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Economic System Simulation With Big Data Analytics Approach

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ABSTRACT The economic system is a complex adaptive system (CAS), which is composed of many heterogeneous, dispersed and interconnected actors. Because of ignoring these features, traditional macroeconomic models have many defects. In view of the fact that economic security problems are characterized by multiple and miscellaneous source data, wide range of involvement and complex behavior, an economic system needs to be simulated. In this paper, based on big data technology, we conduct china's economic security simulation from three aspects: economic security simulation method, economic security simulation modeling and calibration technology, and economic security early warning simulation visualization technology. In the end, we apply the method of this paper to a case study of a rare earth new material company, and analyze the advantages and disadvantages of various safety investment schemes based on the simulation results. Case analysis proves that the method proposed in this paper can simulate economic dynamics to achieve dynamic assessment of economic development and economic security prediction.

INDEX TERMS Complex adaptive system, big data, economic security simulation, simulation modeling, simulation visualization.

I. INTRODUCTION

Complex Adaptive System (CAS) refers to the ability of individuals in the system to communicate with other individuals in the environment. In the process of such communication, ''learning'' or ''accumulating experience'' is evolving and learning constantly, and changes its structure and behavior based on what it has learned [1]. The economic system is a complex adaptive system, which is composed of a large number of heterogeneous, decentralized and interconnected actors [2]. But the traditional macroeconomic model has many defects because it ignores these actors. First, it cannot analyze the behaviors and interactions of heterogeneous individuals [3]; Secondly, it cannot take into account the limited rationality of behavioral individuals with incomplete information [4]; Third, they cannot predict or avoid economic crises; Finally, macroeconomics is different from natural sciences. Its experimental environment is not repeatable, and the results of demonstrations that are not rooted in essentially unchanged microeconomic laws may not be deductive of the future, whose logic likes Lucas's criticism.

The Chinese economy needs more simulation. First, traditional macroeconomic models cannot analyze many structural problems that China faces. Second, traditional macroeconomic models cannot quantify the design of China's micro-mechanisms. Thirdly, because the traditional model ignores the expected role of limited information, it cannot reflect China's macroeconomic phenomenon in detail. China's economy does not have a good information transmission mechanism and coordination mechanism. Because of the availability of micro-data and the ability of ultra-high speed computing, it is possible to construct a macro-economic simulation system. Our research on complex problems has gradually got rid of the limitation of computability in modeling, and paid more attention to the exploration of the internal mechanism of the economy, so as to gain insight into the ever-changing macro-economic phenomena through clear micro-economic basis.

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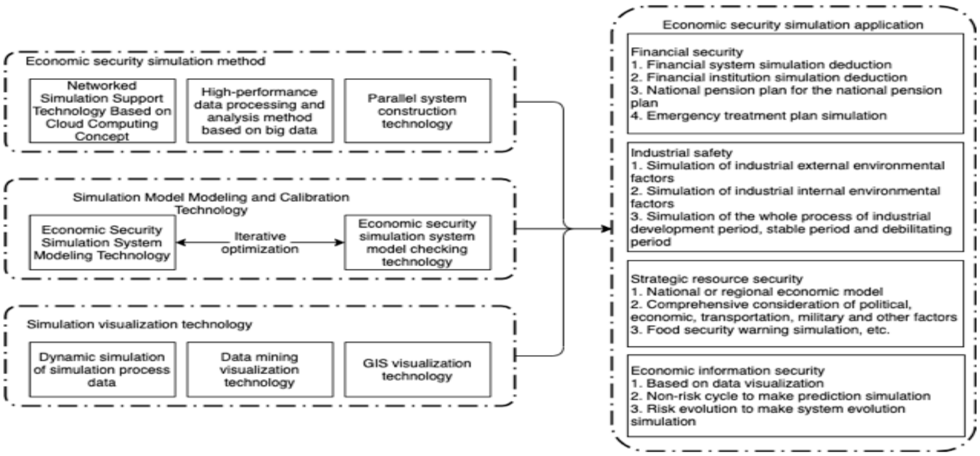

FIGURE 1. The framework of economic security simulation.

The main research contents of the economic security simulation direction include the following three aspects: economic security simulation methods, economic security simulation modeling and verification technology research, and economic security early warning simulation visualization technology research.

II. RESEARCH BACKGROUND

National economic security refers to the fact that a country's economy enjoys a stable foundation, healthy operation, steady growth and sustained development on the whole. And national economic security can continue to operate steadily and develop healthily in the face of various internal and external factors and keep its economic interests from being seriously damaged [5].

National economic security risk refers to the possibility of national economic insecurity and the hidden danger of losses [6]. At present, with the transformation of China's economy from focusing on the speed of development to focusing on the connotation, as well as the slowdown of external demand, the national economy is facing great risks. Economic security has become the core of national security. It provides material guarantee for national political security, military security, social security, cultural security and information security. It is related to social stability and long-term national stability.

China's reform and opening up has made great economic achievements, and also accumulated a lot of economic security risks; Severe risks exist in China's national economy, which has attracted extensive attention and high attention [7]. After the global financial crisis broke out in 2008, the national economic security issue became more prominent. The Financial Times pointed out that China's economy is at risk [8]. Renowned economist Professor Robert James Schiller of Yale University said that China faces no less economic risks than other countries [9]. Wei Jianing, deputy director of the Macroeconomic Research Department of the Development Research Center of the State Council, pointed out that China's economy is facing serious risks [10]. Liu Shangxi, deputy director of the Institute of Fiscal Science of the Ministry of Finance, pointed out that China's economy faces many risks [11]. The famous economist Mao Yuyi said that China is breeding various economic risks [12]. Professor Cao Jianhai of the Chinese Academy of Social Sciences pointed out that the Chinese economy is facing severe risks and challenges [13].

Therefore, early warning and simulation of economic security risks can provide insight in advance and avoid "late warning" decision-making and supervision. There are many literatures on national economic security, but work on early warning and simulation of economic risks based on big data has just begun. Most of the existing researches are qualitative risk analysis, and quantitative risk measurement research is extremely scarce. In consequence, there is a large potential research space for quantitative research on national economic security risk issues.

III. ECONOMIC AND SECURITY SIMULATION METHODS

Simulation is a powerful tool used in system science to describe or evaluate system behavior, verify system models, and predict system response. It has become one of the essential key steps in system modeling and system analysis [14]. Based on the economic model, economic security simulation research focuses on the key technologies such as large sample of economics, complex economic behavior safety prediction, multi-source data fusion, analysis and processing and so on, which owns the economic security simulation capability with high simulation confidence and autonomous control of the whole process.

Economic and security issues are characterized by many and complex source data, involving a wide range, and complex behaviors [15]. Figure 1 is a framework of economic security simulation in our research. In view of the common characteristics of these problems, we study key technologies such as networked simulation support technology based on cloud computing concept, high-performance data processing and analysis method based on big data, and parallel system construction in the economic field, so as to realize simulation capability of economic dynamics, dynamic evaluation of economic development and economic security prediction.

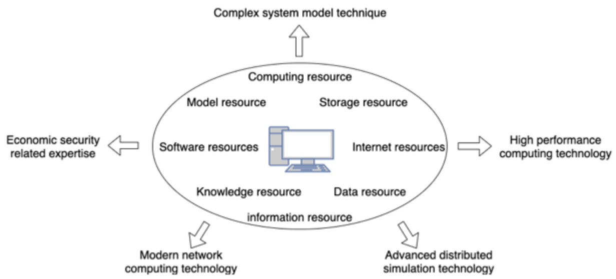

FIGURE 2. Network simulation support framework of economic security technology based on cloud platform.

A. CLOUD-BASED NETWORKED SIMULATION SUPPORT TECHNOLOGY

For the large amount of data in the economic field, the scale and structure of the economic security simulation system will be expanded and complex increasingly, and the simulation needs in economic field will be grown more in distribution, heterogeneity, collaboration, interoperability, reuse and so on [16]. Supported by modern network technology, the ''network modeling and simulation system'' will help people to obtain the required modeling and simulation services at anytime and anywhere without any obstacles through the network, so as to realize the safe dynamic sharing and reuse, collaborative interoperation, and dynamic optimal scheduling and operation of various resources [17]. As shown in the Figure 2, based on cloud computing concept, synthesis of various kinds of application technology, including complex system model technology, high performance computing technology, advanced distributed simulation technology, modern network computing technology, economic security related professional and technical, this study will implement the system in all kinds of resources (including model resources, computing resources, storage resources, network resources, data resources, information resources, knowledge resources, software resources, etc.) safely on-demand sharing and reuse. It will realize multi-user cooperation and interoperability of online resources on demand, and support economic system operation, risk assessment, early warning and other activities.

B. HIGH-PERFORMANCE DATA PROCESSING AND ANALYSIS METHODS BASED ON BIG DATA

The era of big data has broadened the source of information for economic analysis from sample data to overall data. The large amount of data can accurately obtain the current macroeconomic situation and micro development details, and the real-time characteristics of the data will significantly increase the speed of economic analysis or economic development trend prediction. Big data computing technology has significant advantages in early warning analysis in the economic field, but big data analysis will bring certain technical challenges to data processing and analysis [18]. Therefore, economic security analysis based on big data will face the following problems: First, the amount of data in the information age is growing rapidly; Second, after data collection, how to store and manage these massive heterogeneous data at the minimum cost of hardware and software is a problem; Third, because of the heterogeneity, scale, real-time, and complexity of big data, big data analysis must efficiently mine data at different levels (modeling, visualization, prediction, and optimization) to improve decision-making efficiency. Therefore, there is an urgent need to study high-performance data processing and analysis methods to effectively process structured, semi-structured, and unstructured data obtained through various channels, and integrate relevant data into interconnected data sets, which form a data processing system framework oriented to the economic field, and finally strongly support research on economic security related issues based on big data.

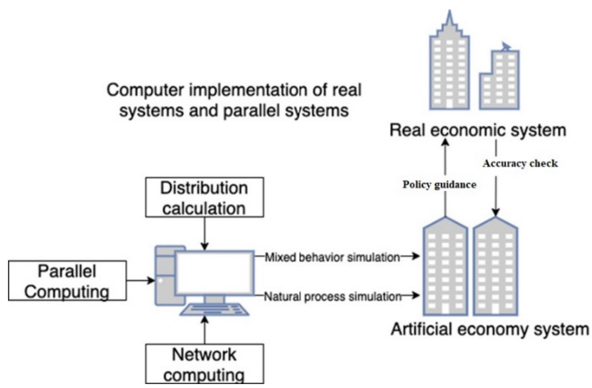

FIGURE 3. Computer implementation of real and parallel systems.

C. PARALLEL SYSTEM CONSTRUCTION TECHNOLOGY

As shown in the Figure 3, the artificial system and the real system are two mutually parallel systems. A good artificial system can restore the relationship between variables in the real system, and check the accuracy of the artificial system through the evolution of the real system. By studying online learning, offline computing, virtual and real interaction and other technologies of the artificial system, the artificial system can be closer to the real system, providing reference, estimation and guidance for the possible situation of national economic operation, and then providing efficient, reliable and applicable scientific decision-making and guidance [19]. The construction of the artificial economic system will be based on the mathematical equations of numerical calculation as the main means, and will also affect the behavioral factors in the social economy. In this study, based on parallel computing, distributed computing, and grid computing, combined with natural process simulation based on differential difference processes and behavioral simulation methods based on dynamic discrete events and mixed processes, artificial economic systems are generated through computer languages. Organically combine artificial economic systems with real systems to realize the spontaneous evolution of artificial economic systems, and ensure the portability, scalability, and exchangeability of calculations, and provide guarantee for the implementation of economic and security simulation experiments.

IV. ECONOMIC SECURITY SIMULATION MODELING AND VERTIFICATION

The reliability of economic security simulation based on model is bound to be a problem. Different modeling methods lead to different results. Therefore, the suitability of modeling methods needs to be verified by certain verification methods. The model is the basis of simulation, and simulation is a tool for model checking [20]. As shown in the Figure 4, through the mutual iteration between modeling and simulation, the accuracy of the model can be improved in order to make more reasonable economic predictions. According to different economic and security simulation models, the common methods in the models are extracted, and the reliability evaluation method and evaluation process matching with the methods are developed.

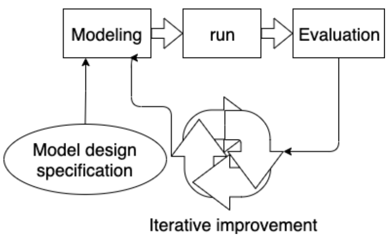

FIGURE 4. Modeling and verification process.

A. MODELING TECHNOLOGY of ECONOMIC AND SAFETY SIMULATION SYSTEM

The constituent elements of the system of the economic model are widely and closely related, and have the characteristics of many constituent elements and complex correlations. On the basis of sound economic and social system analysis, the use of computer simulation methods to study and observe economic systems requires the following processes [21]: 1. Simplify the economic and social system model; 2. Define the elements of the environmental model; 3. Define the time-varying behavior of model parameters in simulation; 4. Set various properties of the subject of economic and social system research according to the actual investigation; 5. Define the behavior of the research subject, and realize the self-adaptation of the behavior in the simulation process. The process is as shown in the Figure 5. Therefore, to reproduce the evolution process of economic system by using computer simulation method, the modeling process should be able to realize the following functions: First, using the computer-based simulation method based on

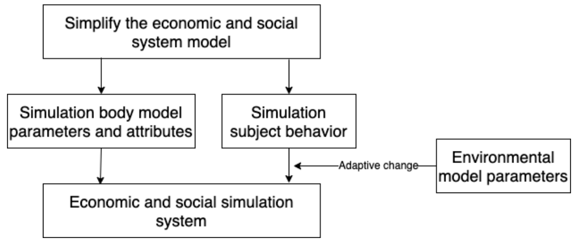

FIGURE 5. Simplified process of economic and security simulation modeling.

the main body, to demonstrate the macroeconomic evolution process in the form of micro-foundation implementation; The dynamic support and timely deployment of simulation support factors such as environmental models; The model parameters can be changed over time. In order to adapt to the time-varying characteristics of the model; It can realize the dynamic loading of the subject attributes of economic and social system research and subject-based adaptive changes in subject behavior. In view of the above process, it is necessary to break through the micro-realization technology of macro model, dynamic loading of environmental model, adaptive change of subject behavior and other key technologies, and conduct more realistic economic modeling to provide technical support for the simulation process of economic security.

Based on system dynamics, the simulation modeling method for predicting the total loss of corporate safety accidents is aimed at the problems in corporate safety management decisions. Using the principles and methods of system dynamics, the qualitative and Quantitative research and analysis, and finally use simulation software to model the system and run simulation to objectively explain the problem.

Various complex system structures are nothing more than a variety of simple subsystem modules obtained through necessary combinations. The method of modeling and simulation based on system dynamics also starts from simple first-order and second-order systems, from shallow to deep, and gradually expands to complex systems.

In the system dynamics modeling method, it can be known from the nature of various variables that the feedback loop must contain state variables, and the number of state variables determines the complexity of the system behavior. The more the number of state variables in the loop, the more the system behavior complex.

System dynamics uses the state-space method to describe the system in the time domain. The state equation of the system can be described as $x = f(x, u, t)$, $x \in R^m$, $u \in R^t$. Among them, R is Euclidean space, vector x is m dimension, and u is r dimension [22].

For simplicity, a first-order stationary free system is used as an example. In this case, $m = 1$, $r = 0$, and L is the state of the system, and $f(L)$ is the control strategy function. Then use a polynomial to fit $f(L)$ and get:

$$\frac{dL}{dt} = f(L) = a_0 + a_1L + a_2L^2 + \ldots \tag{4-1}$$

According to different approximation requirements, there are three basic first-order differential equations:

① Keep constant term

$$\frac{dL}{dt} = f(L) = a_0 \tag{4-2}$$

The original function was solved as:

$$L = a_0 t + C \tag{4-3}$$

Among them, C is a constant, and the system grows linearly at this time.

② Retain once

$$\frac{dL}{dt} = f(L) = a_0 + a_1 L \tag{4-4}$$

The original function was solved as:

$$L = \frac{c}{a_1} e^{a_1 t} - \frac{a_0}{a_1} \tag{4-5}$$

Here, c is a constant. It can be known that when $a_1 > 0$, the system exhibits an exponential growth characteristic; when $a_1 < 0$, the system exhibits an exponential decay.

③ keep quadratic term

$$\frac{dL}{dt} = f(L) = a_0 + a_1 L + a_2 L^2 \tag{4-6}$$

The original function was solved as:

$$L = \frac{a_1 c e^{a_1 t}}{1 - a_2 c e^{a_1 t}} \tag{4-7}$$

Here, c is a constant. It can be seen that when $a_1 > 0$, $a_2 > 0, t \to \infty > 0$, L tends to a constant value, and the system presents an S-shaped growth characteristic.

1) FIRST-ORDER POSITIVE FEEDBACK SYSTEM

In the positive feedback process, the variable grows exponentially with time under the effect of the self-growth mechanism. At this time, the growth rate is proportional to the level of the variable itself. That is, the greater the level of the variable, the greater the corresponding growth rate.

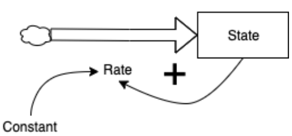

FIGURE 6. Flow of first order positive feedback system.

Figure 6 is a system dynamics flow diagram of a first-order positive feedback system, where *State* is the state variable, *Rate* is the rate variable, *Constant* is the proportionality constant, and the system dynamics equation is:

$$State(t) = State(t - dt) + Rate * dt \tag{4-8}$$

$$Rate = State * Constant \tag{4-9}$$

The above formula is equivalent to

$$\frac{dState}{dt} = Constant * State \tag{4-10}$$

Finding the original function of the above formula, we get:

$$State = State_0 * e^{Constant*t} \tag{4-11}$$

It is consistent with the case of the first-order differential equation ②, where dt is the calculation interval. It can be known that *Rate* is a function of *State* and represents the relationship between rate and state. Initialize the variables, $INITState = 15; Constant = 0.3$, run the model, and get the following state variable's change curve with time.

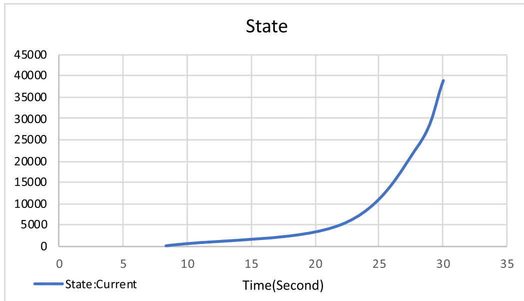

FIGURE 7. Dynamic changes of first order positive feedback system (1).

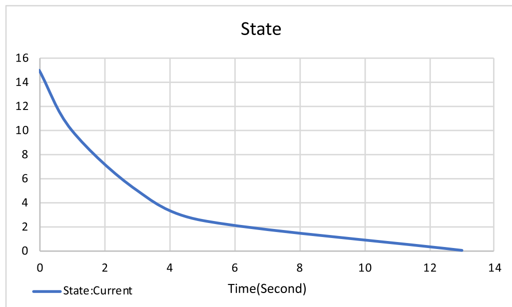

FIGURE 8. Dynamic changes of first order positive feedback system (2).

As can be seen from the Figure 7 above, the curve shows an exponential growth process, when $Constant > 0$; when $Constant < 0$, INIT $Constant = -0.3$, the system exhibits exponential decay, and the system dynamic changes are shown in Figure 8.

2) FIRST-ORDER NEGATIVE FEEDBACK SYSTEM

The dynamics flow diagram of the first-order negative feedback system is shown in the following Figure 9.

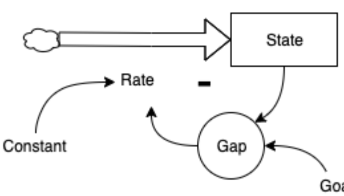

FIGURE 9. Flow of first order negative feedback system.

Among them, *State* is the state variable, *Constant* is the proportionality constant, *Goal* is the target state variable, and

Gap is the deviation between the state variable and the target state variable.

Let *dt* be the calculation time interval, and its system dynamics equation is:

$$State\ (t) = State\ (t - dt) + Rate * dt \tag{4-12}$$
$$Rate = Gap * Constant \tag{4-13}$$
$$Gap = Goal - Constant * State \tag{4-14}$$

Organizing the above formula into a differential equation, there are:

$$\frac{dState}{dt} = Constant * Goal - Constant * State \tag{4-15}$$

Finding its original function, we get:

$$state = Gap - \frac{c}{Constant} e^{-Constant*t} \tag{4-16}$$

Here, c is a constant. Initialize each variable, INIT *State* = 20, *Constant* = 0.3, *Goal* = 5, run the model, and get the following state variable's change curve with time as shown in the Figure 10.

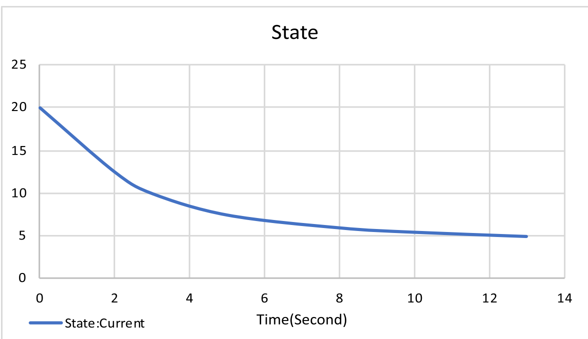

FIGURE 10. Dynamic changes of first order negative feedback system.

It can be seen this is a target exploration system. Under the action of the system's dynamic mechanism, its dynamic target value is infinitely close to the static target value *Goal* set in advance.

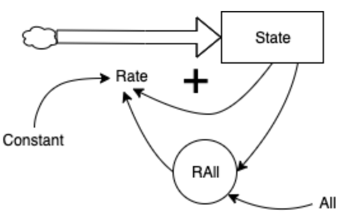

FIGURE 11. Flow of "S" type Growth system.

3) S-TYPE GROWTH

The first-order S-type growth is composed of two loops, one is a positive feedback loop, and the other is a negative feedback loop. The two loops work together on a state variable and interact alternately to form a system S-type growth characteristic. The basic system dynamics flow diagram is shown below Figure 11.

Among them, *State* is the state variable, *Rate* is the rate variable, *Constant* is the proportionality constant, *All* is the total state variable, is a constant, and *RAll* is the difference between the total state variable *All* and the state variable *State*.

Let dt be the calculation time interval, and its system dynamics equation is:

$$State\ (t) = State\ (t - dt) + Rate * dt \tag{4-17}$$
$$Rate = State * RAll * Constant \tag{4-18}$$
$$RAll = All - State \tag{4-19}$$

Sorting the above formula into a differential equation, we get:

$$\frac{dState}{dt} = Constant * All * State - Constant * State^2$$
$$= c_1 State - c_2 State^2 \tag{4-20}$$

Among them, c_1 and c_2 are constants. Find the original function and get:

$$State = \frac{Kc_1 e^{c_1 t}}{1 + Kc_2 e^{c_1 t}} \tag{4-21}$$

It is consistent with the case of the first-order differential equation ③, where K is determined by the initial state of the system. Initialize each variable, *INITState* = $2*10^4$, *All* = $2*10^7$, *Constant* = $0.5*10^{-8}$, and obtain the following state variable's change curve with time as shown in the Figure 12.

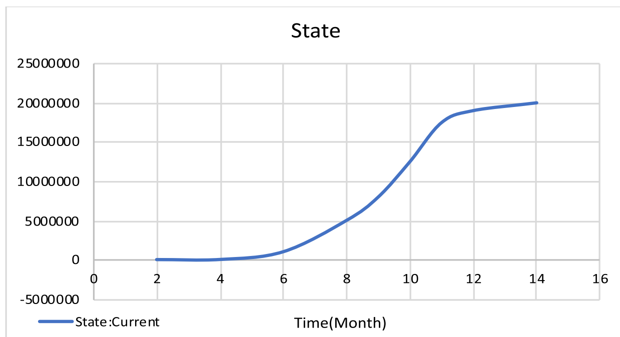

FIGURE 12. Growth of first order "S" type system.

In the same way, we can solve the more complex dynamic behavior of the system by choosing the number of terms of the control strategy function polynomial. However, for a first-order system, no matter how complicated the control function is, the system either exhibits exponential growth, or exhibits exponential decay, or shows gradual growth, or exhibits S-shaped growth. System behavior always tends to a set goal and balance appears. Once the balance appears, it will remain forever. Therefore, overshoot and oscillation do not occur in first-order systems.

B. CHECKING TECHNOLOGY OF ECONOMIC AND SECURITY SIMULATION MODEL

Model check refers to the process of determining whether the machine-related data of the model's implementation accurately represents the developer's concept description and related technical specifications [23]. Through the iterative process of comparing and adjusting the simulation system with the real system, the simulation model is gradually refined. The verification of the economic and security simulation model can be performed simultaneously from two aspects: static verification and dynamic verification. Static verification is the process of determining whether the model source code represents the model correctly. The static verification knowledge developed the consistency between the code model and the conceptual model. Therefore, dynamic verification is needed to verify that the software is running normally, and to troubleshoot software failures and software output results that are not consistent with user expectations. Dynamic check is to evaluate the correctness of the program through the output produced by a given input. In the static check, a large number of detailed design specifications of the inspection model will be formed. In the dynamic check, the analysis of the expected results of the software will improve the effectiveness and reliability of the economic and security simulation software.

V. ECONOMIC SECURITY SIMULATION VISUALIZATION

Visualization technology is a comprehensive discipline that studies a series of issues such as user interface, data representation, processing algorithms, and display methods. And it has become a powerful assistant for people to analyze natural phenomena, social and economic development situations, and understand the nature and changing laws of objective things. The visual technology can make the human-computer interaction of the user and the economic security early warning simulation system more sufficient, thereby improving the decision support efficiency of the simulation system. The status quo and optimization scheme can be displayed intuitively and conveniently, thereby improving ease of use and understandability of the economic security early warning simulation system.

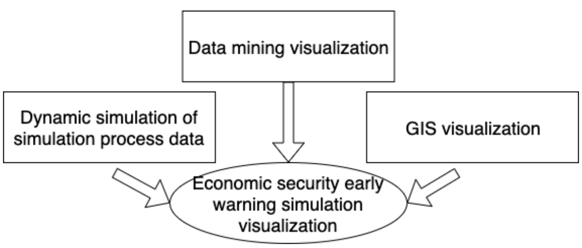

FIGURE 13. The framework of economic security simulation visualization.

As shown in the Figure 13, economic security early warning simulation is a complex system. There are a lot of process data, complex model and strict reasoning in the simulation process. Visualization technology is the process of transforming various data, models, knowledge, and reasoning in the simulation process into intuitive, easy-to-understand, static and dynamic pictures that can be interactively analyzed and interactively controlled. This conversion process enables users to ''see'' the characteristics of the data, the characteristics of the model, the realization of the inference mechanism and so on, so that the decision-making is based on a scientific and reliable foundation. The common visualization forms of data, model, method and reasoning used in the simulation process include text description, sequence diagram, bar chart, pie chart, scatter diagram, hierarchy diagram and correlation diagram. This topic will sort out the data and models involved in the economic security early warning simulation, and provide users with a process to further solve decision problems through visualization technology. At the same time, it uses visual human-computer interaction processes to help users gradually deepen and adjust their understanding of the problem structure through tentative and inspiring problem-solving methods. In addition, through the dynamic display of the process, the entire simulation process can be monitored, the intermediate factors in the evolution of the economic security model can be better discovered, and a more comprehensive analysis of economic security issues can be achieved.

VI. ECONOMIC SECURITY SIMULATION CASE STUDY

This section takes a large-scale rare earth new material manufacturing company's safety and economic decision-making prediction as an example. The economic and safety simulation simulates the enterprise's decision-making, and analyzes and evaluates the advantages and disadvantages of various safety investment schemes based on the simulation results.

A. INTRODUCTION OF XXX RARE EARTH NEW MATERIALS COMPANY, LTD.

Established in June 2012, XXX Rare Earth New Materials Company, Ltd. is a high-tech enterprise that produces more than 10 rare metals such as metal neodymium, metal lanthanum, metal thorium, metal thorium, and metal yttrium. The products are exported to Japan, the United States, and Europe, and the products produced have been listed as national spark projects and national key new product projects. The company has more than 800 employees, including more than 60 senior and intermediate technical and management personnel. It owns five domestic rare-earth metal production lines with an annual production capacity of 900 tons.

In 2014, the company passed the ISO9002 quality system certification. The rare earth industry is facing new opportunities and challenges. The company takes ''first-class quality, first-class service, first-class efficiency'' as the enterprise goal, ''create value, achievement hope, dedication to society'' as the enterprise objective, and ''integrity, dedication, cooperation, innovation'' as the enterprise spirit. During the ''Eleventh Five-Year Plan'' period, it will build a domestic first-class modern large-scale rare earth material production enterprise, and the annual production capacity of rare earth metals will reach 1,500 tons, thereby the development of China's rare earth industry and the revitalization of the local economy play its active role.

B. HYPOTHESIS AND PARAMETER ESTIMATION OF MODEL BASIC SIMULATION

Before carrying out the safety and economic decision-making simulation of XXX Rare Earth New Materials Company, Ltd., the following simplifications and assumptions need to be made:

1) Simplify the processing of multiple products produced by the enterprise and merge them into one;

2) The product price is determined by the average price of various products;

3) The safety investment of various production lines and processes are unified into safety technology investment, safety education investment and safety management investment.

After the system dynamics model of the enterprise security and economic system is established, all parameters of the equations in the model need to be determined before computer simulation. These parameters include constants, table functions, and initial values of horizontal variables.

For the determination of constant parameter values, the first is to collect the required data through enterprise surveys. The first is to use professional knowledge to estimate model parameters using statistical methods, prediction techniques and other mathematical methods based on previous years' statistical data. It also summarizes the company's long-term allocation of security resources in terms of security technology, security education, and security management, and finally determines the basic parameters of the enterprise in the field of security investment. For some parameters that are difficult to obtain but necessary for simulation, considering the insensitive nature of system dynamics to changing parameters, appropriate reference is made to relevant data of similar enterprises and appropriate assumptions are made.

For the nonlinear relationship between system variables, the function of Vensim table can be used to demonstrate the advantage of combining qualitative and quantitative methods of system dynamics [24]. The determination of table functions is mainly based on the following principles:

1) Determine the variation range and value range of independent variables according to the actual background of the enterprise and the difficulty of obtaining data, as well as the requirements of sensitivity and accuracy;

2) predict the approximate shape and slope of the curve formed by the table function, and set several special points as references;

3) Set the slope of the curve according to the nature of the influence represented by the table function, with negative feedback being a negative value; on the contrary, positive feedback is a positive value;

4) Determine the value of the slope and curvature in the middle of the curve under edge conditions to set the shape of the curve. The curve becomes flat when the influence of the elements weakens or saturates, while the curve shows a rising and falling shape when the influence of the elements increases. Therefore, the relationship between the influence factors of the table function influencing factors and the target factors and the feedback mechanism must be carefully studied, and finally the purpose of using a few reference points to effectively determine the table function is achieved.

C. SIMULATION OF SAFETY AND ECONOMIC DECISION

According to the current development trend of XXX Rare Earth New Materials Company, Ltd. and the conception of future production and operation strategies, the size of the company and the number of employees will increase to a certain extent in the next two years. The increase in production scale will increase the application of new equipment, processes and materials. And the increase in the number of employees will also lead to an increase in unsafe behaviors of new employees. These will undoubtedly further increase the number of dangerous sources in the enterprise, so that the company's safety and economic decision-makers must adjust the decision-making plan accordingly to meet the guarantee of accident control effect and safety benefits.

Four different security investment decision-making schemes were selected for simulation. The decision-making schemes are shown in the Table 1.

TABLE 1. Plans of safety economic decision.

Control variable	Program A	Program B	Program C	Program D
Preventive technology investment base	80000	70000	30000	30000
Control technology investment base	30000	20000	80000	40000
Safety Management Investment Base	30000	10000	15000	20000
Investment Base for Safety Education	20000	60000	35000	70000

The total investment of the four schemes is the same, about 1% of the sales revenue of rare earth materials of the XXX company in the previous month. Therefore, the core problem to be analyzed and studied by the simulation results of the above four schemes is which safety investment scheme can achieve the best accident control effect and the highest safety benefit and finally achieve the purpose of rational and scientific allocation of safety resources under the circumstance that the enterprise has certain safety resources at its disposal.

D. SIMULATION RESULTS ANALYSIS

By applying the parameters of the above four schemes to the established model of enterprise safety and economy system for simulation, the dynamic prediction law representing enterprise accident control effect and safety investment benefit, such as average direct accident economic loss, accident overall loss, accident frequency, accident volum and safety benefits, can be obtained.

Among them, Figure 14 shows the impact of different safety investment schemes on the average direct economic

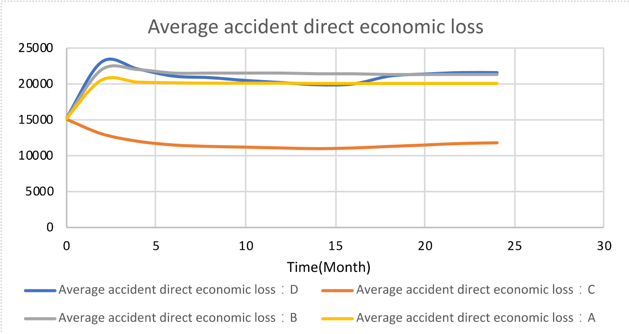

FIGURE 14. **Average accident direct economic loss.**

loss of an accident. From the distribution ratio of Table 1, when the control technology investment technology is large, the corresponding average direct economic loss of the accident is also relatively low. The allocation of safety resources according to the A, B, and D schemes has a large overall value. The average direct economic loss of the accident is higher than its expected value. It cannot meet the acceptable level of the average accident loss of the enterprise within two years, so it is not desirable. In plan C, the average direct economic loss of the accident has slowly decreased in the first 4 months, and has gradually stabilized over time, and this period has always been lower than the average direct economic loss expectation of the enterprise.

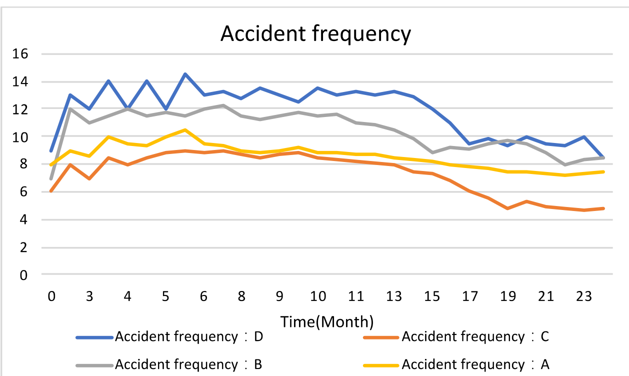

FIGURE 15. **Accident frequency.**

Figures 15 and 16 show the impact of different safety investment schemes on the frequency and volume of accidents. Reducing the probability of accidents is the most important indicator of accident risk control and the primary goal of safe economic decision-making. It can be seen from the figure that the four investment schemes are effective in reducing the frequency of accidents. The frequency of an accident is lower than the expected value of the frequency of accidents that occur every month. Generally speaking, as time goes by, the accident control effect achieved by scheme C is the best. Although the frequency of accidents also fluctuates randomly, the amplitude of its fluctuations is significantly smaller than the other three schemes, and the control effect is

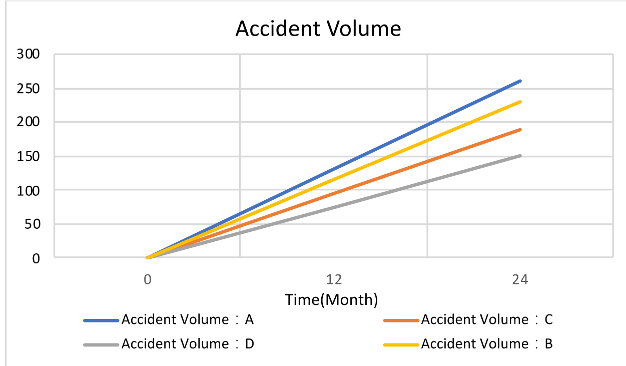

FIGURE 16. **Accident volume.**

also the best. It can be seen from Figure 16 that the cumulative change trend of the total accidents in scheme C is also slower than that of other schemes, indicating that the increase rate is getting smaller and smaller, which shows that the safety and economic decision of scheme C is superior in accident controlling.

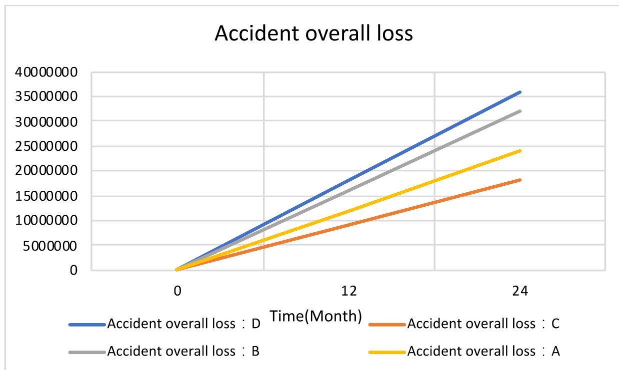

FIGURE 17. **Accident overall loss.**

Figure 17 is the simulation and forecast trend chart of total accident loss. It is not difficult to visually change the trend of total accident loss from Figures 14, 15, and 16. Because of the superiority of scheme C in the control of accident frequency and the direct economic loss control of the accident, it's more obvious that the control effect of the total loss of corporate security accidents is better.

Figure 18 is the prediction of the security benefits generated by different security investment schemes. Obviously, the investment benefit of scheme C is significantly better than the other three schemes. When the system reaches a stable state, the enterprise's security investment of 1 yuan can obtain a benefit of about 9.5 yuan.

In theory, there are other security economic decision scheme can achieve better effect, but through the analysis of the prediction of the above factors have been able to show that in the current economic conditions and the safety of the disposable under the condition of limited resources, with emphasis on the security resources rational allocation

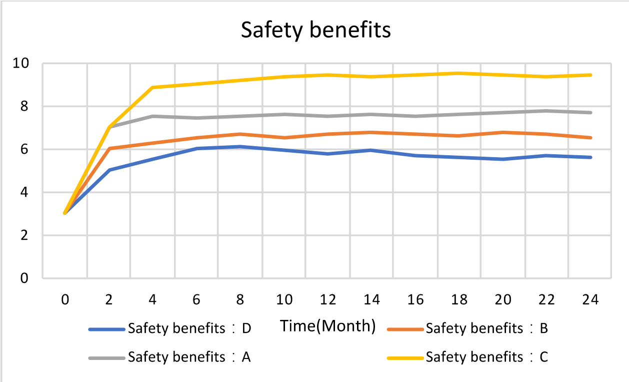

FIGURE 18. Safety benefits.

in security technology, security management and security education three aspects, the safety of the ideal social economic benefits can be achieved. A reasonable safety and economic decision-making plan should first combine the company's own reality and development status to meet the accident prevention and control technology investment guarantee. As far as possible, by reducing the total number of dangerous sources and reducing the unsafe state of machinery and equipment, the purpose of achieving "intrinsic safety" of the enterprise is achieved. When it is in a sufficient state, it is necessary to appropriately reduce the growth rate of technical resources and allocate limited safety resources to safety education and training and the construction of safety management systems. Through the prevention and control of employees' unsafe behaviors, it reduces the rate of human accidents and improves the overall safety of the enterprise.

VII. SUMMARY AND OUTLOOK

Economic security is simulated from three aspects: economic security simulation methods, economic security simulation modeling and verification technology research, and economic security early warning simulation visualization technology research.

Aiming at the common characteristics of economic and security issues with many source data and complex, wide-ranging, and complex behaviors, we study key technologies such as networked simulation support technology based on cloud computing concept, high-performance data processing and analysis method based on big data, and parallel system construction in the economic field, so as to realize simulation capability of economic dynamics, dynamic evaluation of economic development and economic security prediction.

The model-based economic security simulation method inevitably brings credibility. Different modeling methods bring different results. Therefore, the suitability of modeling methods needs to be verified by certain verification methods. The model is the basis of simulation, and simulation is a tool for checking the model. Through the mutual iteration between modeling and simulation, the accuracy of the model can be improved in order to make more reasonable economic predictions [25]–[27]. For different economic and security simulation models, the common methods in the models are extracted, and the credibility evaluation methods and evaluation processes matching the methods are developed.

In the end, visualization technology for the economic security early warning project can make the human-computer interaction between users and the economic security early warning simulation system more complete, so as to improve the decision support efficiency of the simulation system. The present situation and optimization scheme can be displayed directly and conveniently, so as to improve the usability and understandability of the economic security early warning simulation system.

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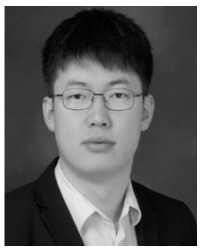

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