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Conceptual framework of economic reliability of production processes

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Abstract. The study presents the authors' approach to defining economic reliability of production processes; interpretation of the essence, content and mathematical implementation of its parameters. The methodology of study includes classical scientific methods like observation, analysis, synthesis, formalization and logic. Also, some special methods were used like knowledge base and database creation, variance analysis, economical and statistical methods of data processing, economical and mathematical modeling. The authors' approach to control of economic reliability of production processes suggests transition from classical elasticity coefficients of relations between two factors to elasticity functions, including multidimensional ones. Rigidity functions are introduced as a counter-concept of elasticity functions. As a result of the study the following notions are defined: extreme technologies, basic principle of the technology extremality; assessment of production process reliability, as well as essence, content and mathematical implementation of its parameters. The suggested method is implemented in a number of large-scale projects in various branches of Russian national economics.

Introduction

When making decisions on economic systems management the economists mainly use the category of economic reliability as a tool for assessing competitiveness of economic systems starting with Michael Porter [1]. Many authors, including V. Nechiporenko, interpret economic reliability as the state of an organization which provides reasonable use of its resources, effective and sustainable development, meeting of the stakeholders' interests within the tolerable risk limits [2]. B. Prykin, A. Raikin and J. Forrester define economic reliability as "integration of internal and external actions of a system by means of cybernetic model functioning" [3, 4, 5], which they present as a set of actual balanced parameters at a given moment of time.

For quantitative assessment of economic reliability of an organization V. Kabanov and N. Zheglova suggest defining an integral parameter as a comprehensive result of a diagnostic assessment of production processes [6] and a complex parameter of its financial state [7].

Similar approaches to quantitative assessment of economic reliability are demonstrated by foreign authors who suggest using systems of indicators (tests): in quality control [8]; in statistical assessment of economic reliability [9], for defining reliability variation vector

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(calculation of company indicators related to industry, general economy, reputation) [10]; for assessing reliability by the costs related to reliability procedures [11].

The mentioned approaches to interpretation of the notion of economic reliability and its assessment reduce the possibility of its application as a parameter for managing economic systems, considering today's soaring uncertainty. Literature review in the field showed that the methodical instruments and model mechanisms for providing economic reliability of the made decisions for economic systems is little developed. This research problem is characterized by the following factors: large scale of information required for making a decision; high subjectivity of the decisions made and uncertainty of conditions for decision making which significantly exceeds the uncertainty of decision making in technical systems.

First, the category of "reliability" appeared as an important parameter of technical systems management, where in practice reliability is provided by including predetermined elements of counteractions against negative disturbing effects in management mechanisms. Unfortunately, in practice of economic systems management such mechanisms are not always developed in advance, more often "struggle against risks" occurs [12].

Reliability of technical systems is determined as a system's ability to perform certain functions within a given period of time or as a probability of achieving a certain goal. Reliability can be assessed in two ways: (1) with a system of quantitative parameters of reliability properties of an object [13] or (2) with a system of statistical parameters of variation. In production process and technology management this approach is reflected in the "input – output" categories of production process or a technology.

The authors of this study support the second approach to defining reliability and interpret reliability of production systems as "probability of performing a given task within a required period of time with a required quality level and provided resources" [14].

When forecasting production processes the uniqueness of parameters for decisions to be made is lost, which forces to consider a lot of various scenarios. In the end of the day, whichever number of scenarios has been considered, only one can be recommended for implementation, in most cases it differs from the actual scenario. In such circumstances certain stock-piles and mechanisms shall be provided to compensate for the existing inconsistency.

To describe the management procedures for production processes such categories as economic reliability, economic manoeuvre, and flexibility are used. But in most cases they cannot be implemented in operational use, one of the reasons is poor mathematical training of specialists in the field, which raises a serious issue in the conditions of digital economy development.

The experience of managing economic components of complex production processes shows that there are three types of reactions to negative disturbing effects: flexibility, mobility and stability. These reactions are implemented in a system of parameters with a common economic reliability parameter. When managing technical aspects of production processes some mechanisms are developed for their adaptation to negative effects, whereas in economic management such mechanisms are not provided, especially for extreme production processes.

Contribution to the development of mechanisms for production processes adaptation to negative effect and methodical tools for providing economic reliability has been made by V. Smirnov and V. Sokolov. First in 1975, V. Smirnov and V. Sokolov in their article "Adaptive Parameters of a Plan" suggested a conceptual framework and quantitative parameters of a new subject domain which was economic reliability. Later, computing technology advances made it possible to use these parameters in practice of economic systems management. Today such possibilities has increased manifold.

The methodical framework for providing economic reliability of decision making has been developed in the following monographs of the authors: Assessment of Plan Reliability and Manoeuvre Parameters (1978), System Modeling of Planning Reliability (1984), Study of Flexibility and Reliability of Economic Systems (1990), Justification of Resource Provision in Innovative Projects (2008), Economic Reliability of Investment Management in Construction (2013).

The purpose of this study is presentation of the authors' approach to defining economic reliability of production processes, and interpretation of essence, content and mathematical implementation of its parameters.

Research methods

The research methods include classical scientific methods like observation, analysis, synthesis, formalization and logic; and some special methods like knowledge base and database creation, post-hoc analysis of the level of production process goal achievement, variance analysis of input parameters variation for this processes such as technology and resource provision or standard performance parameters. Also, economical and statistical methods of data processing were applied for post-hoc assessment of production processes reliability; economical and mathematical modeling was performed for production processes of certain companies, branches and the national economics in general.

Results

Any production process is understood as an aggregate of technologies applied for solving practical tasks, including product manufacturing, performance of works and services. The modern period of technological development is characterized by the growing extremality level. By extreme technology the authors mean such technologies that provide the maximum output per resource unit in comparison with other ones.

The growing number of extreme innovative technologies considerably enhances the production processes efficiency, as well as the risks. The following principle arises: when some technology provides a better output per resource unit than the other, this technology will suffer bigger losses in case of the resource deficiency. The authors call this principle the basic one in extreme technologies.

Losses of extreme technologies are especially detrimental for innovative production processes. Technical failures in managing production processes sometimes cause considerable financial losses. However, the records show that damage caused by faults in providing economic reliability of the processes is much higher.

The paradox arises that proves the extremality principle of technology: the lower technological efficiency is the less loss it brings to the production process in case of negative effects (disturbances). For instance, the coal stock at a central heating and power plant can be considered as one of the least efficient technologies, for it doesn’t provide products manufacturing.

However, in case of extreme disturbing effect like non-delivery of coal this stock will transit from the category of cold standby to a fully-fledged technology. Due to external factors this paradox is consciously or subconsciously ignored in production processes management, since the society cannot reject scientific and technological advances, i.e. extreme yet more efficient technologies.

Assessment of economic reliability of a production process means mathematical expectation of the level of completion of a planned task or of some other controlled parameter of the process. To provide reliability one shall organize control of deviations or variations of possible parameter values of a production process from the mean value. It shall be noted that languages of technical and economic components do not coincide and their information bases have almost no common data. These factors require a specific approach to providing production process reliability taken as an integral whole of technology + economics.

On the one hand, economic reliability of a production process performs as a single parameter (mathematical expectation of the level of achievement of a planned value of a certain controlled parameter). On the other hand, it is a complex parameter which includes several properties of reliability: mobility, adaptability, flexibility, elasticity, stability, rigidity, reversibility, etc. These parameters are only implemented in quantitative forms. They are easily integrated in interaction charts for generally used economic categories of production processes management. Quantitative assessment of a production process economic reliability can be expressed by a "potential probability of performing a planned task for the k^{th} parameter" [15, p.61].

Let us assume that the value P_k^0 is the value of some k^{th} output plan parameter of the process development and functioning, failure to achieve this parameter at a certain period can be interpreted as maloperation. P_k is assumed to be a probable actual value of this parameter. It may differ from the planned one due to possible change in the conditions of process implementation. Then, the probability of $P_k > P_k^0$ occurring within the studied period of time shall indicate reliability of the project task performance for the k^{th} parameter. This definition of a potential reliability can be implemented as follows:

$$q_k = q\ (P_k > P_k^0), \tag{1}$$

where $q\ (P_k > P_k^0)$ – probability of $P_k > P_k^0$.

The most important requirements to economic reliability parameters are the possibility of their quantitative assessment and interpretability. This primarily concerns certain parameters of economic decision. The basic parameter that retrospectively characterizes reliability of economic decision is the degree of its performance (percent, share). Using the previously introduced nomenclature this parameter can be expressed as follows:

$$H_k = 1 - E\ [(P_k^0 - P_k\ ) / P_k^0],\ k = 1,\ldots,K, \tag{2}$$

where H_k – reliability performance for k^{th} parameter of economic decision; E – mathematical expectation; K – nomenclature of parameters; P_k^0- design (planned) value of the k^{th} parameter; P_k – its probable actual value.

It is natural that the reliability assessment (1) is formally inconsistent with assessment (2). What is more, in some cases H_k can formally be greater than 1. Nevertheless, it is useful to apply it in economic components of production processes in the form approximate to assessment (1) in a sense that their qualitative assessments vary synchronically.

Moreover, for defining the sufficient level of economic reliability of a production process retrospective assessments in the form (2) are acceptable. In this case reliability of a production process becomes a controllable parameter. One of important factors of its control is elasticity function applying which enables one to use technological, structural, material, financial, organizational and other reserves. Positive correlation exists between the reliability assessments (1) and (2) for production processes.

For extreme production processes the complex parameter of adaptability is especially important, it denotes their ability to adapt and adequately react to changes of internal and external environment. Adaptability is motivated by natural substitution of conventional processes and technologies with new and extreme ones.

In this case we observe the rigidity parameter of production process economic reliability. Rigidity occurs under the influence of firmly established competences, experience, traditions, information support system for document flow, habits. The more resources are invested in the production process the more rigid this process is.

Reduction of production processes rigidity is achieved by actively effecting both internal and external environment, and adapting to it. It is an implementation of adaptability. Parameters of economic reliability of production processes related to adaptability are flexibility and mobility. Flexibility of the process, which means the ability to adapt without changing technological and organizational structure, mostly reveals under little disturbances. Whereas mobility of the production process, or its ability to adapt by means of technological, structural and organizational changes, is manifested under strong disturbances.

Stability of a multistage production process is reflected in its ability to eliminate negative disturbances, for example, in a logistics chain of freight and passenger transportation. Here, the basic extremality principle is implemented: the elimination of disturbances comes faster in non-efficient technologies because of smaller number of stages, such technologies are characterized by a high stability level.

Conclusion

The issue of formation of economical and mathematical framework for providing economic reliability of production processes can be solved by using the suggested approach to its understanding and implementation, especially when applicable to extreme technologies. During the study the following notions were defined: extreme technologies, basic principle of the technology extremality; assessment of production process reliability, as well as essence, content and mathematical implementation of its parameters.

The suggested approach has practical value for controlling economic reliability parameters of production processes, which is validated by implementing certain projects in various branches of economics: gas flows optimization while planning the development of a unified gas supply system of the country with the account of economic reliability; optimization of dynamic input-output balance of the country; optimization of development plans for iron and steel industry infrastructure in Western Siberia; flexible pricing and tariffs formation for production and transportation systems with the account of economic reliability; interactive model of reliability assessment for long-term target program implementation, etc.

Prospective direction for further research in this field can be development of universal adaptive systems for providing economic reliability and adaptability of production processes to negative effects – economic robots. Such robots are unit-based economical and mathematical models, with each unit corresponding to a certain scenario. The general system constraints are requirements on reliability of achieving the required goals like volume of production, amount of revenue, etc.

The central unit of such robot may correspond to the most probable conditions for decision making. Other units will correspond to different scenarios with less probable conditions. The connection between the central unit and a certain scenario is implemented by constraints for adaptation of a decision corresponding to the central unit to another unit.

These constraints are related to flexibility and mobility. At the same time, mobility implies change of production process structure, like replacement of some production technology or its cancelling. Mobility constraints will enable to make the process stable to, for example, fluctuations of prices or demand on the market.

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