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Mathematical model of operational management technological complex continuous type

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Abstract: *Mathematical model of operational management technological complex continuous type.* In the article are considered main questions of operational management of technological complexes of continuous type. The authors propose the construction of a mathematical model of operational management of technological complexes of continuous type, in which the best strategy of development of TC continuous type on the basis of performance evaluation. The features of the management of TC continuous type and the algorithm of choosing the optimal strategy based on the index of the efficiency.

Key words: technological complex continuous type, operational management, performance evaluation, performance index, strategy

INTRODUCTION

Technological complexes (TC) of continuous type and subsystem at a specific point in time is characterized by a state that is expressed by the equation in the coordinates of the state [Prokopenko 2013]:

$$\begin{cases} x_i = A \cdot x_i + B \cdot u_i + D_1 \cdot w_i \\ y_i = C \cdot x_i + D_2 \cdot w_i \end{cases} \tag{1}$$

where:
x – the state vector of the system;
u – management;
y – the output of the system;
w – inputs (external perturbation);
A, B, C, D – matrix.

As indicated in [Ladaniuk et al. 2014], it is expedient in the operational management of complex organizational and technological objects to use the situational management based on artificial intelligence theory. The essence of this method lies in the representation of knowledge about the object of control, and ways to control them using the logical-linguistic models, fuzzy logic, procedures, learning and generalization in the generation of management decisions according to current situations to build a multi-step solutions.

In the theory of fuzzy logic therm formalized as a fuzzy set with membership function [Zadeh 1989]:

$$\sigma(A) = \{x | \mu_A(x) > 0\} \tag{2}$$

where:
A – fuzzy set;
$\mu_A(x)$ – membership function of x to A.

According to the equation in the coordinate condition (1) for TC of continuous type for solving the problem of state estimation of complex organizational and technological object reference model is used, which corresponds to the model object (1) [Parsheva 2001]:

$$\begin{aligned} \dot{x}_{mi} &= A_{mi}x_{mi}(t) + B_{mi}r_i(t) \\ y_{mi} &= L_i x_{mi} \end{aligned} \tag{3}$$

where:
$r_i(t)$ – the vectors the elements of which are partially-continuous bounded functions;
A_{mi}, B_{mi} – matrix Hurwitz;
$L_i = [1, 0, ..., 0]$.

The objective function for this system is the expression [Ladanyuk et al. 2013]:

$$\lim_{t\to\infty}(x_i(t) - x_{mi}(t)) = 0 \tag{4}$$

The most effective operational management of the TC continuous type is possible by changing the material and technological conditions. Therefore, the assessment of efficiency of functioning of the TC continuous type gives the possibility of determining the future prospects and make appropriate management decisions.

Given the conditions of uncertainty and complexity of organizational and technological objects are considered the source of knowledge about such objects and control methods may not be sufficient. Therefore, the system of operational management of complex organizational and technological objects in conditions of uncertainty must be able to adjust their knowledge about the objects and methods of management. Thus in the context of operational management must develop appropriate knowledge base with the assistance of experienced experts about the object of management, its functioning, the ways to manage them, as well as knowledge of indicators and performance criteria and corresponding solutions.

MATERIAL AND METHODS

For TC continuous type characteristic complex processes (heat and mass transfer, hydrodynamics, chemical transformations), producing the finished product from the raw materials, energy and material resources. Operational control subsystem may be designed on the basis of an expert system whose main objective is to assess the state of the object and the choice of strategic scenarios for the development of TC on the basis of the estimates. The working memory of the expert system may include the following areas: process variables to display real-time evaluation and comparison with the permissible limits of deviations of parameters and indicators that are kvassheim in the allotted time (the forecast horizon), evaluation of generalized indicators; interim financial information for the task of diagnosing TC and forecasting of techno-economic performance [Ladanyuk et al. 2008].

Performance evaluation will be based on the efficiency criterion, which is expressed through the index of the efficiency of organizational and technological object. The index of the efficiency is formed by identifying the most significant characteristics (performance) TC continuous type and is determined according to the formula:

$$W = \sum_{i-1,\ldots,n} \mu(x_i) w(x_i) \tag{5}$$

where:
$w(x_i)$ – the weights of certain performance indicators TC x_i , corresponding to the subsystems of the TC and drive the development of the technological component of profits;
$\mu(x_i)$ – the corresponding values of the membership functions.

Thus, the effectiveness of TC continuous type is defined as:

$$f(F_{st}, F) = W \tag{6}$$

The original function $f(s, w)$ and criterion function efficiency $E\left(s, w, f(s, w)\right)$ allow us to evaluate the effectiveness of organizational-technological object is changed by law:

$$x = f(s, w) \tag{7}$$

where s is the strategy selected according to a certain performance index w.

The set W is the set of the indices of effectiveness w. The initial condition x_0 for equation (7) is considered as parameter perturbation belongs to the set of indexes of efficiency of W, i.e.

$$x_0 = w \in W \tag{8}$$

The objective function associated with the criterion function of the efficiency E is determined using the equation:

$$Z(s, w) = E\left(s, w, f(s, w)\right) \tag{9}$$

The expression (9) allows us to determine directly the dependence of the objective function Z in contrast to the criterion function E is selected from strategy s and index of the efficiency w. Indirectly through the function of the efficiency E of the objective function Z based on (7) depends on the value of x, that is affected via the function f of the decision y.

Then you need to choose a strategy on the feasible set of strategies S

$$\overline{s} \in S \tag{10}$$

to all w from W the inequality:

$$Z(\overline{s}, w) \le \tau(w) \tag{11}$$

where: τ is the function is enabled, specifies the maximum allowable value of the objective function Z, which coincides, according to (9) with the criterion function E.

To solve the formulated problem of selecting the best strategy for TC continuous type on the basis of an evaluation of the effectiveness of TC (7)–(11), the authors proposes an intelligent method, which is based on a combination of the methods of expert estimates, decision tree, dynamic programming, and heuristics.

In the process of building strategic tree the set S of all possible strategies divide into subsets $S_1, ..., S_m$, where each strategic decision $S_j\ j=\overline{1,m}$ is assigned the index of the efficiency w_j, i.e.:

$$S_j = \sum_{j=1}^{n} s_j(w_j) \quad (12)$$

$$f(S_1, S_2, ..., S_m) = \max_{x_i \in X_i} W(x_1, x_2, ..., x_n)$$

$$i = 1, 2, ..., n;\ n = 1, ..., N$$

$$j = 1, 2, ..., m;\ n = 1, ..., M \quad (13)$$

We introduce the resource limits for each strategy S_j:

$$\sum_{k=1}^{l} r_{jk} \le R_j, \quad l = 1, 2, ..., L \quad (14)$$

According to the optimality principle of Belman [Bolshakov 2006] to have:

$$f_n(S_{1n}, S_{2n}, ..., S_{mn}) =$$
$$= \max_{w_n \in W_n} \{f_{n-1}[W_{1n} - w_{1n}(x_n), W_{2n} - w_{2n}(x_n), ...,$$
$$W_{mn} - w_{mn}(x_n)] + Z(s_n, w_n)\} \quad (15)$$

The algorithm of solving the problem of choosing the optimal strategy based on the index of the efficiency TC continuous type is as follows:

1. Assesses the effectiveness of the functioning of the TC continuous type in the time interval t_n by defining a index of the efficiency W_n.
2. Defines the set of admissible strategies S_n, $n = 1, ..., N$ according to the index of the efficiency W_n.
3. The solution of the functional equation (15) in the time interval t_n and determination of the sequence $f_n(S_{mn})$, $m = 1, ..., M$ and corresponding dependencies $x_n(f_n)$, $n = 1, ..., N$ and also functions $S_{jn}(f_n)$, $j = 1, ..., M$.
4. The definition of $E = \max_{W_n} f_n(S_{mn})$, which are the constraints (14) for $m = 1, ..., M$.
5. Restoring optimal strategy according to dependencies $f_n(S_{mn})$ and $x_n(f_n)$.
6. The end of the algorithm.

CONCLUSIONS

Effective management of complex organizational and technological relation TC continuous type in market conditions requires the introduction of new information technologies and a radical improvement of information support of management activities. The main ways of increase of efficiency of functioning of TC continuous type is not only the optimization and modernization of production, reduction of production losses and technological consumption of energy, but effective innovation, increase the reliability and speed of obtaining information necessary for making strategic and operational management decisions under uncertainty and risk. Therefore, decisions taken at a specific point in time, is a part of the general implementation of the chosen strategy. For selection of control at a certain stage it is necessary to evaluate the effectiveness of the operation of the control object, and also to predict the results of the decision in the current situation.

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Streszczenie: *Matematyczny model typu ciągłego w analizie operacyjnego zarządzania złożonymi technologiami.* Tematyka artykułu dotyczy zagadnień zarządzania produkcją. Przedstawiono główne problemy związane z zarządzaniem operacyjnym kompleksów technologicznych typu ciągłego. Zaproponowano matematyczny model pozwalający na wybór strategii rozwoju, bazując na ocenie wyników i efektywności działalności firmy.

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