Tools for intellectual support of project decisions based on analyzing uncertain factors of a different nature

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Abstract. Today, the management of complex innovative projects to create new aircraft is carried out in the conditions of uncertainty, which is due to the lack of "high-quality" (complete, accurate, consistent, etc.) data on their internal and external environment. In this situation, to support the adoption of project decisions, it is advisable to use an approach based on the identification and assessment of NON-factors that have a negative meaning in natural language and deny one of the basic properties of formal systems. The authors propose a procedure for analyzing NON-factors in project risk management, based on the assessment of uncertain factors of internal and external project environment using various methods of data mining (particularly, neural fuzzy classifier, fuzzy pyramidal networks, fuzzy logic methods, fuzzy Kalman filtering algorithms). Using the proposed approach will increase the validity of decisions on the viability of such innovative projects and a set of measures for risk management.

1. Introduction

The aircraft industry is one of the Russian science-intensive industries facing the acute problem of import substitution. This is due to the fact that its products solve the strategic tasks of ensuring national security, meeting the transport needs of the people and business, creating jobs. In addition, it is a major consumer of products of many sectors (in particular, metallurgy, nanoindustry, petrochemistry, fuel and energy complex, mechanical engineering, etc.).

In the XX century, the USSR was one of the leaders in the world aircraft industry. However, after its collapse, there was a reduction in funding and a decrease in effective demand for air transport services. This led to a sharp decline in aircraft production. In turn, one-off production led to the arrival of the largest foreign companies Boeing and Airbus on the domestic market [1]. However, the recent macroeconomic and geopolitical events (in particular, the introduction of various sanctions against Russia) have shown the strategic need for intensive development of the domestic aircraft industry. This should be carried out by the creation of advanced aircraft technology using new composite materials and fuel-saving technologies.

Analysis of aircraft manufacturers revealed a set of specific features that must be taken into account when developing complex projects to create new aircraft:

- long cycle of aircraft development (the creation of a new aircraft takes over 10 years, and its flight tests and preparation of serial production take another 8-10 years);
• high cost of complex projects to develop new aircraft (the creation of a large commercial aircraft costs about $10-15 billion) [2];
• long payback period for the purchase of an aircraft (for example, for a regional air carrier it often exceeds 15 years);
• high cost of an error (according to research by the Gartner Group, error elimination requires $1 at the stage of aircraft design and $1 million at the stage of serial production);
• a long period of aircraft operation (the average flight life is about 40 years), which determines the importance of the system of maintenance and repair.

The above features confirm the high importance, duration and cost of the planning stage. Moreover, special attention should be paid to the identification and analysis of various risk situations that may arise during the project implementation. According to the latest foreign studies, in the short term, risk situations may be due to the following reasons:
• long supply chain (often there are only a few suppliers of critical parts);
• fluctuations in prices of key components and raw materials;
• need for highly qualified personnel with unique competencies [3];
• significant impact of force majeure situations (terrorist acts, armed conflicts, natural and technological disasters, pandemics, etc.) on the use of air transport;
• strong influence of geopolitical decisions on the development of the aircraft industry, air transport and air communication;
• constant tightening of requirements for design, maintenance, pilot training and flight safety regulations [4];
• constant growth of prices for aviation fuel;
• increase in the number of cybersecurity threats [5].

Each fact can lead to various risk situations that will negatively affect the project implementation. They can not only significantly increase the duration and cost of the project, but also lead to its complete failure. This determines the high importance of the project risk management system.

This system should be based on the analysis of information that comes from various elements of the internal and external environment of a complex project to create aircraft. The internal project environment is formed by the participants of the technological chains, whose activities are influenced by various factors of the external environment. As a result, the number of factors that have different (positive or negative) effects on the project implementation becomes quite large. This leads to a complication of the task of risk modeling, and, consequently, an increase in the cost and duration of the project planning stage. In this regard, the task of identifying and assessing the factors of the internal and external project environment, which can extremely negatively affect the effectiveness of its implementation, acquires particular relevance.

Today there are many approaches to identifying and assessing project risks, which are largely based on qualitative analysis and probabilistic statistical methods [6, 7]. However, the unique nature of the projects, due to the above-mentioned features of the industry, does not allow the formation of a sufficient amount of "qualitative" data on the internal and external environment, necessary for the project risk analysis. This determines the feasibility of using artificial intelligence methods, which make it possible to obtain informed decisions in conditions of information uncertainty.

The aim of this work is to develop an approach to identifying and assessing the risks of complex projects to create aircraft, based on using intelligent analysis of data on the factors of the internal and external environment, which can lead to a decrease in the effectiveness of its implementation.

2. Procedure for the NON-factor analysis in project risk management
In conditions of information uncertainty associated with the lack of "qualitative" (complete, accurate, consistent, etc.) data on the factors of the internal and external project environment, it is advisable to use the approach of identifying and modeling the NON-factors, which is considered one of the key directions of artificial intelligence development in recent years [8].
The term NON-factor was proposed by Narinyani A.S. to describe "partial knowledge" as an element of the Knowledge System. It was used to designate a set of factors that have a negative assessment in natural language and deny one of the basic properties of "classical" formal systems [9]. The concept of NON-factors has received significant development only in recent years when artificial intelligence methods have been actively used to model real socio-economic and technical systems and to support decision-making. So, the study of NON-factors was carried out by Borisov A.N., Vagin V.N., Rybina G.V., Tarasov V.B. who offered various criteria for their definition and classification. However, despite some differences, these authors used it to describe the features of a set of properties that correlate with various “defects” of both the knowledge itself and the Knowledge System. Another approach suggested by Valkman Yu.R. defines and classifies NON-factors based on the object of the study identifies universal (common to all subject areas) and special (specific only for a specific area) NON-factors, and methods for their modeling.

In the foreign literature, the concept of NON-factor is not directly considered. However, there are works devoted to the study of various factors of uncertainty. For example, Denœux T, Dubois D. and Prade H. investigated the factors of inaccuracy and uncertainty and proposed their modeling based on quasi-measures of possibility and necessity using the theory of fuzzy sets [10]. Beynon M. investigated the problems of modeling the inaccuracy and unconfidence of expert judgments used in developing project solutions. He proposed a hybrid method for analyzing risk sources based on the combination of the Saaty analytical hierarchy process and Dempster-Shafer theory [11].

Based on the analysis of the subject area specifics and the scientific problem, a generalized procedure for assessing NON-factors is proposed. This procedure can be used to support decision-making on risk management of complex projects to create a new aircraft:

1. Detecting a set of factors of the internal and external environment that can in any way affect the project implementation. Its result will be a set of NON-factors that can lead to negative consequences for the project.
2. Identifying NON-factors (sources of project risks) which consists of their distribution into pre-allocated classes that determine the degree of their criticality for the project.
3. Assessing the possibility of a systemic effect from the impact of a set of NON-factors on the project. Its results will justify the choice of tools for assessing NON-factors and their combination.
4. Assessing of NON-factors identified in the internal project environment. Its result will be a quantitative assessment of one or several risks that are most significant for the internal project environment.
5. Detecting and predicting the values of NON-factors of the external project environment, which are subject to serious changes over time (e.g., various macroeconomic indicators).
6. Assessing NON-factors of the external project environment carried out taking into account the prediction of the dynamics. The result will be a quantitative assessment of one or several risks that are most significant for the external project environment.
7. Combining the results of quantitative assessments of NON-factors, i.e. a generalized assessment of risks will be obtained for the internal and external environment separately.
8. Aggregating assessments of risk identified in the internal and external project environment.
9. Making a management decision on the project viability taking into account the results of the project risk analysis. In case of a positive decision, a set of measures to manage project risks will be developed.

Due to the lack of "qualitative" statistical information about the analyzed project, it is proposed to use the methods of intellectual analysis as tools for implementing the above procedure. The methods considered below make it possible to work with both metric characteristics and linguistic descriptions of factors in natural language.
3. Tools for the implementation of the proposed procedure for the NON-factors analysis

3.1. Neural fuzzy classifier for identifying NON-factors
In general, the identification of NON-factors that can negatively affect the effectiveness of the project implementation is reduced to the classification task. It consists of distributing various factors of the internal and external project environment into pre-allocated classes according to their importance (criticality).

To solve this problem, it is proposed to use a neural fuzzy classifier that combines the advantages of neural networks and fuzzy logic methods. It allows classifying NON-factors based on the analysis of available information and expert opinions.

The authors proposed to use a five-layer neural fuzzy classifier to identify the NON-factors of the internal and external project environment. The input is submitted by expert assessments of the investigated NON-factor, the volume and quality of the available information. The output is the degree of membership of the NON-factor to predefined classes [12].

The use of the described neural fuzzy classifier allows identification in conditions of information uncertainty caused by the lack of "quality" data about the investigated NON-factor.

3.2. Hartley emergence coefficient for assessing the systemic effect
When choosing tools for assessing NON-factors, it is necessary to take into account the fact that they can have a negative impact on the project, both individually and in combination. However, situations of influence of one NON-factor are typical only for simple projects (for example, production of analog products). The implementation of complex project to create aircraft is usually influenced by a large number of NON-factors of various nature, which have complex interrelationships.

With the simultaneous influence of several NON-factors on the project, the emergence property (or systemic effect) may appear. It is associated with the emergence of new properties in a complex system due to the interaction of its elements, i.e. the properties of the system do not coincide with the properties of its subsystems.

In the considered scientific and practical task, NON-factors (i.e. sources of project risks) will be considered as elements of the system. Thus, the risk of an innovative project will be the result of the appearance of a systemic effect from a certain set of NON-factors.

For a quantitative assessment of the value of the systemic effect, it is proposed to use the Hartley emergence coefficient [13]. It characterizes the relative excess of the amount of information about the system, taking into account various systemic effects, over the amount of information determined without taking them into account.

The results of calculating the emergence coefficient will be used to select a method for assessing NON-factors that affect the implementation of the project:

- If the value of this coefficient is small, then the project risk is due to a single NON-factor or a simple combination of a small number. In this case, it is advisable to use fuzzy logic methods.
- If the coefficient has a high value, then all the NON-factors must be combined into a system. In this case, it is advisable to use fuzzy pyramidal networks, which allow analyzing complex relationships between system elements.

3.3. Fuzzy pyramidal networks for assessing NON-factors
To assess the NON-factors affecting the project implementation in the aggregate, it is proposed to use fuzzy pyramidal networks that allow describing the structure of complex systems in a natural language form. They are based on the growing pyramidal networks developed at the Institute of Cybernetics of the Academy of Sciences of USSR.

The advantage of the apparatus is the automatic construction of the network, regardless of the initial data. Knowledge representation is optimized by adapting the network structure to the characteristics of the incoming information without introducing a priori redundancy.
A pyramidal network is an acyclic directed graph consisting of receptors (particularly, sources of project risks in the internal/external project environment), conceptors (intermediate vertices), outcomes (integrated project risk assessments). The construction of a pyramidal network consists of determining the structural relationships between the indicative descriptions of the subject area.

The peculiarities of the scientific problem determine the need to modify the learning and recognition algorithms for the growing pyramidal network [14]. The [15] describes in detail the modification of the original algorithms of growing pyramidal networks, performed by introducing elements of fuzzy logic. Its result was the ability to assess the influence of some factors on others and the degree of their importance in the process of finding a single solution.

The use of the described apparatus makes it possible to assess the project risks of the internal and external environment, taking into account the complex relationships between their sources, even in conditions of information uncertainty.

3.4. Fuzzy Kalman filtering for predicting NON-factors
When analyzing the external project environment, usually there are factors determined with various distortions, which can be considered as the "noise" of observations. In conditions of "noisy" data, it is advisable to use a predicting tool such as the Kalman filter [16]. However, the presence of information uncertainty makes it impossible to use the statistical Kalman filter. In turn, this determines the need for its modification by introducing elements of fuzzy logic.

In article [17] it was proposed to use two contours of the Kalman filter:
- the first circuit processes information about the state of the macro- and microeconomic environment and generates a state assessment vector, which is involved in adjusting the parameters of the second filtering circuit;
- the second circuit carries out a short-term forecast of the values of some NON-factors of the external project environment.

The proposed approach, based on the complex use of statistical filtering algorithms and fuzzy logic methods, will make it possible to form a short-term forecast of values of NON-factors in conditions of noisy data, the volume of which does not allow using the known variants of the Kalman filter.

3.5. Fuzzy inference algorithms for assessing and aggregating NON-factors
To assess NON-factors that are independent of each other and do not lead to a systemic effect, it is advisable to use fuzzy logical inference according to the Mamdani algorithm. It allows assessing the possibility of a risk event as a result of triggering a small number of NON-factors based on the analysis of available quasi-statistics and expert data.

The combination of the results of assessing NON-factors that negatively affect the implementation of an innovative project to create high-tech products is carried out in two steps. First, the project risk assessments are integrated for the internal and external project environment separately. Next, their results are combined, i.e. the final assessment of project risks is formed.

To perform the operations of combining the results of assessing the identified NON-factors, it is proposed to use fuzzy logical inference according to the Larsen algorithm, which is characterized by increased calculation accuracy.

4. Conclusion
The implementation of complex projects to create new aircraft is a very long and highly costly process that requires careful planning, with special attention to the analysis of project risks. Traditionally, probabilistic and statistical methods are used to assess risks; however, the unique nature of such projects does not allow collecting a sufficient amount of "qualitative" (complete, accurate, consistent, etc.) data, i.e. a situation of information uncertainty arises.

To solve this problem, the article proposes a new approach to analyzing the viability of complex projects, based on the identification and assessment of NON-factors (sources of project risks) that arise in the internal and external environment. It is based on the complex use of various methods of data
mining (in particular, neural fuzzy classifier, fuzzy pyramidal networks, fuzzy logic methods, fuzzy Kalman filtering algorithms). Its practical application will make it possible to timely identify and adequately respond to risk situations that can have an extremely negative impact on the project results.

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References

[1] Russia’s Aircraft Industry is Endeavouring to Preserve its Key Competences, Russian Aviation Insider, available at: http://www.rusaviainsider.com/

[2] Aircraft Technology Roadmap to 2050, International Air Transport Association, available at: https://www.iata.org

[3] The Top 10 Risks the Aviation Industry is Facing, Satair, 2020, available at: https://blog.satair.com

[4] European Plan for Aviation Safety (EPAS) 2021-2025 Volume III, European Union Aviation Safety Agency, available at: https://www.easa.europa.eu

[5] Lykou G, Iakovakis G and Gritzalis D 2019 Aviation cybersecurity and cyber-resilience: assessing risk in air traffic management. Critical Infrastructure Security and Resilience. Advanced Sciences and Technologies for Security Applications. eds. Gritzalis D, Theocharidou M and Stergiopoulos G (Cham: Springer) p 245

[6] Bernardo A E, Chowdhry B and Goyal A 2012 Assessing project risk. Bank Am. J. Appl. Corp. Finance 24 (3) 94 https://doi.org/10.1111/j.1745-6622.2012.00393.x

[7] Chen Z C, Yao and Yang J J 2014 A research review of project risk assessment methods. Appl. Mech. Mater. 496-500 2857 https://doi.org/10.4028/www.scientific.net/AMM.496-500.2857

[8] Gordienko LV and Ginis L A 2018 Expert estimates processing and decision-making taking into account NON-factors. Proc. XIV Int. Scien.-Techn. Conf. on Actual Problems of Electronics Instrument Engineering (Novosibirsk: IEEE) p 84

[9] Narinyani A S 2019 Introduction to underdetermination. Problems of Informatics 1 61 [in Russian]

[10] Denœux T, Dubois D and Prade H 2020 Representations of uncertainty in AI: beyond probability and possibility. A Guided Tour of Artificial Intelligence Research. eds. Marquis P, Papini O and Prade H (Cham: Springer) p 119 https://doi.org/10.1007/978-3-030-06164-7

[11] Beynon M 2002 DS/AHP method: A mathematical analysis, including an understanding of uncertainty. Eur. J. Oper. Res. 140 148 https://doi.org/10.1016/S0377-2217(01)00230-2

[12] Bulygina O V and Emelyanov A A 2020 Analysis of NON-factors in innovative project management CEUR Workshop Proceedings 2782 217

[13] Bulygina O V, Emelyanov A A and Ivanova O A Intelligent tools for analyzing NON-factors of the project environment. J. Phys. Conf. Ser. 1862 https://doi.org/10.1088/1757-899X/1862/1/012017

[14] Gladun V, Velychko V and Ivaskin Y 2008 Selfstructurized system. International Journal Information Theories and Applications 15 (1) 5

[15] Bulygina O V and Chernovalova M V 2016 Application of fuzzy pyramidal network tools for analyzing the IT-project feasibility Proc. of the Int. Academic AMO-SPIITE-NESEFF (Smolens: Publishing “Universism”) p 89

[16] Kalman R E 1960 A new approach to linear filtering and prediction problems. J. Basic Eng. 86 (1) 35 https://doi.org/10.1115/1.3662552

[17] Dli M I, Bulygina O V, Emelyanov A A and Selyavskiy Y V 2020 Intelligent analysis of complex innovative project prospects. IOP Conf. Ser.-Mat. Sci. 919 042019 https://doi.org/10.1088/1757-899X/919/4/042019