Engineering of modernization of high technology products based on the concept of strategic risk

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Abstract. The analysis showed that the most important results of the Aviation Industry Development Strategy are: an increase in the share of Russian manufacturers of aviation products in the world market; reorientation of the production of aviation industrial complex to the innovative segment of the global market. The aim of the study is to develop an engineering mechanism for the modernization of science-intensive products of the aviation industry. In accordance with this, a method is proposed for assessing the strategic risk of high technology products, a model for assessing the effectiveness of modernization of high technology products based on the concept of strategic risk as defining elements of the engineering process in the aviation industry. The practical implementation of the model is carried out.

1. Introduction

Analysis of the Strategy for the development of the aviation industry of the Russian Federation for the period up to 2030 made it possible to identify the following targets:

- achieving by 2030 the revenue of industry organizations in the amount of 2.6 trillion rubles, which corresponds to growth in nominal terms at the level of 8-9% per year in the period up to 2025 and 5-6% in the horizon of 2026-2030, while the share of export through the supply of final products and components will exceed 40%;
- growth of the share of Russian manufacturers of aviation products in the world market to 6.3%;
- reorientation of the production of products of the aviation industrial complex to the innovative segment of the global market;
- formation of competitive and profitable world-class organizations in the main sectors of the aircraft industry.

Thus, the Aviation Industry Development Program pays special attention to the need to increase the share of Russian aviation products in the world market. Science-intensive products of the aviation industry: airplanes, helicopters, unmanned aerial vehicles, in accordance with the government's approach, should have a certain degree of technological, material and technical, strategic efficiency, that is, a low level of strategic risk. Consequently, this type of product needs to be systematically modernized, to develop effective modifications in the face of strategic risks and a cost approach to increase competitive advantages, increase the share of Russian products in the aircraft market.

Analysis of literary sources showed that the works of B Gorelov, M Gyazova [1,2], A Burdina, A Bondarenko [3], M Pichler, N Krenmayr, E Schneider [4], N Kulikova, V Smolentsev, A Tikhonov...
and others are devoted to the issues of product modernization. However, the authors do not propose mechanisms to justify the need to modernize science-intensive products based on an analysis of the strategic risk of science-intensive products arising from systematic innovations in the field of materials, technologies, toughening of customer requirements, breakthroughs of competitors.

The aim of the presented study is to develop an engineering mechanism for the effectiveness of modernization of science-intensive products of the aviation industry based on the concept of strategic risk.

2. Methodology
The hypothesis of the study is the presence of strategic risk in high-tech aviation products. It is proposed to consider the strategic risk of science-intensive products in the context of the deterioration in the development of technological, material, technical, functional characteristics that affect the competitiveness of products at a certain stage of the life cycle. It is assumed that the strategic risk of a science-intensive product (product) is a complex indicator that characterizes the likelihood of a decrease in the effectiveness of a product performing its functions, a decrease in competitiveness due to a deterioration of the above characteristics [6].

The study developed a mechanism for engineering the modernization of science-intensive products of the aviation industry, which includes the following stages:

Stage 1. Analysis of the regulatory and methodological support of the process of creating science-intensive products of the aviation industry. In addition, at this stage it is recommended to analyze the experimental and testing base, existing technologies and materials used in the creation of aviation components in the context of sanctions, import substitution and analysis of the performance indicators of enterprises participating in project cooperation [6].

Stage 2 of the engineering mechanism involves analyzing the effectiveness of the product's performance of target tasks.

Stage 3. Analysis of the strategic risk of science-intensive products of the aviation industry based on the analysis of trends in the development of materials, technologies, customer requirements, etc. Prediction of parameters, characteristics of science-intensive products based on neural network modeling [7].

The authors of the study proposed a portfolio approach to the analysis and assessment of the strategic risk of high technology products. The portfolio components of the strategic risk of science-intensive products have been determined: the risk of systems that provide control of weapons systems; flight operations risk; flight performance risk; risk of systems providing control; the risk of the general characteristics of the product and the key characteristics are highlighted for each risk from the portfolio.

To analyze the strategic risk of a product, it is necessary to assess each portfolio risk component using the model (1):

\[ R_i = b_i \times \sum_j w_{ij} \times d_{ij} \]  \hspace{1cm} (1)

where \( w_{ij} \), significance \( j \) of characteristic \( i \) of risk; \( d_{ij} \), discount, calculated by the formula (2):

\[ d_{ij} = \frac{1 - \exp(-0.05 \times K_{ij})}{0.05 \times K_{ij}} \]  \hspace{1cm} (2)

where \( K_{ij} \), assessment \( j \) of characteristic \( i \) of the risk of a science-intensive product; \( b_i \), significance of risk.

The strategic risk of a knowledge-intensive product is determined by the formula (3):

\[ SR = \sqrt{0.25 \times (\sum_i R_i)^2 + 0.75 \times \sum_i (R_i)^2} \]  \hspace{1cm} (3)

In the case of a high strategic risk, in accordance with the risk ranking scale for a science-intensive product, it is necessary to make a decision on modernization. The study proposes to determine the risk-weighted cost (cost) of products and compare it with a similar indicator of competitors [7]:

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where \( \text{COST}_w \), production costs.

The paper substantiates the expediency of using neural network modeling based on exponential smoothing in the process of analyzing external and internal conditions, predicting product parameters in order to effectively manage the life cycle [8]. Neural network training will be carried out based on the analysis of factors: analysis of materials, technologies; analysis of human resources; analysis of technological equipment; analysis of the company’s production facilities; errors in the implementation of target tasks, etc. [9-11].

\( N \) parameters were selected as indicators of the external environment. Thus, from the selected indicators, it is possible to form a vector \( \vec{x} \in R^N \). It can be argued that in its most general form there is a certain vector-function \( f: R^N \rightarrow [1; 5] \), the analytical expression of which is absent due to complex nonlinear interdependencies between the arguments. It is necessary to implement this mapping and prove that the obtained function quite reliably determines the risk of portfolio components of the strategic risk of a science-intensive product. In general, a fully connected neural network, in which each neuron of one of the hidden layers is connected to each neuron from the next layer, has the structure shown in figure 1.

\[ \text{COST}_w = \text{COST} \times \text{SR} \quad (4) \]

Figure 1. Neural network structure [9].

\( x_1 \ldots x_N \), neural network input parameters;
\( \varphi(s) \), neural network activation function;
\( S_i = \sum_{i=1}^{N} x_i \cdot W_i \), weighted amounts;
\( W_1 \ldots W_{p+1} \), weight matrices;
\( p \), number of hidden layers;
\( y_1 \ldots y_N \), neural network output.

Thus, it is proposed to evaluate the components of strategic risk of a science-intensive product using a learning neural network on an appropriate scale that analyzes the degree of compliance of the components of strategic risk, global trends, customer requirements, development of materials, technologies. In the case of a high strategic risk of the product, that is, with insufficiently effective performance of functions, it is necessary to make a decision on the modernization of the product.

The fourth stage of the mechanism: evaluating the effectiveness of modernization of science-intensive products of the aviation industry and determining the directions of modernization using an optimization model for managing the life cycle of science-intensive products (5):

\[ \text{SR}(\overline{x} + \Delta \overline{x}) \rightarrow \min_{c_{\text{res}}} \quad (5) \]
\[
\begin{align*}
A_{\min} & \leq A_i(X^t + \Delta X^t) \leq A_{\max}, \quad \forall i \in 1...a \\
M_{\min} & \leq M_i(X^t + \Delta X^t) \leq M_{\max}, \quad \forall i \in 1...m \\
E_{\min} & \leq E_i(X^t + \Delta X^t) \leq E_{\max}, \quad \forall i \in 1...e \\
L_{\min} & \leq L_i(X^t + \Delta X^t) \leq L_{\max}, \quad \forall i \in 1...l \\
H_{\min} & \leq H_i(X^t + \Delta X^t) \leq H_{\max}, \quad \forall i \in 1...h
\end{align*}
\]

\( SR \), strategic risk;
\( \overline{X^t} \), vector of expected parameters (portfolio components) of strategic risk, which determine the life cycle of science-intensive products and the development of an aviation industrial enterprise in the time period \( t \);
\( \Delta \overline{X^t} \), deviation of the values of the strategic risk parameters of science-intensive products due to modernization, which determine the development of an aviation industrial enterprise under the influence of a control action in the time period \( t \);
\( j \), the number of portfolio components of strategic risk;
\( Li, Ei, Ci, Ai, Mi \), characteristics of various resources used in the process of modernizing science-intensive products (materials, technologies, personnel, equipment, etc.);
\( m, e, l, c, a \), the maximum values of indicators in the corresponding groups in the developed system of indicators for the modernization of science-intensive products of the aviation industry enterprise, taking into account the requirements of investors and the state;
\( I \), indicator number from the corresponding group in the indicator system;
\( Hi \), indicators of R&D expenditures, investments in equipment, production costs and other enterprises of the aviation industry, taking into account the requirements of investors and the state;
\( h \), number of indicators characterizing costs.

The study shows the possibility of determining the optimal value of the indicator of the efficiency of modernization of a science-intensive product by finding the extremum of this function. The criterion for optimization in this task is the indicator of the strategic risk of high technology products [6]. Thus, life cycle management of science-intensive products of aviation enterprises, especially for the implementation of backbone aviation projects, consists in developing a set of measures aimed at forming a vector of changes in the portfolio components of strategic risk, in which the strategic risk of the products of an aviation industrial enterprise will be minimal under a given system of restrictions.

As a result of the introduction of a model for assessing the effectiveness of modernization, engineering solutions are developed for life cycle management of science-intensive products of the aviation industry [12]:

- recommendations on the use of existing at the enterprise / new modern materials, technologies in the production of science-intensive products;
- recommendations for replacing technology materials, integrating new materials and technologies in the creation of components and structural and functional elements of science-intensive products;
- recommendations for retraining of personnel;
- forecasting the demanded characteristics of high technology products using neural network modeling;
- development of project options for the modernization of high technology products based on the values of the strategic risk indicator, customer requirements and the system of restrictions;
- selection (creation) of enterprises producing the necessary materials for the components and systems of high technology products; developing and / or possessing the necessary technologies in the field of creating science-intensive products;
• substantiation of the decision on state support of projects for the creation and modernization of products.

3. Results
The study carried out a practical implementation of the mechanism for engineering the efficiency of modernization of high-tech products: an analysis of the market for unmanned aerial vehicles (UAVs); its dynamic growth is justified; the effectiveness of the project to create the UAV “Yastreb” was assessed, and the strategic risk of this project was analyzed and assessed; the expediency of modernizing the project at the early stages of the life cycle was substantiated.

The specificity of the Russian UAV market is the prevalence of military drone manufacturers over consumer and commercial vehicles. At the same time, the overwhelming majority of military UAV manufacturers have either technically outdated models in their portfolio, or only modern prototypes that are demonstrated at exhibitions, but do not enter mass production. The products of Russian companies now do not compete with modern foreign samples.

Among the main consumer characteristics of the “Yastreb” UAV are:
• Acquisition of images with high resolution, night images (IR sensor).
• Work in all weather conditions (equipped with weather sensors, lightning display sensor).
• Independent target recognition, tracking of a moving target and the use of high-precision weapons on them, placed in the internal compartments.
• This unit will have folding wings for placing UAVs in hangars or on an aircraft carrier.
• Sensors for tracking and collecting information about the location, speed of the object.
• Robust lower fuselage to withstand hail, bird and lightning strikes.

Scope of the “Yastreb”: providing tactical aerial reconnaissance, observation missions (sea and ground observation) in real time, search and rescue missions, military reconnaissance missions; environmental monitoring for scientific purposes; elimination of the consequences of natural disasters (fires, hurricanes, etc.).

The calculated unit price of a prototype is 4 157 820 thousand rubles. To calculate the amount of R&D costs and the acceptable price for 1 unit. The methodology for determining the permissible cost of development and serial production of weapons and military equipment at the initial stages of the life cycle of weapons and military equipment and taking into account economic factors influencing decision-making in the justification and formation of the state weapons program and the state defense order was used [5].

| Indicator | Base value | Including interest on the credit |
|-----------|------------|---------------------------------|
| NPV       | 7 753 963  | 5 848 336                       |
| IRR       | 13.33%     | 11.76%                          |
| PI        | 1.67       | 1.51                            |
| PPS       | 10.72      | 12.21                           |
| PPD       | 14.00      | 14.67                           |

Table 1. Indicators of project effectiveness.

Formula for the estimated sample price ($C$ – the cost of serial production, $K$ – the weighting factor, $P$ – the profitability standard):

$$ESP = \sum_{i=1}^{n} C \times K \times (1 + P)$$

The economic efficiency of the “Yastreb” UAV project has been assessed (table 1) and a model has been implemented for assessing the effectiveness of product modernization based on the concept of strategic risk (figure 2).
Figure 2. Practical implementation of a model for assessing the effectiveness of modernization of high technology products based on the concept of strategic risk.

4. Conclusion
The study presents a mechanism for engineering the effectiveness of modernization of science-intensive products in the aviation industry based on an assessment of strategic risk, contributing to an increase in the efficiency of product lifecycle management through modernization. The introduction of the mechanism will improve the following technical and economic indicators of enterprises in the aviation industry:

- To increase the level of production and products, the share of products that exceed or corresponds to the highest achievements of science and technology.
- Reduce the proportion of products that are obsolete and subject to modernization or withdrawal from production.
- To raise the level of the technical base in the industry and, as a consequence, to carry out qualitative and structural changes in the manufactured science-intensive products, to increase the volume of production using effective innovative technological processes.
- To increase the technical and economic safety of aviation enterprises involved in the creation and maintenance of high technology products. We consider it necessary to conduct further research in this area.

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