

Methods of scientific foresight in assessing the sustainability of the functioning of enterprises in high-tech industries

*Irina Kazmina*¹, *Valentina Rodionova*², *Anna Krasnikova*², and *Tatiana Shchegoleva*³

¹ Military Training and Research Center of the Air Force " Air Force Academy named after Professor N.E. Zhukovsky and Yu.A. Gagarin", 54 "A" Old Bolsheviks str., Voronezh, 394064, Russia

² Voronezh state technical University, Moscow avenue, 14, 394006, Voronezh, Russia

³ Voronezh State Agrarian University named after Emperor Peter the Great, Michurina str., 1, 394087 Voronezh, Russia

Abstract. The article analyzes the methods of scientific foresight for making managerial decisions at high-tech enterprises. It is determined that the stability of production and the competitiveness of the enterprise in the domestic and foreign markets can be determined by such a parameter as the stability of the functioning of the enterprise. Therefore, the stability of its functioning is considered as a predictable parameter characterizing the state of the enterprise. Increasing the stability of the enterprise can be achieved through the systematic analysis of special indicators that determine the integrated stability in the complex. When predicting the stability of the functioning of a high-tech enterprise, it is possible to use various methods. Based on the analysis of existing methods of scientific prediction of indicators and characteristics of industrial enterprises for making managerial decisions and their features, the most promising forecasting methods are identified, combined into the following groups: mathematical (statistical) forecasting methods based on mathematical models and patterns; computational methods of multi-stage forecasting based on artificial neural networks included in the software a digital double in an industrial company; expert forecasting methods involving the use of intuition, knowledge and expert assessments. The integral stability of the functioning of the enterprise is developed under the influence of a complex of factors of the macro environment and the internal environment of the enterprise. They are grouped depending on the environment of occurrence, the nature and direction of the impact, the object of the impact.

1 Introduction

Based on the analysis of the tasks solved by modern management systems of high-tech enterprises, it becomes obvious that an essential feature of promising management systems of high-tech enterprises is the orientation of these systems for the long term. Determining the orientation of management systems of high-tech enterprises for the long term and the

* Corresponding author: kazminakazmina@yandex.ru

upcoming changes in management, it is important to proceed from the actual trends and management methods in the field of industrial production in Russia during the formation of the digital economy.

The achievement of a common understanding and the implementation of such an approach in the functioning of management systems of high-tech enterprises allow us to assume that the direction of development of management systems associated with the ability to predict the indicators and characteristics of an industrial enterprise is one of the priorities. At the same time, the forecast is a scientific prediction of any information about the company in the future.

Forecasts are assumptions about what will happen in the future in a certain area, based on current data, trends, analyses and expert opinion. Forecasts are probabilistic in nature and therefore contain a set of alternative indicator values with different probabilities of execution.

The stability of production and the competitiveness of the enterprise in the domestic and foreign markets can be determined by such a parameter as the stability of the functioning of the enterprise. Therefore, as a predictable parameter characterizing the state of the enterprise, we will consider the stability of its functioning.

Increasing the stability of the enterprise can be achieved through the systematic analysis of special indicators that determine the integrated stability in the complex [1,2].

When predicting (scientific foresight) the stability of the functioning of a high-tech enterprise, it is possible to use various methods.

2 Methods

Based on the analysis of existing methods of scientific prediction of indicators and characteristics of industrial enterprises for making managerial decisions and their features, the most promising forecasting methods are identified, combined into the following groups [1-3]:

- mathematical (statistical) forecasting methods based on mathematical models and patterns;
- computational methods of multi-stage forecasting based on artificial neural networks, which are part of the digital twin software in an industrial company.
- expert forecasting methods involving the use of intuition, knowledge and expert assessments.

3 Results

We will conduct a detailed analysis of the application of the above promising forecasting methods to assess the sustainability of the company's activities in the long term.

Mathematical methods of forecasting. Mathematical methods of forecasting include the following [2,3]: extrapolation, interpolation and causality.

Extrapolation is a method of determining the quantitative characteristics of unobserved phenomena by transferring to them the results of observations of similar phenomena in the past to the future. The extrapolation is based on the analysis of historical data for the most recent period [4-10].

Along with various extrapolation options, the interpolation method is also used in forecasting. Interpolation is a method of determining unknown intermediate values of a dynamic series.

A feature of this method is the construction of new function values based on existing values. It is used when the available data about the function is not continuous. Interpolation

allows you to calculate the values of a function between existing points or predict the value of a function outside the available data range. There are several interpolation methods that depend on the type of function and the features of its change. The most common methods are linear interpolation, polynomial interpolation, and spline interpolation.

Both the same and different methods can be used for extrapolation and interpolation, but in any case they are all based on the fact that the identified trend in a given period of time will persist both outside and inside it.

Causal forecasting methods are based on determining the dependence of one predicted characteristic on the development of other characteristics (factors). These methods make it possible to predict future events based on the analysis of causal relationships between various factors. They are used to predict changes and trends, as well as to make decisions. Causal forecasting is based on the idea that if you understand the causes of past events, you can predict future ones. To do this, statistical methods, machine learning and other technologies are used to determine the dependencies between various factors and make a forecast based on them. With a functional relationship, the change in the Y attribute depends on the action of another factor attribute. In the case of correlation, the change in the effective attribute Y is determined by the influence of the factor attribute S not completely, but only partially.

Figure 1 shows an algorithm for predicting the integral stability of the functioning of the enterprise for the j time interval.

The method of predicting quantitative characteristics using extrapolation has received the greatest development.

However, forecasting by indicators is a complex process, due to the fact that the choice of an indicator is a task that requires an integrated, systematic approach and a lot of labor associated with the formation of initial data and computational actions.

Forecasting by indicators is based on the use of various indicators and oscillators that display the current state and help predict its further change. Indicators can be of various types, such as moving averages, relative strength indices, stochastic oscillator.

Forecasting by indicators is carried out by analyzing their values and determining the expected change based on their behavior in the past. Forecasting by indicators is not accurate and is prone to errors. Therefore, other factors must be taken into account before making a decision.

The development of a list of private indicators that determine the stability of the functioning of the enterprise (block 1, see Figure 1), and the justification of analytical relations for calculating private indicators for assessing stability in the j time interval (block 2, see Figure 1) is carried out taking into account the methodology for assessing the integral stability of the functioning of the enterprise.

Computational multistep forecasting methods based on artificial neural networks.

Neural network-based forecasting uses machine learning methods to predict future values based on past data. Neural networks work on the principle of simulating the functioning of the human brain and allow you to extract complex dependencies from data.

Multistep forecasting based on artificial neural networks, which are part of the software of the company's digital twin (DT), is used to implement the forecast. It is intended to determine the patterns of changes in the state of the enterprise in the future on the j time interval.

Let's say the system has learned to determine the stability of the functioning of the enterprise in the j time interval. Next, the system predicted the stability of the operation of the enterprise at the next j+1 time interval, when the last of the images known to it was submitted to it. After that, the system performs further forecasting and the next received system image is fed to the input. The last element of this image at a given time interval of operation (mileage) is the forecast of the system.

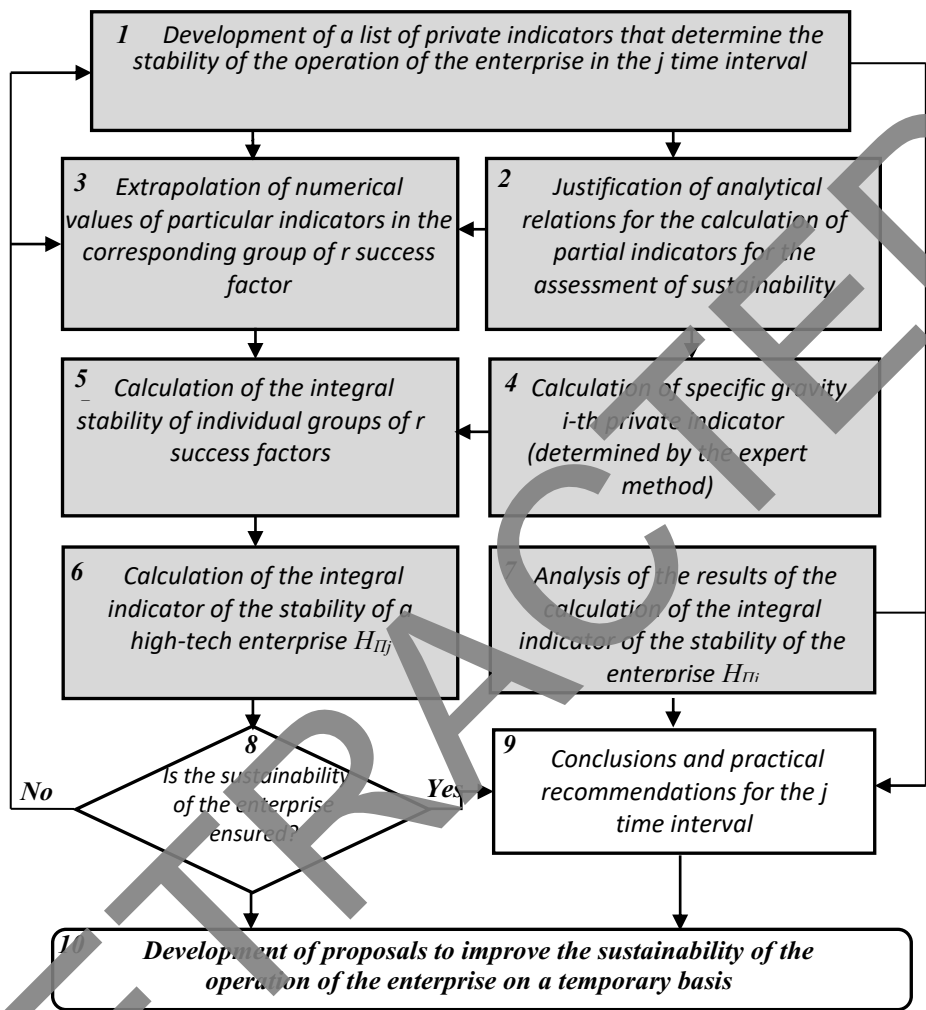


Fig. 1 – Algorithm for assessing the stability of the functioning of a high-tech enterprise in the j time interval

The method of forecasting the stability of the functioning of a high-tech enterprise is based on mathematical methods that allow you to determine the presence of the stability of the system and determine its degree of stability. Bifurcation analysis is also used. This method allows you to determine changes in the stability of the system when the system parameters change. It can be used to predict possible changes in the stability of the system and to determine the optimal parameters to achieve the desired level of stability. Experimental methods for predicting the stability of systems, including strength testing and long-term testing, are of great importance. These methods allow us to determine the real sustainability of the enterprise. The choice of the stability prediction method depends on the specific situation and system requirements. Some methods may be more suitable for certain types of systems or for certain purposes. However, it is important to use several methods to achieve the most accurate predictions of the stability of the system.

Based on the fact that the presence of a data center in an enterprise is one of the main conditions for forecasting based on artificial neural networks, it is necessary to assess the role and extent of the spread of data centers in high-tech enterprises. The beginning of the widespread use of DT in high-tech production dates back to 2015, thanks to the development of artificial intelligence. DT (one of the main trends in the development of the 4th Industrial Revolution) is a digital "virtual" model of an enterprise, from obtaining raw materials and delivering products to the consumer to issuing probabilistic recommendations to ensure the sustainability of the enterprise for a given period of time.

It can be argued that DT is now becoming a key instrument of economic activity of foreign and domestic enterprises, as well as an instrument of innovative activity of high-tech enterprises, allowing to anticipate the level of competitiveness in the future.

The use of the data center allows you to make a forecast of the state of the enterprise for a given period of time, including assessing its stability and stability of functioning in the long term at the j time stage.

Figure 2 shows a graphical example of forecasting the results of the stability of the functioning of an enterprise using artificial neural networks of the Central Data Center.

A graphical example of the forecast allows us to draw conclusions about the dynamics of changes in the stability of the functioning of the enterprise at different stages of production. This figure also shows an example of a negative variant of the functioning of the enterprise at stage $j+2$ (see Figure 2, curve W).

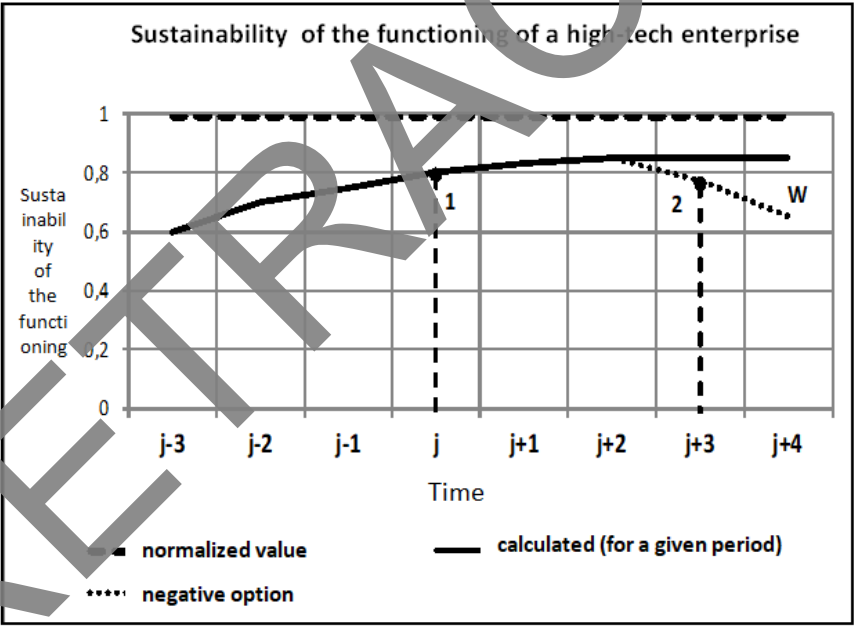


Fig. 2 - Is an example of a possible graphical assessment of the integral stability of the functioning of an enterprise using a data center at the j time stage

The algorithm for assessing the stability of the functioning of the enterprise at the j time stage based on artificial neural networks uses a feedback process to improve forecasts over time. At the same time, the neural network teaches SVT to process data in the same way as the human brain. The architecture of neural networks repeats the structure of the human brain.

Based on the results of the assessment obtained with the help of artificial neural networks, the company's management decides to launch a new cycle of the sustainability management process. The stability of an enterprise is determined on the basis of a systematic analysis of the entire set of private indicators in conditions that allow objective observation and measurement. For this purpose, a set of private indicators that determine the stability of the company is analyzed. An enterprise can be considered sustainable if the value of the integral indicator of the sustainability assessment corresponds to the required value (see Fig. 2).

A number of large domestic companies (Transmashholding, Russian Space Systems, KAMAZ, etc.) have announced the introduction of an operational planning and management system for technical operations based on DT. However, the cost of software for solving these problems is significant. [1].

Experts predict that by 2026, the market for products such as DT will reach 16 billion US dollars. Therefore, in the short term, the import of high-tech software created by highly qualified investments of large private capital in the largest economies of the world will be necessary for the domestic industry to create a digital repository.

DT for modeling and predicting the behavior of an object in various conditions. The digital twin can be used in industry to test the safety and effectiveness of new weapons, as well as in the manufacturing industry to optimize production processes.

DT can provide financial benefits by assessing the sustainability of the company using artificial neural networks for a given period of time, creating a complete digital model of the company that functions without human intervention, as well as predicting the level of competitiveness of the company in the future.

Thus, multi-step forecasting of the stability of the enterprise's functioning on the basis of artificial neural networks, which are part of the enterprise's data center software, will allow to anticipate the level of stability and competitiveness of the enterprise in the future, creates the basis for the continuous development and adaptation of the enterprise management system.

Expert forecasting methods. Methods involve the use of intuition. They are based on expert judgments reflecting an individual assessment by specialists of the prospects of the company's condition, and are not methods of scientific foresight.

In the conditions of dynamic development of technology and information technologies, the effectiveness of using statistical forecasting methods is decreasing. Under these conditions, one cannot rely too much on statistical methods. Therefore, the intuition of specialists, called experts, acquires a special role in predicting the future. Based on intuition, an expert can make a conclusion about the company being studied. The methods of expert judgments include methods of analysis and generalization, judgments and assumptions based on the intuition of experts.

The essence of the expert judgment method is that a group of experts evaluates certain parameters or indicators using their knowledge, experience and expertise in a certain area. The method can be used to predict future trends, make decisions in the absence of complete information, or to assess risks. The criteria on which expert judgments are based may include qualitative and quantitative parameters, as well as other factors.

There are different methods of examination:

- 1) individual or group (collective);
- 2) personal (full-time) or correspondence (by sending questionnaires).

Figure 3 shows a graphic illustration of the essence of the method of expert assessment of the integral stability of the enterprise in the future at the j time interval. The survey was attended by 10 experts who assessed the integral sustainability of the enterprise in the future using a quantitative assessment of judgments. This forecasting method is based on expert judgments, which reflect the individual assessment by specialists of the prospects of

the company's condition in the future. Based on intuition, an expert can draw a conclusion about the company under study. At the same time, when assessing sustainability, it is necessary to take into account all types of sustainability of the enterprise, such as:

- Financial stability: the availability of sufficient financial resources to cover current and future costs, as well as the ability to effectively use financial resources.
- Technological stability: possession of efficient production technologies, their continuous improvement, as well as the ability to adapt to changing technological requirements.
- Managerial sustainability: the availability of qualified and experienced managers who are able to effectively manage the enterprise and make the right decisions in conditions of uncertainty.
- Marketing sustainability: the ability to adapt to changing consumer preferences, create competitive advantages, retain their customers and attract new ones.
- Personnel sustainability: availability of highly qualified employees who are ready to effectively perform tasks and develop in rapidly changing conditions.
- Legal stability: compliance with legislation and the ability to adapt to changes in legislation in the field of activity of the enterprise.
- Economic sustainability: availability of sufficient inventories, integrity of management and production systems, as well as high labor productivity.

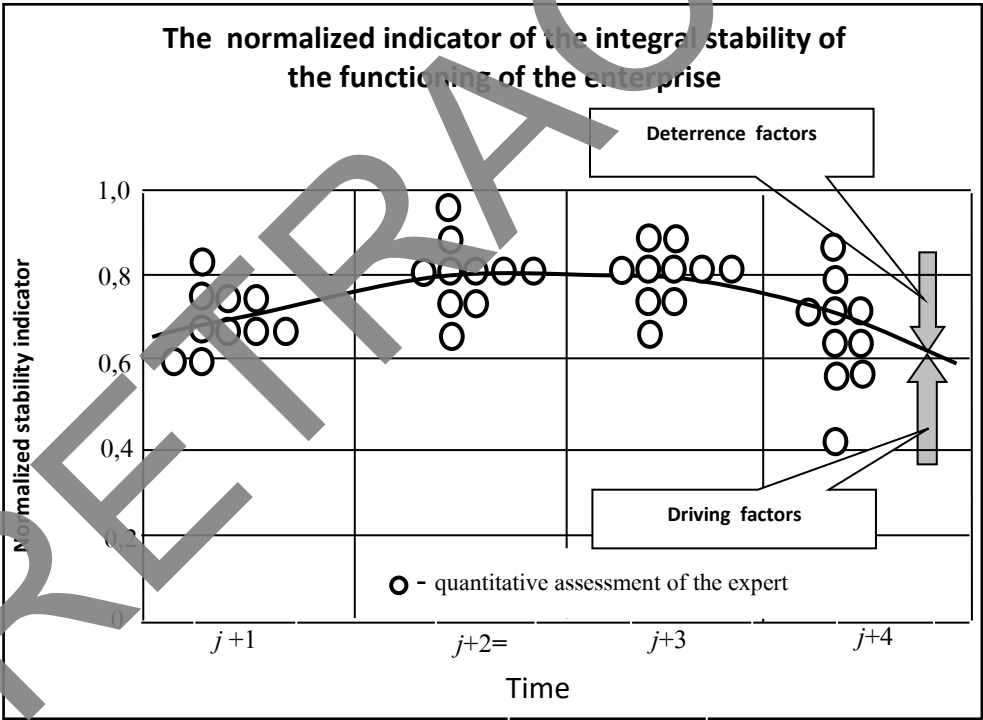


Fig. 3 – Graphic illustration of the essence of the method of expert assessment of the integral stability of the functioning of the enterprise for the j time interval

It should be noted that the integral stability of the functioning of the enterprise is developed under the influence of a complex of factors of the macro environment and the internal environment of the enterprise.

Stability factors (not stability) are the reasons that can cause an increase or decrease in integral stability (the course of the curve shown in Figure 3). They are grouped depending on the environment of occurrence, the nature and direction of the impact, the object of the impact.

The actions of different factors (deterrence factors or driving factors, Figure 3) have different effects on the sustainability of the enterprise.

The first two of the considered forecasting methods relate to scientific foresight, since on the basis of modeling and mathematical programming, the forecast of particular indicators is carried out, and then the calculation of the integral stability of the enterprise on the j forecasting interval.

The third of the considered forecasting methods relates to foresight based on intuition, knowledge and expert judgments. In this case, the forecast of private indicators that determine the integral stability of the enterprise is not carried out. Experts give an assessment of the integral stability of the functioning of the enterprise for the j interval.

The disadvantage of the expert assessment method is the subjectivity of the assessment and the dependence of the assessment on the availability of experts familiar with the predicted situation. Consequently, these forecasting methods are based on expert assessments that reflect the private judgments of specialists regarding the prospects of the state of the enterprise in the future.

Based on intuition, the expert is able to make a conclusion about the integral stability of the functioning of the enterprise for j time interval.

When making a forecast, the question arises about the reliability and accuracy of the forecast results. In this regard, verification of forecasts carried out using the methods under study is required, based on the analysis of the background of the stability of the functioning of the enterprise and comparison of the results of the forecast with the previously known. The forecasting method, which provides the smallest error in the results of the forecast, is advisable to use when assessing the stability of the functioning of the enterprise for the j time interval.

If the results of the forecast of the integral stability of the functioning of the enterprise for the j time interval do not correspond to the required ones, then it is necessary to develop recommendations for increasing stability in the j time interval.

4 Discussion

Increasing the stability of the functioning of enterprises in the j time interval can be ensured by a systematic analysis of the main directions of assessing the stability of the functioning of the enterprise and their subsequent correction, if necessary. At the same time, the key areas of increasing the sustainability of enterprises are:

- implementation of adaptive development of the management system at high-tech enterprises;
- organization of control of the level of stability of the enterprise;
- implementation of a high-enterprise sustainability management mechanism;
- to provide training for the qualifications of workers, specialists in the field of information technology;
- organization of protection of information circulating in the digital environment of the enterprise.

The indicated directions of increasing the stability of the functioning of high-tech enterprises will be able to ensure an increase in the stability of the functioning of the enterprise in the event of a negative variant of the functioning of the enterprise in the j time interval in the future.

5 Conclusion

Thus, the direction of development of management systems of high-tech enterprises, associated with the ability to predict the indicators and characteristics of the enterprise, is one of the priorities. Forecasting the integral sustainability of the enterprise is implemented for the long term in order for the planned indicators to be justified in terms of achieving goals. Forecasting is probabilistic in nature and therefore contains a set of alternative values of the indicator that have a different probability that they will come true.

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