The potential of the materials as the economic security’s factor of innovative projects

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Abstract. The purpose of the study is to reveal the specifics of assessing the potential of the material’s economic safety of the aviation product. The strategic directions of the aviation materials’ development and technologies of the Russian Federation have been studied. There was mentioned the necessity for analysis and assessment of the development level of the design base involved in the development and the creation of the aviation equipment at the enterprises: from the materials of the structural elements to the service support (for the purpose of import substitution). The article offers a categorical measure of the potential of the materials analysis. The scientific novelty of the research lies in the study of the economic safety of the product in the context of the elements: material, technical and technological, personnel, service and financial potential. As a result, a new meaningful interpretation of the concept of ‘economic safety of a product’ is given, an additive-multiplicative model for analyzing the level of the potential of the materials’development of an innovative project of the aviation industry is shown and an element of methodological tools for the assessing the level of the potential of the materials’ddevelopment of a product is presented.

1. Introduction

The large system-forming innovative projects (IP) of the aviation industry (AI) are implemented through the cooperation of many enterprises of the industry. The production system of an industrial enterprise is currently subject to systemic international force majeure risks. In difficult conditions of isolation, enterprises and in the post-isolation period need to ensure the reproduction process, maintain the competitiveness of products. Researchers have noted the importance of economic protection of vital aspects of the enterprise's economic activity from internal and external threats by implementing legal, financial, information, organizational and engineering measures [1-3].

At present, industrial enterprises of AI of the Russian Federation (RF) have problems of technical and economic safety of IP, which directly depends on the technical and economic safety of products. For the aviation equipment, it is important to have a low failure rate and a long service life. The reliability of the aviation equipment is directly determined by the quality and the level of development used in its materials’ production [4]. The intermetallics, intelligent materials, the metamaterials, the nanocrystal metals, and the polymer composite materials (PCM) are actively developed in the aviation industry [5,6]. PCM are necessary for the creation of the next-generation aircraft products. The resource base of IP of the AI has a pressing need of the import substitution for the ensuring of the national, strategic, technological and economic security (ES) of RF.
Analysis of the chemical industry market revealed the following significant material and raw material problems of the industry [7]: 1) there are the risks of materials and components’ short supply from other countries; 2) there is a problem of exporting chemical products that have passed the primary processing abroad, where, after processing, they return to RF in the form of finished products with high added value; 3) the production of the adhesives, the sealants, the polyamides, the polycarbonates, the special-purpose rubbers was partially stopped; 4) in the future, it is possible to close the production of the carbon materials used in the production of the aircraft products. The main producers of the composites today are China – 28%, USA – 22%, European Union – 14%. The share of the RA market is within the statistical error and amounts to 0.3-0.5%; 4) in connection with the change in the situation in the country and the world, a problem arose with the supply of raw materials for a number of industries of the military-industrial and machine-building complexes of RF and there is the need for the import substitution of a number of the chemical products, the technologies and the equipment purchased from foreign suppliers.

The potential of the materials’ assessment relevance is also confirmed in the process of engineering and technical and engineering-economic support of aviation equipment (the engineering of the life cycle of the aviation equipment) by such factors as: designing a new technological structure in the aviation industry; developing the complex technical systems and the resource base; global competition in the global aviation market; economic and political crisis phenomena; specific industry features of aviation products.

Researchers have noted that the assessment of ES sometimes does not take into account the historical features of the development of a particular territory, as well as the specifics of the previously implemented measures of state regional and industrial policy [8,9]. The efficiency of using the material and resource base of the project directly depends on the competencies of the production staff, the technical and technological component and other factors. The level of these elements’ development should be taken into account in the decision-making process on the implementation of IP. Other researchers also have mentioned the relevance of this study, also considering the risk aspect [10,11] in the implementation of the project activities: ‘... Economic security should provide an effective functional basis for risks’ minimizing [12]. However, in the presence of a wide range of works, this problem of obtaining a comprehensive quantitative assessment of ES of IP from the point of view of the material component and the criterion of import substitution is still relevant. The purpose of this article is to analyze the traditional methods of the assessing the potential of the material of IP as a factor of ES, to identify its advantages and its disadvantages, as well as to offer methodological tools for a comprehensive assessment of the level of development of potential of the material of IP.

2. Methodology
The variety of the methods and criteria for the assessing the economic safety and efficiency of the products, the investment projects is presented in the regulatory legal acts of the Russian Federation, the state development programs, in the well-known theoretical provisions of strategic, financial and investment analysis in the studies of domestic and foreign scientists.

Strategically important and high-tech aviation equipment in the context of rapidly developing aviation technologies and materials in the world are evaluated primarily in terms of their constructive safety and economic efficiency (for example, product profitability) [2,13,14], competitiveness and social significance [1,2], reliability [15-17]. Scientists have mentioned the following components of ES: financial, information, personnel, technical and technological, legal, energy [1]. The authors propose to conduct studies of the level of development of materials in this way - to form a company's patent portfolio and a global patent scenario for materials used in the aerospace industry [18]. The authors have proposed to evaluate ES using the theory of latent variables (the Rush model for estimating latent variables), but the analysis model does not consider the following factors: 1) the material component of ES of IP; 2) the import substitution criterion underlying the developed product; 3) the specifics of the production of high-tech aviation products, for example, the broad division of the aircraft into functional systems and subsystems. There is no system or tools for assessing the level of
development of the material design base during the examination by the main enterprises of AI and the Ministry of Industry and Trade of RF. Scientists have mentioned the element of the methodological tools for ensuring ES in the personnel context [13].

The document ‘Strategic directions for the development of materials and technologies for their processing for the period until 2030’, developed by the All-Russian Research Institute of Aviation Materials, defines ‘the priorities for the development of the materials and the technologies for their processing until 2030’. When implementing the strategic directions for the development of materials and technologies for their processing, the principle of continuity and unity is used: ‘material - technology – construction’.

In this article, the economic safety of a product is proposed to be considered as a complex indicator that accumulates the impact of material, technical and technological, personnel, service and financial potentials on the characteristics and condition of the product in terms of its consumer properties. Also, this concept includes the state of protection of the product in relation to country risks, taking into account the criterion of import substitution. The study puts forward a hypothesis (figure 1) that the assessment of ES of IP should take place in the context of assessing the five potentials of the elements of a high-tech product. It is possible to obtain an assessment of ES of a product by analyzing separately each of the listed potentials (figure 1) for all structural and functional elements of the product.

![Figure 1. Research hypothesis in the field of assessing the economic safety of a product.](image-url)

Thus, we think that with all the development of the theory and the variety of existing foreign and domestic methods and models for assessing the economic security and effectiveness of innovative projects, any of them chosen as the base requires significant adjustments and adaptation. The methodological approach to the analysis of the level of development of the potential of the material of IP is based on the use of a point additive-multiplicative assessment model. The work on assessing the economic security of the project is preceded by an analysis of the materials used. An organized collection, processing and visualization of the information received is required. Further, the method of
scoring and the method of expert estimates is used. The tabular analysis model and the steps of the method are presented in the next section.

3. Results and discussion
The model for analyzing the level of development of the potential of the material of an innovative project of the aviation industry is presented in table 1.

Table 1. Model for analyzing the level of development of material potential.

| Count | 1 | 2 | 3 | 4 | 5 |
|-------|---|---|---|---|---|
| 1     | Comprehensive assessment of the MP of a structural element of a product | $K_{n}^{\text{Material}} (X_i)$ | $B_{i}^{\text{Material}}$ | Country risk | Weighted estimate of the MP of the component |
| 2     | Product feature component | $K_{i}^{\text{Material}} (X_i)$ | | | |
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The analysis process consists of the following main stages: at the first stage, the structural and technological division of the product into structural elements and components is carried out. The weights of the components of the structural elements of the product and the structural elements of the product are determined in accordance with the principle of the importance, manufacturability and safety of the component / structural element in the entire product system. At the second stage, using the developed methodological tools (tables 2-3), the expert commission determines the category of the material potential of each of them for the corresponding component.

Table 2. Methodological tools for analyzing the level of development of the material potential of engine blade.

| Component of an aircraft engine | The level of development of materials | Evaluation |
|---------------------------------|--------------------------------------|------------|
| Engine blade                    | high-strength steels and alloys on nickel and iron-nickel bases, nickel-based alloys with heat-resistant and thermal barrier coatings, ceramic composites 1200-1500 °C; intermetallic alloy (VKNA-4 U, VKNA-1 V (MONO); refractory metals niobium with silicide coating, rhenium coated with iridium, molybdenum, tantalum, tungsten | 3 |
| nickel and titanium alloys without low performance thermal barrier coatings used since 1960. titanium alloys VT8-1, VT-8, VT-10, chromium steels 13Kh11N2V2MF, 13Kh14N3V2FR, nickel alloys ZhS-6K, ZhS-6F, ZhS-6UVI | 2 |
|                                 | 1 |

In accordance with the theory of technological paradigms, it is proposed to evaluate the product according to the rating scale: 1 – low level of development of material potential; 2 – the average level
of development of the potential of the material; 3 – the level of development of material potential is above average; 4 – the highest level of development of material potential.

Table 3. Methodological tools for analyzing the level of development of the material potential of working double shaft shaft, combustion chamber and heat pipes, screw drive turbine.

| Component of an aircraft engine | The level of development of materials | Evaluation |
|---------------------------------|---------------------------------------|------------|
| Working double shaft shaft      | chromium-nickel steel of low composition characteristics: carbon from 0.3 to 0.4%, nickel from 3 to 5% and chromium from 0.6 to 1.0%, chromium-nickel steel of medium composition characteristics, alloys 40KHNMA, EI961SH, EP517 High-performance PCM using the vacuum infusion method | 1          |
| Combustion chamber and heat pipes | chromium-nickel alloys for temperatures of 600-750 °C Kh20N80T, KhN60B, KhN 70Yu, KhN 38BT, Kh 24N25T chromium-nickel alloys for temperatures of 950 °C - alloy KhN60VKh20N80T, KhN38VT, KhN75MVTYu chromium-nickel alloys for temperatures of 950-1200 °C - alloy XH60B with glass enamel coating intermetallic alloy based on nickel intermetallic compounds (VKNA-4 U, VKNA-1 V (MONO), alloys resistant to thermal shock, oxidation resistance, with heat-resistant gas corrosion coatings, with thermal barrier coatings and ceramic cladding | 2          |
| Screw drive turbine            | Russian nickel-based alloys El 437BU-VD and El698VD Russian steels EP742ID, EK79U, EP962, R88DT titanium intermetallic alloys 650-1040 °C carbon composite materials | 3          |

At the third stage, the potential of the material of the product structural elements is assessed taking into account the degree of country risk. The territory of materials production for the aviation products and the territory of the assembling units, the assemblies and the aviation products themselves is extremely important from the point of ES view and the effectiveness of IP of AI in RF. Those constructive elements of the product that are created with the involvement of domestic industrial potential are recognized as economically safe and effective.

An additive-multiplicative model for assessing the level of the potential of the material’s development of the product’s m-th structural element is represented by summing the multiplication of the criterion weight by the quantitative estimate of the parameter (equation (1)).

\[
K_m^\text{Material}(X^i) = \sum_{i_m=1}^{n_m} K_{i_m}^\text{Material}(X^i) B_{i_m}^\text{Material} CR_{i_m}
\]

where \( K_{i_m}^\text{Material}(X^i) \) – assessment of the material potential of the \( i_m \)-th component of the m-th structural element of the product; \( n_m \) – number of components of the m-th structural element of the product; \( i_m=1\ldots n_m \) – component of the m-th structural element of the product; \( m=1\ldots m' \) – product structural element; \( B_{i_m}^\text{Material} \) – significance (weight) of the \( i_m \)-th component of the m-th structural element of the product, in fractions; \( CR_{i_m} \) – country risk ratio for production of the \( i_m \)-th element of the product.

The reliability of the assessment depends on the objectivity of the experts in the assignment of the marks and the weights. The examination process plays a special role. Forecasting, monitoring and
assessment of the level of the potential of the material’s development should be carried out by collecting and analyzing open information on RF and foreign databases: – Reference edition ASM Handbook; – Questel Orbit; – Google Scholar; – Google Patent; – SciFinder; – Information Disclosure Center ‘Interfax’; – ‘Mimosa’ database of Rospatent; – Springer Science Database; – Springer Links Database; – Information and statistical system of Rosstat; – Composites; – Project database Russian Foundation for Basic Research; – Public procurement database analytical tool. Also, the sources of data for the analysis are national and interstate standards.

There is an example of the analysis of the potential of the material of the TV7-117SM engine, the developer of which is joint-stock company Klimov for use on the Il-114 aircraft (table 4).

Table 4. Analysis of the potential of the material of the TV7-117SM engine.

| Feature Component                                      | Assessment | Weight | Country risk | Total value |
|--------------------------------------------------------|------------|--------|--------------|-------------|
| 1. Vane                                                | 4          | 0.1    | 0            | 0           |
| 2. Working twin shaft                                   | 3          | 0.2    | 1            | 0.60        |
| 3. Crankcase and shaft bearings                         | 3          | 0.1    | 1            | 0.30        |
| 4. Reducer                                             | 2          | 0.1    | 1            | 0.20        |
| 5. Air propeller                                       | 4          | 0.03   | 1            | 0.12        |
| 6. Combustion chamber and flame tubes                   | 3          | 0.34   | 0            | 0.00        |
| 7. Combined compressor                                 | 2          | 0.05   | 1            | 0.10        |
| 8. Single-stage and two-stage screw drive turbine       | 3          | 0.03   | 1            | 0.09        |
| 9. Generator                                           | 3          | 0.03   | 1            | 0.09        |
| 10. Jet cone                                           | 3          | 0.02   | 1            | 0.06        |
| 11. Turbo piping and tubes                             | 3          | 0      | 1            | 0           |
| 12. Sound absorbing structures                         | 4          | 0      | 1            | 0           |

In general, it should be noted that the materials used for the production of the engine belong to a greater extent to the fourth and third development categories. However, materials for the production of the engine blades (the specific weight of a blade in the structural and technological division of the engine is 10%) and the combustion chamber (the specific weight of a blade in the structural and technological division of the engine is 34%) are purchased abroad – the stratum risk coefficient is zero, which is in turn, ‘devalues’ the material potential of the engine components, reducing the estimate from 2.98 (excluding country risk) to 1.56 (low level of development). Thus, we think that it is necessary to strengthen the ES of the project by involving in the project a completely RF material and raw material base. It is also necessary to simultaneously analyze the level of development of human and technological potential for working with materials. The gap in the levels of development of the personnel, material and technological component of the project also significantly affects the results of IP.

4. Conclusion

The study reveals the features of the trends in the development of the chemical industry of the Russian Federation and the aviation materials. The scientific result of the research is the proposed hypothesis for studying the economic safety of a product in the context of material, technical and technological, personnel, service and financial potentials and a developed model for analyzing the level of development of the material potential of an innovative project of the aviation industry, which can be used by the main investor of the Ministry of Industry and Trade of the Russian Federation and
Managing organizations, and directly by the industrial enterprises themselves, implementing an innovative project.

The proposed analysis model allows the project management to establish the development level of the potential of the resource base in order to manage the product life cycle, to substantiate the presence of strategic risk of aircraft products, to analyze the external conditions of the project and the development trends of the materials, the technologies, the customer requirements, the competitors' products, to predict the characteristics of the products for the future, to analyze the feasibility of changing the material and raw material design base. Fundamentally, it is necessary to achieve a strategic balance – the correspondence of the project's capabilities to the desired and declared ultimate goals – both in terms of the economic security of the project and in terms of economic efficiency, quality and competitiveness of the final product. An automated information and analytical system for digital technologies for managing the life cycle of aviation products will help improve and speed up the process of engineering and appraisal activities.

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References
[1] Barkalov S, Moiseev S, Poryadina V and Kvasov D 2020 Economic security evaluation model of enterprises based on the latent variables theory. *E3S Web Conf.* 164 09050 doi: 10.1051/e3sconf/202016409050
[2] Tarasova E V, Nikolenko T Y, Gorbunov G L and Semina L V 2018 Implementation of investment projects at industrial enterprises. *Russian engineering research* 38(4) 295 doi: 10.3103/S1068798X18040214
[3] Nikolenko T Y, Semina L V and Burdina A A 2019 Role of digital economy in creating innovative environment. *IJRTE.* 8(3) 6477 doi:10.35940/ijrte.C4594.098319
[4] Li J and Xu H 2012 Reliability analysis of aircraft equipment based on fmeca method. *Physics. Proc.* 25 1816 doi: 10.1016/j.phpro.2012.03.316
[5] Ma B and Zhou Z 2014 Progress and development trends of composite structure evaluation using noncontact nondestructive testing techniques in aviation and aerospace industries. *Acta Aeronautica et Astronautica Sinica* 35(7) 1787 doi: 10.7527/S1000-6893.2013.0490
[6] Tie-Cheng G, Heng-Fei, Chuan-Zhen Z, and Wu B 2017 Progress of nondestructive testing techniques for aerospace composites. *Journal of Tianjin Polytechnic University* 36(1) 71 doi:10.3969/j.issn1671-024x.2017.01.013
[7] Eremin M Y, Moskvicheva N V and Melik-aslanova N O 2020 Servicing of imported airplanes by means of performance-based logistics. *Russian engineering research* 40(2) 146 doi: 10.3103/S1068798X20020112
[8] Gagarina G Y, Sorokina N Y, Chainikova L N, Sizova D A and Nadyrov S M 2019 Tools to ensure the economic security of the old industrial regions. *Entrepreneurship and Sustainability Issues* 7(1) 747 doi: 10.9770/jesri.2019.7.1(53)
[9] Burdina A A, Bondarenko A V and Manyenkov Y T 2019 Technology and structure of the development of personnel strategy of a project in the aviation industry. *IJRT.* 8(3) 416 doi: 10.35940/ijrte.C4208.098319
[10] Ryapukhin A V, Kabakov V V and Zaripov R N 2019 Risk management of multimodular multi-agent system for creating science-intensive high-tech products. *Espacios* 40(34)
[11] Tarasova E V, Nikulina E N and Moskvicheva N V 2017 Analysis of risk assessment methods of innovative projects. *Espacios* 38(49) 18
[12] Plakhova L V, Alekhina T A, Simonova E V, Pokrovskiy N V and Karpova I V 2020 Mechanisms and tools of the economic security system of economic entities. *AISC* 1100 468 doi: 10.1007/978-3-030-39319-9_54
[13] Klychova G, Zakirova A, Dyatlova A, Klychoval A, Zaugarova A and Zalyalova N 2019 Methodological tools to ensure economic security in the personnel management system of enterprises. *E3S Web Conf.* **135** 04008 doi: 10.1051/e3sconf/201913504008

[14] Popkova E, Abramov S A, Ermolina L V and Gandin E V and 2015 Strategic effectiveness evaluation as integral part of the modern enterprise management. *CCSE* **11**(20) 16 doi: 10.5539/ass.v11n20p16

[15] Tsybulevsky S E, Murakaev I M, Studnikov P E and Ryapukhin A V 2019 Approaches to the clustering methodology in the rocket and space industry as a factor in the formation of a universal production model for the economic development in the space industry. *INCAS Bulletin* **11**(S) 213 doi: 10.13111/2066-8201.2019.11.S.21

[16] Zolkin A L, Galanskiy S A and Kuzmin A M 2021 Perspectives for use of composite and polymer materials in aircraft construction. IOP Conf. Ser.: Mater. Sci. Eng. **1047** 012023 doi: 10.1088/1757-899X/1047/1/012023

[17] Ma L, Zhang J, Yue G, Liu J, and Xue J 2015 Application of composites in new generation of large civil aircraft. *Fuhe Cailiao Xuebao/Acta Materiae Compositae Sinica* **32**(2) 317 doi:10.13801/j.cnki.fhclxb.20150122.001

[18] Nagashireshaa G, Sridharb T S and Chandrac S 2012 Global patent scenario of materials: An IP analysis. *Mater. Sci. Forum* **710** 792 doi: 10.4028/www.scientific.net/MSF.710.792