Formalization of the Model of Management of the Technological Innovations

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Abstract. *Research goals and objectives*: to describe the discrete dynamic system consisting of technological innovation (TI), to formulate a meaningful statement of the goal of managing TI taking into account risks, to develop a formal statement of the task of TI-management with risks. It is subject to the influence of controlled parameters (controls) and uncontrolled parameter (vector of risk or interference).
Subject of research. The process of formalization of management of technological innovations is investigated. To describe the process of managing technological innovation, it is needed to know the parameters of the system. The process of management of technological innovations is described by a discrete vector (recurrent) equation. The phase vector characteristic of management of technological innovations includes three components: the same unrealized products for the period, products for the period, and flow rates for the next period.
Research methods used: to build an economic and mathematical model, a class of deterministic models is used. Its dynamics is described by a vector linear discrete recurrent relation.
Results of the research: The obtained model of management of the TI can be used for economic-mathematical modeling and the practical use of optimal processes for predicting data management. The development of modular models can serve as the basis for the development of software and hardware systems for training programs that are effective in the operational strategies of innovative technologies.

Keywords. technological innovation, dynamic optimization, model formalization, deficiency conditions.

1 Introduction

The researching of the task of a management of the technological innovations (TI) requires the decision of a dynamic economic-mathematical model, taking into account the presence of control influences. It has uncontrolled parameters as risks, modelling errors, etc. and a lack of information. Existing approaches for solution this problem is based mainly on static models and use a stochastic modelling apparatus. However, its application requires knowledge of the probability characteristics of the basic parameters of the model and special conditions for the providing of the considered process.

Note for using of the stochastic modelling apparatus, very stringent conditions are needed, which in practice are usually not feasible in advance.

In this article a deterministic approach to formalize the initial dynamic task of management of the TI at a given point in time, taking into account the presence of risks is proposed. In this case, the risks in the TI system of management will be understood as the factors which has negatively or even catastrophically affect on the results of the considered processes in it.

2 Analysis of Literature and Problem Statement

To formalization of the model of TI-management it is necessary research the procedure of their identification. The term "identification" has become widely used as one of the basic sections of the theory of control in the 50s of the last century. Today, researchers from many spheres of science and technology, in particular, for the synthesis of control systems, consider the problem of building adequate, efficient models. One of the founders of the theory of identification is Professor P. Eikhoff [1]. Subsequently, other approaches to task of the problems of constructing models for different classes of objects, methods of their description, signals used in the case of different approaches and algorithms of identification, other problems of construction and analysis of models of processes or systems. In addition, among the most significant works devoted to the questions of the identification of dynamic systems, one should point out the research of D. Grope [2], E.P. Sage and J.L. Melsa [3], L. Leung [4], and also Y.Z. Tsipkin [5], N.S. Raybman [6], S.E. Steinberg [7] and others.

The active development of computer technology in recent decades has led to the emergence of new algorithms and software tools designed to automate professional activities. This significantly affected the methods of solving identification problems. The using of specialized software for scientific, technical and engineering calculations, on the one hand, enables us to learn the studied industry more deeply. At the same time transforming the main part of tasks for the researching, debugging of algorithms and programs for the correct statement of the problem. Usually this frees the researcher from solving many related issues: confirmation of the model validation, studying the identification error, the properties from received estimates, etc. On the other hand, the pace of software development is quite high. However, the comprehension of the obtained results and their competent use is often impossible. There is a certain contradiction between the ease of execution of a large number of rather complicated tasks, rapid achievements of results and insufficient understanding of their content. This leads to the impossibility of their further effective use [8-10].

Construction of economic and mathematical models of one or another type based on the obtained results of observations on the behavior of objects and the researching of their properties is the main content of the formalization problem.

3 The Meaningful Statement of the Task of Management of the Technological Innovations

The purpose of the paper is to research of the TI-management with the influence of the risks and the formalization

of the model of the management of TI for the solving of a problem of identifying parameters of the linear dynamic system. It provides the development of a method that allows combining the procedures for solving multidimensional systems of the linear algebraic equations and interpolation of output data. In this case, the goal is to evaluate the parameters that are missing in separate periods.

To achieve the research task, the following objectives were set:

- to formulate a meaningful statement of the goal of managing TI taking into account risks;
- to develop a formal statement of the task of TI-management with risks.

TI involves the transition to production based on the innovation process. This process takes into account various types of factors of production, raw materials, options for the using and storage of materials, intermediate and final products, the influence of various internal production and external factors, including risks, as well as other components of the technological process. It can consist of certain technological ways of organizing production. They provide using of exist or replacement (full or partial) of technological equipment.

Management of TI is carried out in separate periods of life cycle of the innovation during their implementation. Management of TI includes the value of production volumes of new products, the vector of replenishment of material and labor resources for its production and the vector of investments for the providing of TI [11, 12]. They form a management scenario for relevant innovation. There is the possibility of using different scenarios of innovation management, depending on the variation of the values of its respective components.

It is necessary to implement such rational management of TI with the appropriate scenario for a given time interval of its life cycle by choosing from a variety of alternatives to possible influence of management [13]. In this case, the overall performance criterion should be maximum [14]. Moreover, if several implementation options of various TI are considered based on relevant innovation processes, then you must also make a choice between them and find rational management according to the chosen criterion [15].

Having developed a meaningful economic-mathematical model of TI management, let us turn to its formal formulation [16].

4 Formulation of the Task of Management of the Technological Innovations in the Presence of Risks

Let us introduce the designation: let it be $\bar{x}(t) = (x_1(t), x_2(t), \ldots, x_n(t))' \in \mathbf{R}^{\bar{n}}$ – a phase vector that characterizes the state of management of technological innovations (the availability of production volumes of the enterprise, financial, investment, technological, other productive resources, etc.) in the period t [17].

To describe the process of managing technological innovation, it is necessary to know the initial values of system parameters (at the beginning of the investigated time interval). Consider its structure. It includes volumes of products, other initial productive resources, etc., as well as investments aimed at TI [18]. At the expense of initial investments I_0, the purchase of equipment, production resources, etc. necessary for the "launch" of technological innovation. Since the volume of initial investment is a key factor for the implementation of the innovative technological process, in the phase vector $\bar{x}(0)$ we select them separately, that is $\bar{x}(0)=\{x_0, I_0\}$.

The process of controlling TI is described by a vector discrete (recurrent) equation:

$$\bar{x}(t+1)=A(t)\bar{x}(t)+B(t)\bar{u}(t)+C(t)\bar{v}(t), \quad \bar{x}(0)=\{x_0, I_0\} \tag{1}$$

where $t\in\overline{0,T-1}=\{0,1,2,...,T-1\}$ – discrete moments of time, divided by the period in the month, quarter, year, in which the choice of management is carried out; $\overline{0,T}$ – a given time interval (T>0 and integer);

$\bar{x}(t+1)\in\mathbf{R}^{\bar{n}}$ – a phase vector that characterizes the state of management of TI over a period of time (t+1) and consists of vectors of volumes of production, inventories, costs, financial resources, and investment volumes formed over a period of time (t+1) (stocks in the period (t+1)).

Consider the formation (1) by the example of the vector of production volumes of the enterprise: $x_i(t+1)$ – is the quantity of the i-th type of products $i\in\overline{1,n}$ that formed in the warehouse before the beginning of the time period (t+1) (product stocks in the period (t+1)), which is formed from the stocks $x_i(t)$ of the previous period of time and produced at the enterprise products for the period t.

Equation (1) consists of three components, which we shall consider below (the balances of unrealized output during the period, manufactured products in the period and the impact of risks for the period under study).

Balances of unrealized products during the period t+1.

Note that if at the beginning of the time period t in the warehouse there were stocks in the number $x(t)$, then by the end of this period, that is, before the beginning of the time period t+1, only the part that is equal will be available for sale equal to $A(t)\bar{x}(t)$;

$A(t)=\|a_{ii}(t)\|_{i\in\overline{1,n}}$ – diagonal matrix characterizing the implementation of products (the matrix of "implementation") over a period of time $\overline{t,t+1}$;

$\bar{x}(t)=(x_1(t),x_2(t),\ldots,x_n(t))'\in\mathbf{R}^n$ – the vector of product stocks in the period t ($t\in\overline{0,T-1}$), in which each i-th coordinate $x_i(t)$ denotes the output of the i-th form $i\in\overline{1,n}$ (n - the total number of produced products types), $\mathbf{R}^n$ – n-dimensional vector space of column vectors.

The products are manufactured in the period t+1 (vector $B(t)\bar{u}(t)$*),* where $\bar{u}(t) \in \mathbf{R}^p$ – the vector of management of innovation technology (managerial influence), the components of which are the intensities of using the j-th technological method of production (according to the corresponding innovation technology) in the period t, $p \in \boldsymbol{N}$, for which each j-th coordinate $u_j(t)$ is the value of the volume of material and labor resources and investment production for innovation technology $(j \in \overline{1,n})$, $\forall t \in \overline{0,T-1}$ $\bar{u}(t) \in U_1$, U_1 – a finite set of alternatives that limits the resource of managerial influence;

$B(t) = \|b_{ij}(t)\|_{i \in \overline{1,n},\, j \in \overline{1,p}}$ – "technological matrix" of production, components of which can be represented in the j-way that corresponds to the organization of production in the period t ($t \in \overline{0,T-1}$, $T > 0$), which is characterized by the vector ($b_{1j}(t)$, $b_{2j}(t)$, …, $b_{nj}(t)$) of the resources cost for the production of the unit volume of production of the i-th type ($i \in \overline{1,n}$).

If $b_{ij}(t) < 0$, then $b_{ij}(t)$ determines the consumption of i-th ingredient during the j-th mode of production in a period of time.

If $b_{ij}(t) > 0$, the quantity $b_{ij}(t)$ determines the release of the i-th ingredient during the j-th mode of production in the period t.

An add-on that takes into account the impact of risks, modelling errors on products in the period t+1 (vector $C(t)\bar{v}(t)$, where $\bar{v}(t) \in \mathbf{R}^q$ – vector of risks that affects the production and storage of products, that is, the process of forming a vector $\bar{x}(t+1)$ $q \in \boldsymbol{N}$. For example, investment payments (or their lack of remuneration), lack of delivery of materials, damage to agricultural products during storage or transportation, non-compliance with quality requirements for raw materials or finished products, insufficient investments, etc.; $\forall t \in \overline{0,T-1}$ $\bar{v}(t) \in V_1$ – convex, closed and bounded polyhedron in $\mathbf{R}^q$.

$C(t) = \|c_{il}(t)\|_{i \in \overline{1,n},\, l \in \overline{1,q}}$ – matrix consisting of coefficients of transferring the influence of the risk vector on the products of each species.

$A(t)$, $B(t)$, $C(t)$ – dimensional matrices ($n \times n$), ($n \times p$) i ($n \times q$) respectively, which are formed on the basis of preliminary information from the company's reporting documents, available statistical data on the considered process, with the help of experts, economic forecasts and other sources through application methods of data evaluation and solving a separate problem of identifying the values of the parameters of the system being studied.

5 Discussion of the Results

Formalization of the model of management of the TI requires *formation of constraints for the process of management of TI.* Introduced above vector of innovative innovation management $\bar{u}(t) = (u_1(t), u_2(t), \ldots, u_p(t))' \in \mathbf{R}^p$ and a vector of risks $\bar{v}(t) = (v_1(t), v_2(t), \ldots, v_q(t))' \in \mathbf{R}^q$ in the system (1) such that each pair must satisfy the following given limit:

$$(\bar{u}(t), \bar{v}(t)) \in UV(t) = \{(\bar{u}(t), \bar{v}(t)) : \bar{u}(t) \in \mathbf{R}^p, \bar{v}(t) \in \mathbf{R}^q,$$
$$S_{\min}(t) \le \langle B(t)\bar{u}(t)\rangle_n \le S_{\max}(t), K_{\min}(t) \le \langle C(t)\bar{v}(t)\rangle_n \le K_{\max}(t)\}, \quad (2)$$

where $S_{\min}(t) = (S_{\min 1}(t), S_{\min 2}(t), ..., S_{\min n}(t))' \in \mathbf{R}^n$ – the vector of the minimum acceptable production volume, for which each *i*-th coordinate $S_{\min i}(t)$ is the value of the minimum acceptable volume of production of the *i*-th type ($i \in \overline{1, n}$) (for example, the break-even point for each type of product);

$S_{\max}(t) = (S_{\max 1}(t), S_{\max 2}(t), ..., S_{\max n}(t))' \in \mathbf{R}^n$ – the vector of the upper limit of output, for which each *i*-th coordinate is the value of the maximum acceptable output of the *i*-th type ($i \in \overline{1, n}$) (for example, the maximum capacity of the market for each product, maximum production capacity, etc.). $K_{\min}(t) = (K_{\min 1}(t), K_{\min 2}(t), ..., K_{\min n}(t))'$ and $K_{\max}(t) = (K_{\max 1}(t), K_{\max 2}(t), ..., K_{\max n}(t))'$ – vectors of the smallest and largest values of the influence of the risk vector on output of each species [19].

At the same time, $t \in \overline{0, T-1}$ all the following restrictions must also apply to all:

$$\begin{cases} x_i(t) \ge 0 \quad (i \in \overline{1, n}), \\ u_j(t) \ge 0 \quad (j \in \overline{1, p}), \\ v_l(t) \ge 0 \quad (l \in \overline{1, q}). \end{cases} \quad (3)$$

Note that in the process of controlling technological innovation, the constraints (2) and (3) are a prerequisite that must satisfy the parameters of the system state of generated by the realizations of optimal managerial influences in a discrete dynamic system (1).

In the case if the available statistics on the background of the phase vector x, the vector of control u and the risk vector v are such that the system of linear algebraic equations of the form (1) has an infinite set of solutions, then discrete dynamic models of the form (1) – (3) there will be infinitely a lot. In this case, we form the dependence of the basic unknown values of the system of equations of the form (1) on its free unknowns. Then, substituting arbitrary values of free unknown quantities, we obtain different models from which, based on the introduction of an additional quality criterion, we can form a concrete model suitable for solving this task of TI management.

The obtained results can be applied for the tasks of identifying economic and mathematical models and solving other problems of dynamic optimization of forecasting and data estimation processes taking into account the influence of risks in the conditions of information deficit and uncertainty.

6 Conclusions

The author proposed the formalization of the model of TI in the form of a discrete dynamic system. Its dynamic is described by a vector discrete linear recurrence relation and is subject to the influence of controlled parameters (controls) and an uncontrolled parameter (risk vector or interference).

Such an approach makes it possible to solve the dynamic optimization task of the management of TI. In this case, it is possible to use an algorithm that reduces to the implementation of solutions of systems of linear algebraic equations. This allows to develop efficient numerical procedures that allow one to realize computer simulations of the dynamics of the considered system of the management of TI.

The results presented in the article can be used for economic-mathematical modelling and solving tasks of optimization of the processes of forecasting and management in the condition of lack of information and risk, as well as for developing appropriate software and technological systems to support making effective decisions in practice.

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