# Differential-Integral Approach to the Competition Resistance Evaluation of Aircraft Engine Manufacturing Organization

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***Abstract*** **– The goal was to develop original approach to evaluating the competition resistance of an organization as an integrator of intra-organizational interaction to obtain a synergy effect. Hypothesis: the evaluation of competition resistance should be integral and predictive. The proposed approach allows forming an original set of indicators reflecting the multidimensional nature and specifics of the science-intensive and high-tech industrial organization activity under the conditions of changing external environment. Results: selection criteria, sets of indicators, levels of intensity and competition resistance matrix give science-intensive and high-tech companies timely opportunities identification and innovative development and, accordingly, a stable position in the market.**

***Keywords*** **– Competitiveness of aircraft engines, criteria for the selection of indicators, competition resistance evaluation matrix, synthetic indicators, aggregate competitive potential.**

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## 1. Introduction

Increasing the competitiveness of aircraft engine manufacturing is predetermined by the level of development of an organization's abilities to form key competitive advantages based on timely qualitative transformations of the intra-organizational environment taking into account external factors. The main characteristic of an organization's ability to gain strong positions on the market is the level of intra-organizational interaction in the processes of identifying and creating key competencies. The article is devoted to the implementation of the differential-integral approach to the evaluation of competition resistance as the ability of an organization to reorganize the intra-organizational environment in a timely and efficient manner (processes, structures, methods, and resources) to maintain and strengthen its competitive positions on the market. The basis of forming a set of indicators is an iterative process of selection, based on a specific set of criteria, excluding the subjectivity of evaluations. The development of criteria is the result of the authors' research. A timely assessment of the prospects for the development of the aggregate competitive potential of an organization, the search for possible risks of losing internal stability against the background of various levels of competitiveness intensity, will allow heads of organizations to decide on the urgency of conducting and specifying changes in the organization with the aim of strengthening their market positions. The most critical directions are determined using the organization's competition resistance matrix proposed in the article by analyzing the elements of aggregate competitive potential and various combinations of symptoms of tension in an organization in respect of situations in the external environment, which is also the result of the authors' research.

## 2. Research background

According to the Global Competitiveness Report 2016-2017 on the competitiveness of world economies presented on the World Economic Forum, the Russian Federation ranks 43rd out of 138 countries participating in the study, after Poland, Lithuania, Estonia, China, and India [1]. The analysis is conducted in accordance with twelve groups of indicators: higher education and training; market size; health care and primary education; technological readiness; product market efficiency; innovation; infrastructure; business sophistication; labor market efficiency; financial market development; macroeconomic environment; institutions. The Russian economy in this study is characterized as passing from the first stage of development to the second one, along with such countries as Algeria, Azerbaijan, Bhutan, Bolivia, Botswana, Brunei, Gabon, Honduras, Kazakhstan, Kuwait, Mongolia, Nigeria, Philippines, Ukraine, Venezuela and Vietnam, because Russia's economy is based on the extraction of mineral resources, and mineral resources amount to 70% of export.

However, for 2016-2017 Russia improved its position by 2 points, and moved from the 45th place to the 43rd one. According to the reports of the World Economic Forum for 2013-2014, Russian was actually in 64th place. It can certainly be stated that there is improvement of the real sector of the economy and the investment climate in the country. According to the Ministry of Economic Development of the Russian Federation, the Russian economy has growth prospects. Thus, for the first quarter of 2017, the industrial production index, although slightly, increased by 0.1%. Heavy industry is actively developing, for example, the production of machinery and equipment increased by 8.2% [2]. The first half of 2017 also finishes at a successful note for the Russian economy.

According to the Federal State Statistics Service, the industrial production index in January-September 2018, compared with January-September 2017, amounted to 103.0%, in September 2018, compared to September 2017 – 102.1%, and compared with August 2018 – 102.5% [3]. On the one hand, this indicates the correctness of the choice of import substitution policy. On the other hand, according to Dunets, a process of stagnation has begun in Russia, and even a decline has been observed in all sectors of the economy, which obviously undermines its competitiveness [4].

The most effective tool for improving the competitiveness of an enterprise and the state as a whole at the present stage is the development of high-tech product manufacturing [5].

The Russian aerospace industry, which is capable of supplying competitive products, both to the domestic and foreign markets, is a high-tech industry. In this regard, the main goal currently is to maintain the position of the world's largest aerospace power, which owns the advanced developments demanded by the market.

In recent years, this market has become increasingly competitive. If previously the USA, Germany, Great Britain, Italy, France, Sweden, and Israel were Russia's competitors, now Canada, Brazil, Argentina and Spain, Japan, the DPRK, India and China feel confident in this segment.

The potential of engine manufacturing development is in high demand for its products. The domestic aviation industry and engine manufacturing thus presuppose, for example, a 10-15 percent level of the world market for civil aviation technology in 2020-2025.

To achieve a high level of competitiveness in the global market, the Russian industry should create a line of perspective aircrafts and engines, develop scientific and research, design-engineering, technolo gical and production potentials, expand the use of composite materials, and improve the system of personnel training and retraining.

In June 2017, at the international aviation and space show “Paris Air Show 2017” in Le Bourget (France), the United Engine Corporation demonstrated modern Russian commercial aircraft engines, including the newest PD-14 engine developed for the Russian aircraft MS-21-300 and the Russian-French engine SaM146, installed on passenger aircraft Sukhoi Superjet 100. Despite the fact that because of the sanctions, France banned the import of Russian weapons – and even at military-technical shows, “this year, 25 companies represent Russia at the air show. It is quite sufficient for the West that is bursting into confrontation with Russia”.

So, Boeing and Airbus, whose duopoly has dominated the world market for many decades, will have to make room, although they themselves believe that with programs such as the Airbus A380 and A350 and Boeing 787 they will be able to drown all the strongest aerospace companies: Chinese, Russian and Japanese ones, Canadian Bombardier and Brazilian Embraer. However, the advantage of the Russian United Aircraft Corporation and Commercial Aircraft Corporation of China is that they are state-owned and controlled companies, that is, funded by the government, and commercial considerations may be less important during the development phase of the Russian and Chinese commercial aerospace projects [6], which, surely, can compete with Boeing and Airbus.

To increase the competitiveness of domestic aircraft engines, that is, to achieve high technical

performance, safety, comfortable price, low operating costs, it is necessary to develop new test methods, automate engine creation processes, improve scientific and technical documentation to regulate the engine creation process in conjunction with the widespread use of mathematical models.

The competitiveness of aircraft engines is a complex category, the advantages of which are finally realized in the global market of aviation products, but the basis of competitive advantages is created within the production itself and in all parts of the design process and the production of fundamentally new products.

The dependence of external evaluations of the product competitiveness is evident on the applied technologies and production system, on the quality management system and sales system, as well as on the level of the organization management system, that is, on the organization's ability to maximally satisfy consumer requests and at the same time to have a high level of efficiency of production and economic activity. In this regard, there is a need to improve the internal system of self-evaluation of an organization's competitiveness and link it with external evaluations and in comparison with other competing organizations.

## 3. Methods

The authors clearly differentiate the concepts of competitiveness and competition resistance. It is believed that in relation to an organization, one should speak not about its competitiveness (that is, external evaluation), but about competition resistance, as an internal ability of an organization to form and use in the long-term prospect an aggregate competitive potential that ensures a favorable market position and is a combination of resources, processes and tools that determine the organization's capabilities, boundaries and effectiveness in a dynamic environment.

"A modern aircraft engine is a unique engineering product, which has practically no analogs in terms of voltage and thermal state. In this regard, the aircraft engine manufacturing abroad is included in the list of the most important critical technologies and, while ensuring the creation, is considered as an independent commercial product" [7].

The market of aviation equipment, especially aircraft engines, is strained enough in terms of competition, and to firmly conquer its niche, Russian manufacturers need not only to create mechanisms, resistant to competition but also to constantly monitor it in order to timely transform the internal organizational environment, ensuring the key competitive advantages of their products. Competition resistance involves the stable operation of all production systems of an enterprise in a competitive environment. This more concise concept is revealed by the ability not only to compete with products but also to have all the components of potential at a high competitive level (technology, equipment, trained personnel, economic and financial stability, and social security). Management of competition resistance allows creating and controlling the development and forming the potential of the production system for all its components at a high quality level.

From this point of view, there is an obvious need to develop a method for evaluating the competitiveness of an organization and an original set of indicators for its continuous monitoring.

The evaluation of an organization's competitiveness is integral because it synthesizes into a single complex model the characteristics of product competitiveness, the organization's achieved final business results for a certain period or several time intervals, the state of an economic entity depending on a set of factors (technology and production system, quality and sales system, organization management system) and environmental factors. Surely, such an evaluation will require the systematization of a huge number of different sets of indicators.

Methods. As George L. Michael points out, "the competitive potential of an enterprise is an evaluation of an enterprise's performance in terms of the presence of its internal and external competitive advantages, enabling the enterprise to create competitive goods, both now and in the long run" [8], which confirms the thesis regarding the need to evaluate the competitiveness of an organization and its dependence on the competitiveness of products.

Given that an organization's potential is considered as an aggregate integrity, connecting various combinations of elements (sub-potentials) and the processes of their interaction between themselves and the external environment, and the uniqueness of combinations of components of the potential elements and the processes of their interaction provides such characteristics of the organization that cannot be copied by competitors, thus the differential-integral approach to evaluating the competition resistance of the organization is appropriate:

- differentiation consists in decomposing the aggregate potential of an organization (APO) into constituent elements (sub-potentials) and forming a set of indicators for each of them, to the greatest extent, reflecting the state and development trends, as well as the share of each sub-potential in the aggregate (integral) effect. The structure of APO includes: industrial, organizational and managerial, social and personnel, resource, financial, investment, innovation, environmental, market and integration potential. The integration potential ensures the connection of separate parts of APO and the processes of unification into a single whole and obtaining a specific useful result, as a general total of their joint and coordinated functioning, synergistic interaction and sustainable development;

- integrality is expressed in the synthesis of complexes of indicators for evaluating potentials as part of APO in a single model, which allows describing the result of their interaction. Integrality is a systematic concept reflecting the inseparable connection, wholeness, and unity of integral individualities (groups of indicators, sub-potentials), which logically and harmoniously combine into a single whole to ensure synergy of interaction, otherwise their partnership will not take place.

In this regard, there is a need for the selection of indicators for groups (sub-potentials) according to some criteria – rules, as certain settings, constant ratios, which are the same for everyone.

A question can be raised here: why not use a known system of strategic indicators? [9],[10],[11],[12],[13]. The answer is simple: the system of strategic indicators is bulky, not protected from leaks and not suitable for modeling uncertainties and risks, after its implementation, it requires many years of further development. The authors use traditional indicators and from them create combinations and relations that are selected according to the elaborated criteria.

During the research, the following criteria for the selection of indicators for evaluating the competition resistance of an organization were adopted by the authors:

- equal participation in the investigated phenomenon, which requires weighing and determination of the impact (influence) of a change in an indicator on the general state of the object/phenomenon;
- one-dimensionality of indicators, which is necessary for observing multidirectional and multi-dimensional indicators in one coordinate system. In the authors' case, the method of indexation of indicators is the most acceptable;
- relativity of indicators, that is, firstly, indicators are relations, and secondly, they are the benefit-cost ratios;
- sensitivity of indicators to changes in the external and internal environment of the organization. The indicator is sensitive if it responds to changes by fluctuations of ± 10%;
- taking into account the influence of the external environment, that is, some synthetic indicators that establish the relationship between external and internal factors of competition resistance.

To evaluate the tendency of competition resistance and its forecasting in a graphical format, methods of composite and aggregate indexes are used, which allows using technology to reproduce the planar image of the entire set of indicators for evaluating the competition resistance (or aggregate competitive potential) of an organization in the "n" – dimensional space. In addition, the peculiarities of evaluating the competitiveness of the aircraft engine industry should be taken into account, since the special characteristics of the "aircraft engine made it possible to turn aviation into the most important global transport system and the main component of the country's defense capability" [14].

Given that processing the entire array of indicators is time-consuming and costly, to simplify and increase the objectivity of the results, as mentioned above, the authors have proposed an approach consisting in selecting the most significant indicators according to some criteria. For these purposes, the indicators of each group are divided into:

1) basic one;
2) derived one;
3) synthetic one (Figure 1.).

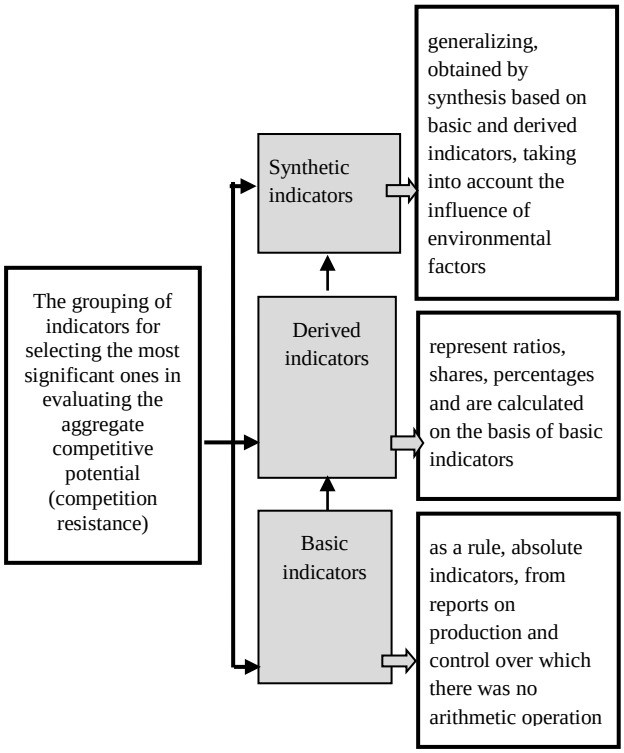


*Figure 1. Differentiation of indicators to select the most significant ones for evaluating the total competitive potential (competition resistance) (elaborated by the authors)*

Basic indicators are indicators, economic values, taken as a basis, comparison bases, comparisons with other indicators. In the elaborated self-evaluation system, the basic indicators are absolute indicators that are accepted in analytical calculations, since they are taken from reports on production and management and with which there was no arithmetic operations – addition, deduction, multiplication, and division. These can be indicators of production and sales volumes, the number of employees, the cost of production and sales of products, fixed and working capital, as well as the number of managerial personnel. Basic indicators are used to calculate derived indicators.

Derived indicators represent ratios, shares, percentages and are calculated based on basic indicators. These may include the indicators of labor productivity, cost of return, average wages, the profitability of production, capital productivity, capital-labor ratio, consumption rates, etc.

Synthetic indicators are generalizing, obtained by means of synthesis based on basic and derived indicators, as well as taking into account the influence of environmental factors.

The selection and choice of indicators from the formed complex in groups, taking into account the division into basic, derived and synthetic indicators, is conducted in the following stages:

1. The selection of indicators according to the principle of "affects – does not affect".
2. Expert evaluation (on a scale from 1 to 10) of the significance of all selected indicators.
3. Elimination of indicators with low scores of significance.
4. Formation of a complex of indicators based on a matrix of pairwise comparison of indicators according to the following system: 0 – the indicator has a lesser significance, 1 – indicators are equal in significance, 2 – the indicator has a greater significance.
5. The calculation of the amount obtained for each indicator and the choice of 10-14 indicators with the highest amount, taking into account the ranking of the indicators.
6. The final selection of indicators by the method of dynamic evaluation, operating with such a characteristic as the degree of the impact of a change in an indicator on the competition.

## 4. Results and discussion

The main effect is arranging information flows, which is as follows:

1) Quick detection of "bottlenecks",
2) Identification of the main blocks and key indicators that are unsatisfactory;
3) Update of the obtained results;
4) Improving the efficiency and quality of decisions;
5) Saving of time.

Thus, an algorithm is used to select indicators for each differentiated group (by sub-potentials or by aspects of the organization's activities). As a result, a complex of a limited number of the most significant (key) indicators for evaluating the competition resistance of an organization is obtained. In the authors' study, the possibility of express evaluation based on the elaborated matrix of the organization's competition resistance has been established (Table 1.).

*Table 1. Matrix of competition resistance of an organization*

| Integral indicators by types of sub-potentials of an organization | Levels of competition intensity | | | | | | | Indicator of risk |
|---|---|---|---|---|---|---|---|---|
| | Level of market concentration | | Profitability level in the industry | Level of the norm of use value | | | | |
| | Index of concentration | Herfindahl-Hirschman index | | econ | tech | soc,psyc. | ecolog. | |
| Manufacturing, $I_{mn}$ | x | x | x | x | x | x | x | x |
| Organizational and managerial, $I_{om}$ | x | x | x | x | x | x | x | x |
| Social and personnel, $I_{sp}$ | x | x | x | x | x | x | x | x |
| Resource, $I_{resource}$ | x | x | x | x | x | x | x | x |
| Investment, $I_{invest}$ | x | x | x | x | x | x | x | x |
| Ecological, $I_{ecol}$ | x | x | x | x | x | x | x | x |
| Market, $I_{mar}$ | x | x | x | x | x | x | x | x |
| Integrative, $I_{integ}$ | x | x | x | x | x | x | x | x |
| Total | | | | | | | | |
| Indicator of "total" internal resistance | | | | | | | | x |

On a 10-point scale (0-10), the state of affairs in the organization is assessed based on scanning informative points and levels of potential competitive intensity, which could have a devastating effect on the competitive resistance of an organization. The matrix was elaborated by the authors on the basis of adapting Ekaterinoslavskii's approach [4].

As informative points in the matrix, integral indicators are used by the types of sub-potentials that make up the aggregate competitive potential. The levels of competition intensity are as follows:

- the level of market concentration, since the aviation equipment market is highly concentrated;
- the level of profitability of the industry;
- the level of the norm of use value.

The level of market concentration involves the definition of the following indicators [9];

- concentration index, which allows identifying the market share of large organizations;
- Herfindahl-Hirschman index, which is used to estimate the degree of uneven distribution of shares of companies in the industry.

The level of profitability of the industry is used to assess the deviations of the profitability of the studied enterprise from the average value of the industry.

The norm of use value allows taking into account the industry specifics. The competitiveness of aircraft engines (AE) is a multiparameter phenomenon, so it is assessed in an integrated manner.

The complexity of achieving the required level of competitiveness of aircraft engines is determined by the need to take into account a large number of time-varying price and non-price parameters that have different structure and content at different levels of data collection and accumulation, as well as the

multidimensional assessments that have developed in the global market of aircraft engine manufacturing.

To assess the level of the norm of the use value of aircraft engines, four main components were identified in this study:

- economic: cost of ownership, cost of maintenance, residual value and sales;
- technical: the level of reliability of the power plant (level of reliability; the frequency of shutdowns in flight, the frequency of visits to the repair shop, the resource until the first removal of a wing); fuel efficiency; the cost of maintenance of aircraft engines; operational producibility (maintainability);
- social and psychological: personnel policy, corporate culture, ambitions and independence of decision-making of performers, the image of the organization, etc.
- environmental: compliance with promising environmental requirements, in particular, the International Civil Aviation Organization standards.

Many studies have a legal component. But most importantly, estimates of the levels of competition intensity are based on comparison with competitors.

The indicator of total internal stability (ITIS) indicates the presence of synergetic problems arising from the simultaneous occurrence of tension in two or more points at the same time. The ideal option is when the ITIS amounts to zero, but if this estimate falls outside “70” limits, then it is urgent to take action. The most pressing directions are determined by analyzing not only the rows of the matrix but also all combinations of symptoms of tension in an organization [4].

## 5. Conclusion

The competition resistance matrix provides an answer to the question: “what needs to be changed today in an organization of production and intra-production cooperation to ensure, over a certain period of time, an increase in the competitiveness of business results (i.e., aircraft engine manufacturing products) and sustainable competitive advantages on the market”. Thus, the differential-integral approach to evaluating the competition resistance of an organization, which is to the greatest extent determined by the level of internal production interaction or the level of organizational synergies under the influence of a changeable external environment, becomes an effective and very important tool for managing the development of an organization's aggregate competitive potential.

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