations of state and output equations of the linear system are of the form:

$$\begin{cases} X = A(t)X + B(t)U \\ Y = C(t)X + D(t)U \end{cases} \tag{6}$$

where $A(t)$ is the transfer matrix, $B(t)$ is the control matrix, $C(t)$ is the output matrix, and $D(t)$ is the transmission matrix.

If f,g or the elements of A,B,C,D are not functions of time, such systems are said to be time-invariant systems whose state space description can be written as:

$$\begin{cases} X = f(X,U) \\ Y = g(X,U) \end{cases} \tag{7}$$

For a linear system it is:

$$\begin{cases} X = AX + BU \\ Y = CX + DU \end{cases} \tag{8}$$

II. A. 3) Description of the system by system dynamics

The description of a system by system dynamics can be summarized in the following two steps:

(1) System Attachment Decomposition

The system S is divided into p interrelated subsystems S_i according to the decomposition principle, i.e:

$$S = \{S_i \in S|_{1-p}\} \quad i = 1,2,\cdots,p \tag{9}$$

Among these subsystems, often only one part is relatively important, and the interrelationships among the subsystems can be reflected by the non-dominant elements of the relationship matrix.

(2) Description of subsystems

The subsystem consists of the basic unit and the first-order feedback loop. The first-order feedback loop contains three basic variables: state variable, rate variable and auxiliary variable. Define the variables and give a mathematical description as follows:

$$\dot{L} = PR \tag{10}$$

$$\begin{bmatrix} R \\ A \end{bmatrix} = W \begin{bmatrix} L \\ A \end{bmatrix} \tag{11}$$

In the above equation, L is the vector of state variables; R is the vector of rate variables; A is the vector of auxiliary variables; P is the transfer matrix; and W is the relation matrix.

II. B. ***Modeling Basis for System Dynamics***

Variables and equations of system dynamics

(1) Variables in system dynamics

In system dynamics, there are the following types of variables.

State variable: or accumulation variable, is the variable that ultimately determines the behavior of the system, with the change of time, the value of the current moment is equal to the value of the past moment plus the amount of change in this period of time.

Rate variables: are variables that directly change the value of a state variable, reflecting the rate of input or output of the state variable. It is essentially indistinguishable from an auxiliary variable.

Auxiliary variable: the value of the auxiliary variable is obtained through the calculation of other variables in the system, the value of the current moment and the value of the historical moment are independent of each other.

Constants: quantities whose values do not change over time.

Exogenous variable: the value changes with time, but this change is not caused by other variables in the system.

(2) Equations of system dynamics

In system dynamics, there are the following commonly used equations.

State variable equation:

$$lvS(t) = S(t_0) + \int_{t_0}^{t} rateS(t)dt = S(t_0) + \int_{t_0}^{t} \left[\inf lowS(t) - outflowS(t)\right]dt \quad (12)$$

where, $lvS(t)$ is the value of the state variable at moment t, but $lvS(t)$ is not a function of time t; $rateS(t)$ is the rate of change of that state variable.

Rate Equation:

$$rateS(t) = g[lvS(t), aux(t), exo(t), const] \quad (13)$$

where, $rateS(t)$ is the rate of change of the state variable: $lvS(t)$ is the value of the state variable at moment t: $aux(t)$ is the value of the auxiliary variable; $exo(t)$ is the value of the exogenous variable: $const$ is the constant.

The auxiliary equations are the operational equations that describe the information in the feedback system, which is expressed as:

$$aux(t) = f[lvS(t), aux^*(t), exo(t), const] \quad (14)$$

where, $aux(t)$ is the value of the auxiliary variable: $lvS(t)$ is the value of the state variable at the moment of t; $aux^*(t)$ is the auxiliary variable except the auxiliary variable to be solved; $exo(t)$ is the value of the exogenous variable; and $const$ is the constant.

II. B. 1) Causality and Flow Diagrams for System Dynamics

(1) Causality diagram

Causality diagram, also known as the influence diagram or to the diagram, the polarity of the feedback loop is mainly determined by the number of negative causal chains, if the feedback loop contains an even number of negative causal chains, the polarity of the entire feedback loop is positive, the cumulative effect of the causal chains of the positive feedback loop is positive, i.e., self-reinforcing effect.

(2) Flow diagram

System dynamics considers feedback systems to contain continuous, fluid-like processes of flow and accumulation. The rate, or rate of change, causes the value of the state variable to either increase or decrease over time. A flow diagram is modeled after the relationship between a valve orifice and a tank of water to describe the relationship between rate and state variables.

II. C.Modeling System Dynamics of Blue Carbon Industry Cluster

II. C. 1) The main factors of the Australian Pearl Pole blue carbon industry cluster system

The blue carbon industry cluster system of the AoZ Pole is a dynamic and complex system, and before modeling and analyzing the whole industry cluster system, it is necessary to organize its rich influencing factors to determine the main factors. Combined with the results of the current situation analysis and research, the main factors affecting the development of the cluster are summarized into the following four aspects.

1) Government Input

Government input is an indispensable source of funds in the development of industrial clusters, and the government provides corresponding subsidies for relevant blue carbon industries to promote the transformation and upgrading of enterprises. During the development of industrial clusters, the government provides support for relevant supporting facilities, such as a good service environment, convenient transportation channels, and an information exchange platform for clusters.

2) Technological Innovation

Through the innovation of existing technology, it can effectively reduce the production cost and improve the product quality, so as to improve the market competitiveness of the whole cluster. For example, the government's investment in scientific research in the blue carbon industry can enable enterprises to continuously improve their production and sales levels and promote the development of the industrial cluster system.

3) Construction of A-Z Pole

The level of AZZ Pole is the core of the whole AZZ Pole blue carbon industry cluster, and the construction level of AZZ Pole directly reflects the brand value of AZZ Pole, the degree of integration of the industry cluster, as well as the area of AZZ Pole and the blue carbon production. In the whole blue carbon industry cluster, the construction and development of AoZhou Pole is an indispensable factor for the development of the industry cluster.

4) Blue carbon production

In the whole blue carbon industry cluster, the primary output value of blue carbon is the main indicator directly reflecting the production of blue carbon, and the increase of the primary output value will bring more operating capital for the industry cluster system and promote its rapid development.

II. C. 2) 2.3.2 Causality analysis of system elements

The enhancement of the output value of the primary industry can effectively improve the basic income of the rural residents of the Macao-Zhuhai Pole Point, thus increasing the consumption desire and consumption power of the rural residents, and then driving the improvement of the comprehensive output value of the industrial cluster.

Accelerating the construction of the Macao-Zhuhai Pole Macao-Zhuhai Pole and improving the construction level of the Macao-Zhuhai Pole are conducive to improving the service level and tourism value of the Macao-Zhuhai Pole, thus promoting the improvement of its brand value, further promoting the integration of the industrial clusters and increasing the number of tourists in the Macao-Zhuhai Pole and improving the comprehensive income from tourism, thus making the comprehensive output value of the industrial clusters increase.

The construction of the AZ Pole also expands the overall industrial cluster area of the AZ Pole, and the industrial cluster area is the direct influence factor of blue carbon production, thus increasing the output value of the industrial cluster.

The increase in government investment in the construction of the AoZ Pole promotes the construction and development of the AoZ Pole, which further expands the area of the industrial cluster and the brand value, thus positively affecting the comprehensive output value of the industrial cluster [16].

The increase in the proportion of leading enterprises in the industrial clusters improves the level of technological innovation in the corresponding blue carbon industry, which expands the proportion of good seed area in the industrial cluster area, increases the proportion of industrial cluster output to total output, and directly enhances the output value of the first production.

The increase in brand value further promotes the increase in the value of the industrial cluster and directly expands the sales of the industrial cluster, thus increasing the output value of the blue carbon primary industry.

II. C. 3) Model Construction of Influencing Factors of Blue Carbon Industry Cluster in Australia-Zhuhai Poles

The system causality loop constructed above reflects the qualitative relationship between the elements in the system, and in order to further study the quantitative relationship of the factors and simulate the development trend of the system, a system data flow diagram is introduced. Using the system dynamics method and the Vensim PLE software, the data flow diagram of the blue carbon industrial cluster system of the AoZ Pole is drawn. In this study, the construction project of the Macao-Zhuhai Pole, the area of the industrial cluster, the total number of blue carbon industries, and the financial expenditure are set as state variables, the increment of the construction of the Macao-Zhuhai Pole project, the increment of the area of the industrial cluster, the increment of the number of blue carbon industries, and the increment of the financial expenditure are set as the flow, and the rest are set as auxiliary variables.

This paper takes the construction of blue carbon industry clusters in the Macao-Zhuhai Pole as the research object to explore the impact of the main action program of the construction of the Macao-Zhuhai Pole on the development of the local blue carbon industry clusters. Considering that the construction of the Macao-Zhuhai Pole began at the end of 2015, and is expected to gradually show its effect since 2018, the model simulation time is 2018-2028, and the simulation time step is 1 year, of which the data from 2018-2021 are real data, and the main data source is the Macao-Zhuhai Pole Statistical Yearbook, and the data after 2021 are the system forecast results. The data afterward are the results of the system forecast. Where the variables are proportions or growth rates, the average value of the corresponding data from 2018-2021 is used instead. If there are significant fluctuations, in order to reduce the simulation error to table function input.

In order to improve the accuracy of the model, the following assumptions need to be made: (1) the model discusses the impact of the construction of the Macao-Zhuhai Pole on the development of industrial clusters, so it does not take into account the interference of other external factors; (2) it is assumed that the construction of the Macao-Zhuhai Pole is basically completed in 2028, and that all the data in the system tends to be stabilized; and (3) the extent of the development of the Macao-Zhuhai Pole's blue-carbon industrial clusters depends on their comprehensive output value. The relationship of variables and parameter settings in the system are shown in Table 1.

Table 1: Partial equation and parameters

Variable type	Main variable	Variables equation and parameters
State variable	The construction project of the Australian pearl pole/one	INTEG (The construction of australian bead project construction, 112)
	The area of the Australian pearl pole/acre	INTEG (Australian bead area increment, 78500)
	The total number of Australian pearls/one	INTEGg (Number of enterprises,141)
	Financial expenditure/Hundred million yuan	INTEGg (Fiscal expenditure increment, 50.50)
Auxiliary variable	Blue carbon yield of Australian pearl/ton	Industrial cluster area times blue carbon production factor
	Production output/Hundred million yuan	Australian pearl pole to create sales + industrial cluster sales
	INTEG rated tourism income/Hundred million yuan	Visitor quantity × tourist consumption factor
	Number of leading enterprises/one	The total number of industrial clusters is the proportion of the leading enterprises
	Blue carbon production cluster sales/Hundred million yuan	Blue carbon industry production by blue carbon industry value
Constants	Blue carbon industry production factor	0.0307
	Tourist consumption factor	0.0409
	Manufacturing factors for cluster production of blue carbon industry	0.0262
	Capital conversion	0.0072

III. The creation and optimization path of the blue carbon industry cluster in the Macao-Zhuhai Pole

III. A. Model validity test

In order to make the model can realistically and accurately simulate the actual development situation of blue carbon industry cluster, this paper needs to test the constructed system dynamics model to ensure the validity of the simulation results and the feasibility of the policy recommendations. According to the system dynamics theory, the model is usually tested by three methods: structure test, stability test and historical data test.

III. A. 1) Data sources

The system dynamics model of blue carbon industry cluster established in this paper combines qualitative description with quantitative analysis. In the process of model establishment, the simulation time interval is set up from 2010 to 2020, and the simulation time step is set up as one year, in which the data from 2010 to 2016 are all from China Statistical Yearbook, China Rural Statistical Yearbook, and Report on the Development of Blue Carbon Industry, and the remaining time is the prediction time of the established model system. The remaining time is the prediction time of the modeling system set up. In addition, this paper takes the development level of blue carbon industry clusters as the research object, so the establishment of specific parameters in the model mainly comes from the Blue Carbon Industry Development Report and the results of previous research.

III. A. 2) Structural inspection

Checking the completeness of the information used in the model, the reasonableness of the variable settings, the causal relationship within the system and the accuracy of the stock flow diagram are the main contents of the model structure test. Before constructing the system dynamics model of blue carbon industry cluster, this paper comprehensively analyzes the specific conditions of the three subsystems, namely, talent scale, capital scale and innovation status, and establishes the corresponding system feedback structure with causal loop diagram and stock flow diagram. The modeling process completely follows the actual development law of the cluster, and the establishment of the relevant index system also meets the modeling requirements.

III. A. 3) Stability tests

Since the system dynamics model of blue carbon industry cluster established in this paper is a stable structure, and the slight change of any parameter value within it will not affect the trend of the system's overall behavioral pattern, it is possible to take any variable from the model, set up different simulation time intervals, and test the validity of the model by observing the operation of the variable when the time interval is changed. The blue carbon industry cluster size in the model is selected as the test object, and the simulation time step is set to 0.5 years, 0.8 years and 1 year respectively, and the results of the trend of the blue carbon industry cluster size simulated by the system dynamics model with different simulation time steps are shown in Fig. 1 for the creation of the blue carbon industry cluster in the AoZ Pole. It can be seen that the three blue carbon industry talent scale trends obtained under different simulation time almost overlap, the magnitude of change between the three is not obvious, and the trend of change remains consistent, from which it can be judged that the system dynamics model established in this paper is stable.

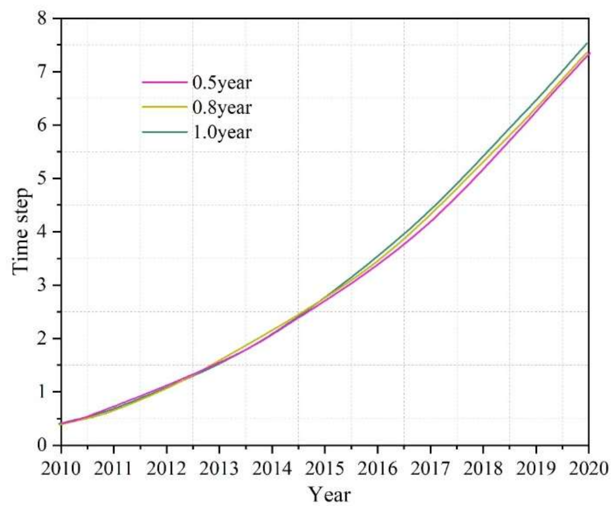


Figure 1: The size of the blue carbon industry cluster

III. A. 4) Historical data examination

Historical data test is also called model adaptability test. It is to use the theoretical idea of statistics to compare the testing variables of the model with the actual data, so as to check whether it can truly simulate the actual situation. Through comparative analysis, if the error between the real value and the simulated value is within the controllable range of 8.5%, it means that the model is effective; if the error is more than 8.5%, it indicates that the constructed system model has defects, and can not truly simulate the actual development situation, and at this time it is necessary to check each step of the modeling to find out the defects that are not enough to improve the system model.

In the system dynamics model, the variables in the model interact with each other and influence each other, and the change of any one variable will lead to the corresponding change of other variables and the system as a whole. Based on this, according to the importance of the indicators and the accessibility of the data, two indicators, namely, the scale of blue carbon industry talents and the per capita consumption level of rural residents, are selected as the test objects, and the stability of the model is observed through the comparison of the simulation results with the error of the actual data, and the results of the adaptability test of the system dynamics model for the development of the blue carbon industry clusters are shown in Table 2. From the model detection results, the selected blue carbon industry talent scale and rural residents per capita consumption level of two variables indicators of the historical data and simulation data error value of the minimum -1.56%, the maximum value of 8.07%, the error rate are kept within the controllable range of 8.07%, which can be judged by this paper's establishment of the system dynamics model fit is better, and able to make the behavioral mode of the actual system analyze and predict the behavioral pattern of the actual system.

Table 2: System dynamics model adaptive test results

Year	The scale of the blue carbon industry			The per capita consumption of residents in the blue carbon industry		
	Original value (10,000)	Simulation value (10,000)	Error rate (%)	Original value (10,000)	Simulation value (10,000)	Error rate (%)
2010	120.54	120.13	-0.59	4389.25	4380.22	0.00
2011	122.92	125.31	-1.52	5181.28	5273.11	-1.56
2012	125.48	123.28	2.27	5939.24	5832.62	0.99
2013	128.13	123.19	5.17	7486.03	7326.26	2.77
2014	132.53	126.61	3.47	8385.14	8058.84	4.04
2015	135.77	126.16	6.64	9199.87	8658.57	6.02
2016	139.93	128.43	8.07	10125.7	9385.83	6.98

III. B. Analysis of industrial cluster sensitivity and simulation results

This study takes the simulation operation of the model as the base situation, selects the more sensitive factors as the key variables of regulation, in order to change the values of the variables and carry out the simulation simulation, analyzes the influence of the change of the parameter values on the level of development of the blue carbon processing industry cluster of the AZZ Pole, and then observes the extent of the influence of each variable on it.

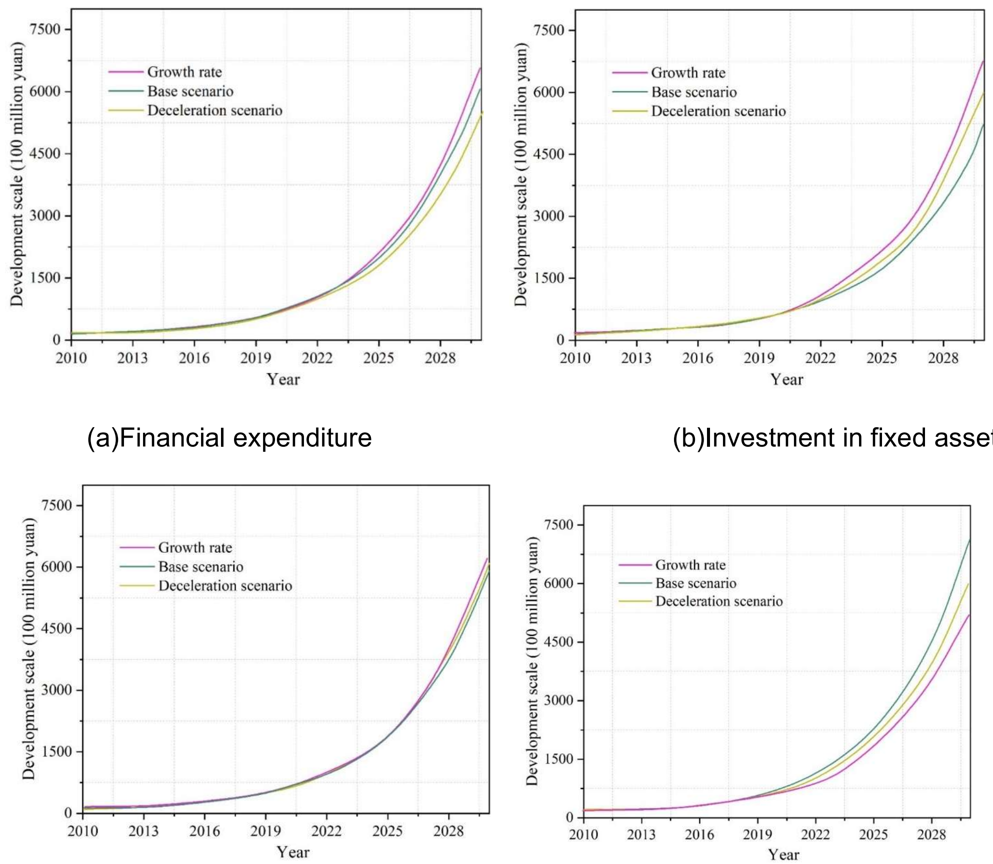
III. B. 1) Sensitivity analysis of the blue carbon processing cluster system

Using the statistical data from 2010-2014 to average the data of fiscal expenditure, fixed asset investment, labor cost and raw material cost, the growth rate scenario and the deceleration scenario are increased and decreased by 1% on the base scenario, respectively. To analyze the impact of changes in these factors on the development of the blue carbon processing industry cluster in the AZZ Pole, the simulation results of the blue carbon industry are shown in Fig. 2, where (a) to (d) represent fiscal expenditures, fixed asset investment, labor costs and raw material costs, respectively.

According to the results of the model sensitivity analysis, the impact of changes in fiscal expenditure, raw material costs and fixed asset investment on the development of the blue carbon processing industry cluster is more sensitive, and the impact of changes in labor costs on the development of the blue carbon processing industry cluster is not sensitive. According to the results of the sensitivity analysis, under the premise of other conditions remaining unchanged by 2030, the development scale of the blue carbon processing industry cluster in the AoZ Pole reaches 66.968 billion yuan and 70.362 billion yuan under the scenarios of fiscal expenditure and fixed asset investment growth rate respectively, which is 9.96% and 23.15% more than that of the base scenario (550.452 billion yuan), and under the scenarios of labor and raw material costs respectively, the development scale of the AZ Pole Blue Carbon Processing Industry Cluster reaches 58.925 billion and 52.707 billion yuan respectively, which is 2.43% and 9.84% less than the base scenario; in 2030, under the premise of other conditions remaining unchanged, and in the context of the respective growth rates of financial expenditures and fixed asset investment, the development scale of the AZ Pole Blue Carbon Processing Industry Cluster reaches 661.319 billion and 680.122 billion yuan, an increase of 9.15% and 14.98% respectively compared with the base scenario; under the scenario of the growth rate of labor and raw material costs respectively, the scale of the development of the blue carbon processing industry cluster in the Australasian-Zhuhai pole reaches 573.315 billion and 506.924 billion yuan respectively, a decrease of 3.48% and 15.02% respectively compared with the base scenario.

III. B. 2) Simulation and result analysis of blue carbon processing industry cluster system

All other conditions being equal, the impact of raw material cost inputs on the development of the blue carbon processing industry cluster is more sensitive, indicating that the impact of raw material cost inputs on the development of the agro-processing industry cluster is greater than the impact generated by several other factors. The inputs of fixed asset investment and financial expenditure also have an important impact on the development of blue carbon processing industry cluster. The three factors (raw material cost, fixed asset investment and financial expenditure) are analyzed by constructing a combination of factors from a general perspective and focusing on them. The highest and lowest values of each constant parameter in 2010-2014 are selected respectively to simulate the state of high-speed development and low-speed development of agro-processing industry clusters, and combined with the base scenario, the development trend of blue carbon processing industry clusters in the 3 states is shown in Figure 3. The positive impact of financial expenditure level and fixed asset investment on the blue carbon processing industry cluster in the AZ Pole is greater than the negative impact of raw material costs. By 2020, the development scale of the AZ Pole Blue Carbon Processing Industry Cluster under the base scenario, the low-speed scenario and the high-speed scenario reached 81.731 billion, 69.004 billion and 85.973 billion yuan, respectively; by 2025, the high-speed scenario was 271.776 billion yuan, which is 30.39% higher than the base scenario and 59.63% higher than the low-speed scenario; and by 2030, the high-speed scenario was 901.301 billion, which is 48.3% and 91.64% higher than the base and low speed scenarios, respectively.



(a)Financial expenditure (b)Investment in fixed assets

(c)Labor cost (d)Cost of raw materials

Figure 2: Blue carbon industry simulation results

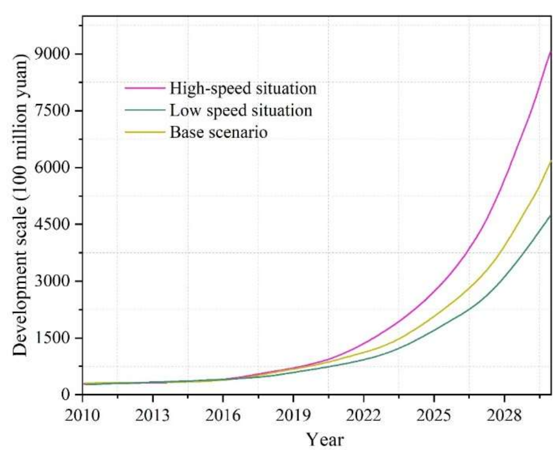


Figure 3: The trend of the blue carbon processing industry cluster in three states

III. C. Optimization Path of Low-Carbon Industrial Clusters Based on the Creation of the Macao-Zhuhai Pole

The construction of a modern industrial system dominated by low-carbon industries and the formation of low-carbon industrial clusters need to be gradually realized in the process of promoting strategic emerging industries, vigorously developing new energy, new materials and modern service industries, fostering and developing the energy-saving equipment manufacturing industry and energy-saving service industry, and eliminating high-energy-consuming industries and backward production capacity. Therefore, the cultivation of low-carbon industrial clusters can be carried out from the aspects of industrial structure adjustment, energy structure optimization and energy efficiency improvement.

III. C. 1) Decarbonization of high-carbon industrial clusters

The main problems of traditional industrial clusters are high energy consumption, high pollution and high emissions, which exert enormous pressure on the environment and energy consumption. The development of a circular economy can be achieved by adopting new materials, new processes and low-carbon environmental protection technologies, promoting common technologies for energy conservation and emission reduction, and developing ecological industries. Through clean production, pollution control and elimination of outdated production capacity, it will promote the transformation of high-carbon industrial clusters into low-carbon industrial clusters, reduce energy consumption and carbon emissions, and gradually get rid of the carbon lock-in situation.

III. C. 2) Transformation from industrial parks to low-carbon industrial parks

Industrial parks promote the development of clusters of enterprises and related organizations through the geographical concentration of enterprises and related organizations, in order to obtain higher production efficiency and competitive advantages. Low-carbon industrial park is an effective carrier for fostering low-carbon industrial clusters, which is a new type of industrial park designed and established according to the concept of circular economy and the principle of industrial ecology, which gathers different enterprises with upstream and downstream relationships through the cycle of material and energy to form a symbiotic combination of industries with resource sharing and exchange of by-products, and realizes the multilevel utilization of energy and minimization of waste, so as to reduce carbon emissions and save energy. (c) To reduce carbon emissions and save energy.

III. C. 3) Great efforts to develop modern service industry industrial parks

Modern service industry refers to the service industry based on new business models, service modes and management methods, with modern science and technology, especially information network technology, as the main support. It includes both the emerging service industry forms generated with the development of technology and the transformation and upgrading of the traditional service industry with the use of modern technology. It takes R&D, design, warehousing and logistics, information and data processing as the main contents of modern service industrial parks, which play an important role in the process of economic modernization and also provide opportunities for the leapfrog development of cities and regions.

III. C. 4) Strategic Emerging Industry Parks

Positioning solar photovoltaic power generation, wind power generation, energy-saving equipment manufacturing, and other strategic emerging industries as low-carbon industrial clusters, forming a pattern of coordinated development for strategic emerging industries such as wind power industrial parks, photovoltaic industrial parks, and energy-saving equipment manufacturing industrial parks. In the high-tech zone, with an emphasis on developing strategic emerging industries, we will adhere to a development path of 'industrial decarbonization and low-carbon industrial clustering', focusing on high-tech and low-carbon strategic emerging industries such as photovoltaic new energy, optoelectronic LEDs, energy-saving equipment manufacturing, aviation industry, biomedicine, and service outsourcing, making the high-tech zone a hub for low-carbon industries.

III. C. 5) Building a low-carbon industrial chain

The industrial chain is a chain-type correlation between various industrial sectors based on certain technical and economic links, and formed according to specific logic and spatial and temporal layout. Low-carbon industrial chain is to implement low-carbon operation in all the links involved in the industrial chain, from R&D and design, raw material supply to manufacturing, from packaging to transportation, from products to after-sales service, all of which are required by strict low-carbon standards for the relevant enterprises to produce low-carbon products and build the green competitiveness of the industrial chain as a whole, and the low-carbon industrial chain is the lifeblood of the low-carbon industrial clusters.

The key to the formation, continuation and prosperity of low-carbon industrial clusters is whether the enterprise groups around the low-carbon industry can form a low-carbon industrial chain with division of labor and collaboration, and realize a dense network of vertical cooperation and horizontal connection between the enterprise subjects on the industrial chain.

IV. Conclusion

This study constructed a model of blue carbon industry cluster in AZ Pole based on the system dynamics method, analyzed the interaction relationship between key factors, and proposed an optimization path. The study draws the following conclusions:

First, government input, technological innovation, the level of construction of the AZZ Pole and blue carbon production are the main factors affecting the development of industrial clusters, and there is a complex causal relationship and feedback mechanism between them.

Second, the results of the model validity test show that the established system dynamics model has good stability and adaptability, and the error rate of the historical data and simulation data of the two variables of the blue carbon industry talent scale and the per capita consumption level of rural residents stays within the controllable range of 8.07%.

Thirdly, the sensitivity analysis shows that fiscal expenditure, raw material cost and fixed asset investment are more sensitive to the impact of blue carbon processing industry cluster development, while the impact of labor cost is relatively small. By 2030, under the fiscal expenditure and fixed asset investment growth rate scenarios, respectively, the development scale of the blue carbon processing industry cluster in the AZZ Pole will reach 661.319 billion yuan and 680.122 billion yuan, which is an increase of 9.15% and 14.98% over the base scenario, respectively.

Fourthly, under the high-speed development scenario, the size of the Macao-Zhuhai Polar Blue Carbon Processing Industry Cluster could reach 271.776 billion yuan by 2025, which is 30.39% higher than the base scenario, and 901.301 billion yuan by 2030, which is 48.3% higher than the base scenario.

Fifth, the optimization path should include the low-carbon transformation of high-carbon industrial clusters, the transformation of industrial parks to low-carbon industrial parks, the development of modern service industry parks, the creation of strategic emerging industry parks, and the construction of low-carbon industrial chains. The implementation of these optimization paths will help promote the healthy and sustainable development of the blue-carbon industrial cluster in the AZ Pole and provide support for the high-quality development of the regional economy and ecological environmental protection.

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