OPTIMIZATION OF USE OF PRODUCTION CAPACITY OF DEFENSE-INDUSTRIAL COMPLEX[1]

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Transition defense industry on the expanded reproduction of innovative products required to optimize the use of its production capacity. The article suggested the models make informed management decisions on the operation of spare production capacity of enterprises of the complex, based on the analysis of the dynamic interactions and dependencies of factors affecting the process under consideration.

Keywords: models, optimization, the military-industrial complex, enterprise, production capacity.

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ОПТИМИЗАЦИЯ ИСПОЛЬЗОВАНИЯ ПРОИЗВОДСТВЕННЫХ МОЩНОСТЕЙ ОБОРОННО-ПРОМЫШЛЕННОГО КОМПЛЕКСА

Переход оборонно-промышленного комплекса на расширенное воспроизводство инновационной продукции потребовал оптимизации использования его производственных мощностей. В статье предложены модели принятия обоснованных управленческих решений по задействованию резервных производственных мощностей предприятий комплекса, разработанные на основе анализа динамического взаимодействия и зависимости факторов, влияющих на рассматриваемый процесс.

Ключевые слова: модели, оптимизация, оборонно-промышленный комплекс, предприятие, производственные мощности.

1. Introduction

The structure of the defense-industrial complex (DIC) of Russia consists of 8 basic military-oriented industries (rocket-space, aviation, shipbuilding, electronics, radio industry, etc.). It includes located in 68 regions of Russia in 1340 large enterprises and organizations (many of which are city-forming), employing around 2 million workers, of whom more than 72% – in industry, and about 28% – in research institutes and design offices. Businesses and organizations of DIC produce 70% of the domestic high-tech products, and they employ about 50% of the scientific staff of the country. Products created by these enterprises and organizations, is consumed by all sectors of the economy. For example, 40% of the equipment required for the fuel and energy complex, supplied by defense companies. In Russian exports of engineering products share of DIC is over 82% (it supplies products to 86 countries of the world) [1].

The main specific feature of DIC is that it meets the main public needs. Therefore, the main directions of its development determines the state in the management and financing of the development of the complex [2]. In 90th years of the last century, the main challenges facing the complex were: institutional transformation (corporatization, the conversion of production, etc.), as well as the «survival» in a systemic crisis of the Russian economy (financial sustainability of enterprises, etc.), at the beginning of the XXI century - reducing the growth of its individual businesses (mainly those whose products are supplied to the global arms market, as the volume of exports of military products to the middle of the last decade exceeded domestic defense contracts) [3].

Currently, due to changes in the military-political situation, increase the economic capacity of the state and the urgent need for technical reequipment of the Armed Forces of Russia, before the defense complex tasked with the sharp increase volume of its production, which by 2020 should be increased by 5 times. For this purpose it is planned to allocate a specified period from the federal budget of about $ 20 trillion rubles [4]. To control the development of the DIC ten federal programs are approved.

However, since the problem of the sharp increase in defense production to date in Russia practically not solved, its scientific elaboration is insufficient [5]. Prior studies of individual issues of the problem were very weak demand practice. Therefore, at present there are only scattered knowledge – mostly empirical algorithms for solving specific tasks of the problem, which is generally weak conjugate. For these reasons, the scientific validity of earlier development programs and its defense industry is inadequate and they are constantly adjusted after approval, which reduced the effectiveness of their implementation. However, the economic, social and military «price» of error in this sphere of nation-building is very high [6]. These circumstances gave rise to the development of scientific problem solving tools to optimize the development of basic management tasks of DIC in a sharp increase of production, including - use its spare capacity, the value of which until recently by some enterprises of the complex was 30–50% [7].

2. Engagement tools to optimize spare capacity of the defense-industrial complex

Processing the input of spare production capacity of DIC can be represented as a function of the strategy to enter the reserve capacity H_p, the available spare capacity $M_p(t_y)$ in the branches of DIC, labor $Q_{mp}(t_y)$ and material $P_p(t_y)$ resources, as well as the able-bodied population of the state $Q(t_y)$ and the level of needs of the Armed Forces in military products: $D_n(t_p)$:

$$t_p = f(H_p M_p(t_y) Q_{mp}(t_y) P_p(t_y) Q(t_y) D_n(t_p)) \qquad (1)$$

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There are two basic strategies engagement spare capacity defense complex. The first strategy is that in the context of creating a new image of the Armed Forces and their technical re-equipment of spare production capacity in the defense industry are loaded fully to the production of additional products [8]. In this case the duration of the process of engagement spare capacity defense industry is a very small amount of time (in terms of long-term planning, it is practically zero, $t_{p1} = 0$). The second strategy is that, due to financial constraints and other factors spare production capacity of defense companies are utilized gradually [9]. For this case, the duration of this process on the defense industry will be equal to $t_{p2} > 0$.

In accordance with the long-term challenges of the development of the defense industry till 2020 is supposed to implement the second strategy, in which any spare production capacity of the i-th branch of the defense-industrial complex connected to the production of military products gradually, i.e.:

$$M_i(t_p) = M_i(t_y) + M_{pi \to i}(t_p),$$

$$\text{where } i = (\overline{1,n}) \tag{2}$$

The major limiting factor in solving this problem is the capacity of the «narrow» industry (industries) of defense complex, which means the industry, whose production facilities or fully employed, or are unable to master the production of new, innovative products [10].

To account for this factor it is necessary to determine the amount involved production capacity by industry of DIC at the time t_p and use the following approach to solving the problem: if the spare production capacity for each sector of defense industry are utilized at the same time, in this case, using the resulting vector $M(t_p)$ is determined by the industry which capacity is the rate-limiting for the production of final products for military purposes $Y_в^в$.

Then the quantities involved production capacity by industries of DIC at the moment t_p are defined as follows:

$$M_i^з(t_p) = \alpha_i^p (M_y(t_p) - \beta_y^p) + \beta_i^p,$$

$$i = (\overline{1,n}), \tag{3}$$

where $M_y(t_p)$ – production capacity of the «narrow» industry at the end of the process of input of reserve capacity; α_i^p, β_i^p and β_y^p – parameters, taking into account the conditions of the delivery and communication technology and minimally necessary volume production of the end products for civil and military use by defense industry at the time t_p.

The changes taking place in the vector Z for the period of time $\tau_p = t_y - t_p$, taken into account by the following expression:

$$\Delta Z_i(t_p) = Z_i^з(t_p) - Z_i^з(t_y),$$

$$i = (\overline{1,n}) \tag{4}$$

where $Z_i^з(t_p), Z_i^з(t_y)$ – gross output of the i-th defense industry, which is determined by the condition $Z_i = M_i$.

The resulting equation (4) is valid in the case if before the defense does not intend to go to the highest possible output of military products. Otherwise, equation (4) can be written as:

$$\Delta Z_i(t_p) = Z_i^з(t_p) - Z_i^з(t_n),$$

$$i = (\overline{1,n}) \tag{5}$$

where $Z_i^з(t_n)$ is determined under condition of h the full capacity utilization of industries of DIC.

The solution of this problem involves the compulsory registration of the values of the coefficients of the matrix of technological connections in the j-th integrated structure of each i-th branch of defense industry $\|y_{ij}\|, \ (i, j = \overline{1,n})$.

Technological matrix of coefficients $\|y_{ij}\|$ and the corresponding system of linkages is called productive if there is a non-negative vector $Z \geq 0$, such that, $\|E - y_{ij}\| Z = Y \geq 0$, where E – the identity matrix and the inverse matrix $\|E - y_{ij}\|^{-1} = \|b_{ij}\|$ – nonnegative. Thus, for the existence of nonnegative values of the vector of gross output $Z \geq 0$ for any vector final product $Y \geq 0$ is necessary and sufficient that all the elements of the matrix of technological coefficients are non-negative, that is actually the case in the problem. Changes of the values of matrix elements calculated by the formula:

$$\Delta y_{ip}^p = \frac{\Delta Z_i(t_p) / Z_i(t_p)}{(\max \frac{b_{ii}}{Z_i(t_p)}) Z_j(t_p) + \frac{\Delta Z_i(t_p)}{Z_i(t_p)} b_{ij}}, \tag{6}$$

where $\Delta Z_i(t_p)$ defined by expression (4) or (5).

It is believed that changing the values of elements y_{ij}, relating to defense industry, which rebuilds the spare capacity, and the values of these elements will be in the range $(y_{ij}^o, y_{ij}^o + \Delta y_{ij}^p)$ – in the absence of the process of reorienting for the highest possible output range or be in the range $(y_{ij}^n, y_{ij}^n + \Delta y_{ij}^p)$ – if any part of the process. Then the maximum possible amount of production of the last of military products to the point in time t_p will be determined as follows:

$$\max_{H_n} Y_{вi}^в(t_p) = \frac{(M_Y(t_p) - (\sum_{j=1}^{n} b_{Yj}^p Y_{вj}^{*p} + \sum_{j=1}^{n} b_{Yj}^p Y_{гj}^p)) K_Y}{\sum_{j=1}^{n} b_{Yj}^p K_j},$$

$$i = (\overline{1,n}), \tag{7}$$

where $K_y \, i = (\overline{1,n})$ – features completeness of military output ($K > 0$); y – index «narrow» industry capacity; K_j – coefficient taking into account changes in production capacity in mind: to increase the working day (k_1), productivity (k_2) and shift equipment (k_3) with the release of the final product Y; $Y_{вj}^{*p}$ – taken into account when solving this problem part of the end-product of military use; $Y_{гj}^p$ – taken into account when solving the problem part of the final product civilian use.

The equation to determine the number of jobs $C_i^{R_3}$, involved in the industrial structure of the defense industry at the time t_p, would be:

$$C_i^{R_3}(t_p) = (\alpha_i^p (M_y^p(t_p) - \beta_y^p) + \beta_i^p)^{\frac{1}{a_{gi}}},$$

$$i = (\overline{1,n}), \tag{8}$$

where a_g – the coefficient of elasticity of the cost of labor in a given time period.

Based on the above relationships, we can determine the duration of the process of engagement (input) of spare production capacity by defense industry. However, you must take into account that the entry of spare production capacity requires training or appropriate staff.

The manpower resources that are required to reserve production capacity of defense industries, is defined as follows:

$$\Delta Q^3{}_i(t_p) = \left(\frac{\Delta Z_i(t_p)}{k_{1i}k_{2i}k_{3i}(\Delta V_i(t_p))^{a_{gi}}}\right)^{\frac{1}{a_{gi}}}, \quad i = (\overline{1,n}), \quad (9)$$

where $\Delta V_i(t_p) = V_i(t_p) - V_i(t_y)$ – amounts of assets defense industries in the absence of the process of its re-orientation to the expanded reproduction of products and $\Delta V_i(t_p) = V_i(t_p) - V_i(t_n)$ – if the process; $\Delta Z_i(t_p)$ – determined by dependencies (4) or (5).

The total number of manpower ΔQ3, that are required in the defense industry to the point in time , is defined as:

$$\Delta Q^3(t_p) = \sum_{i=1}^{n} \Delta Q^3{}_i(t_p) \quad (10)$$

Consider the function of preparation $F_1(t)$ and the inclusion $F_2(t)$ in the manufacturing process for making use of labor resources under use of spare production capacity by industries of DIC:

$$F_1(t) = (at^2 + bt + c)Q^T(t_y, t_n), \quad (11)$$

$$F_1(t) = (1 - e^{-\lambda t})Q^T(t_y, t_n), \quad (12)$$

where $Q^T(t_y, t_n)$ – the working-age population of the state at times t_y or t_n (start and end of the reorientation process of DIC for expanded production of defense products, respectively); λ – parameter taking into account the intensity of the training of human resources.

To determine the function of labor force training and their integration into the manufacturing process for making use of spare capacity defense industry is advisable to use a spline, i.e. the «gluing» of the functions (11) and (12):

$$F(t) = \begin{cases} (at^2 + bt + c)\, Q^T(t_y, t_n) \\ (1 - e^{-\lambda t})\, Q^T(t_y, t_n) \end{cases},$$

at

$$t \le t_{nod}; \quad t > t_{nod}, \quad (13)$$

where t_{nod} – start mass training of human resources in the implementation of strategies to increase production output.

Algorithm for determining the length of training human resources and their integration into the manufacturing process for making use of spare capacity can be represented as follows:

1. It is determined of the working-age population of the state in times of a start and end time of the reorientation process of DIC for expanded reproduction of innovative products:

$$Q_t(t_y, t_n) = (Q(t_м) - \sum_{i=1}^{m} Q_{ni}(t_y, t_n))k_{Tp}, \quad (14)$$

where $Q(t_i)$, $Q(t_м)$ – the total population of the state; $Q_{ni}(t_y, t_n)$ – population at the beginning and end of a process of reorientation of defense industries on expanded reproduction of products; k_{Tp} – the coefficient disability population, defined according to the statistics.

2. Using the relation (10) for a period of time from 0 to t_{nod}, we find the number of employees who need to prepare for DIC:

$$Q^{PG}(t_{nod}) = Q^T(t_y, t_n)(at^2 + bt + c), \quad (15)$$

where the coefficients a, b and c of the function $F_1(t)$ is obtained using the method of least squares are: $a = -1{,}7$; $b = 50{,}2$ and $c = -6.8$.

3. Since at time t_p it is required to prepare $\Delta Q^3(t_p)$ workers that:

$$\Delta Q^3(t_p) - Q^{PG}(t_{nod}) = \Delta Q^3{}_p(t_p) \quad (16)$$

4. Then from the expression $\Delta Q^3{}_p(t_p) = Q^T(t_{nod})(1 - e^{-\lambda t_{p1}})$ is determined the duration of engagement jobs – t_{p1}:

$$t_{p1} = -\frac{1}{\lambda}\ln\left(1 - \frac{\Delta Q^3{}_p(t_p)}{Q^T(t_{nod})}\right), \quad (17)$$

where $Q^T(t_{nod}) = Q^T(t_y, t_n) - Q^{PG}(t_{nod})$; $\lambda = 1/T_n$ – parameter taking into account the intensity of the training of human resources required for the reorientation of defense industry for the expanded reproduction of products, T_n – average time of training per employee.

Use of dependencies (1)–(17) under solution of considering task is allow to optimize the process of engagement of spare production capacity of the defense-industrial complex.

3. Conclusion

The formalization of the management tasks enlarged reproduction of defense products in terms of resource constraints showed the complexity and volume, as well as the presence of many uncertain factors and conditions of various kinds. These circumstances require decomposition of this problem by providing a number of private, logically interrelated problems whose solutions are the stages of strategic management of DIC. Among them is the task of entering the spare production capacity. The paper presents a new object-and task-oriented economic and mathematical tools to optimize its solutions. This tool provides the ability to perform real-time multiple calculations to generate optimal management decisions with a view to shaping the strategies and long-term programs of development defense-industrial complex.

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