Analytical approach to the diversification effect evaluation of the innovative engineering projects portfolio for a machine-building enterprise

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Abstract. As a tool to reduce the risks of innovation at the machine-building enterprises the authors suggest a new methodology aimed at point-based assessment of innovation risks. However, the experts are more likely to give interval estimates when assessing the risks of innovation. To work with interval estimates, a new software system was developed. The authors suggest using a market model that assumes a division of risks into systematic and non-systematic and allows to take into account the effect of diversification of the innovative portfolio of the machine-building enterprise. The steps of the methodology and its approbation on the data on innovative projects of one of Russian Federal Space Agency (Roskosmos) enterprises are presented in the paper.

1. Introduction
At present, machine-building enterprises of the Russian defence-industrial complex are choosing various directions of organizational and economic restructuring that allow them to adapt to market conditions [1-3]. Separation of military and civilian production is used. This ensures an increase in capacity utilization [4]. So, as examples [5-7], it can be noted that in the aviation industry the production of gas turbine units and gas pumping units, oilfield equipment, metal-cutting machines with automated control systems was established. In the electronics industry, the production of integrated microcircuits, electro vacuum and semiconductor devices, and instrumentation equipment began. The shipbuilding industry began to produce firefighting vessels, tugboats, fishing vessels (mainly for export). At enterprises of the rocket and space industry, the development of the production of medical equipment and apparatus for multifunctional environmental monitoring has been developed. These successes were achieved due to a significant reduction in the output of weapons and military equipment, and the complete cessation of certain types of military products [8].

To reduce the defence order, a method of concentration ("squeezing") of military production is used, with the aim of freeing up and effectively using production facilities. At the same time, the market is not studied carefully. Scientific, technological, production and human resources are inefficiently used. Enterprises cannot avoid the following problems [9, 10]:
small-scale type of production typical for the majority of defence enterprises does not allow to master the output of civilian products in volumes sufficient for its competitiveness at a price in comparison with analogues offered on the market by civil enterprises;

- absence of investments into the renovation of the production and technological park and lack of working capital do not ensure the sustainable operation of enterprises in the market;

- primitive civilian products typical for most enterprises are not competitive in price compared to analogues produced by civil enterprises;

- out-dated commodity nomenclature. Enterprises continue to produce "traditional" types of civilian products that they mastered during administrative conversions, which creates sales problems;

- a narrow range of products and unrelated diversification. There is loading of production capacities with products requiring different types of production, which significantly increases production costs;

- inability to work in market conditions. There is no experience in studying the market, which limits the adaptability to changes of the external environment;

- production approach to management which leads to various problems of sales process;

- inefficient strategy of enterprises in the field of conversion;

- low utilization of production capacity, which indicates the inconsistency of the existing production potential with production volumes;

- absence of integration processes, which can be considered as a potential opportunity for the production of technically complex competitive products, including within the framework of the industrial development policy of the region.

The production volumes of military and civilian products are approximately equal for machine-building enterprises of the defence industry. But there is a tendency of re-equipping of production capacities, previously used for the production of weapons and military equipment, for the production of dual or purely civil products [3].

2. Statement of the problem

In this situation, the top management of machine-building enterprises of the defence industry is interested in obtaining effective instruments to reduce the risks of innovation. At the same time, it is necessary to bear in mind that their innovation activity has a significant advantage in comparison with other producers: enterprises have the opportunity to realize all stages of the innovation process from basic research to industrial development. This circumstance should also be taken into account when developing tools to reduce the risks of innovation in the engineering industry.

Thus, the urgency of studying the theoretical and methodological foundations for managing the risks of innovation activities of defence enterprises becomes evident, and practical recommendations for creating an effective, scientifically sound risk management system is emerging [11, 12].

Evaluation of the effect of diversification of an innovative portfolio (IP) of an enterprise becomes possible on the basis of the division of risks into market (systematic) and inherent (non-systematic) for each individual entrepreneur.

Let us consider these types of risks in details.

Non-systematic risks are the risks the impact of which can be subjected only to individual projects or small sets of them. These risks are also called "unique risks", as such risks, as a rule, are inherent in the IP of only a specific enterprise. For illustration, we can give the following risks related to the category of non-systematic:

- business risk – the price of each enterprise IP depends on the level of success of each enterprise;
- financial risk – it depends on financial policy of the enterprise management.

To minimize unsystematic risks, such method as diversification is used. To apply this method it is necessary to compile an innovative portfolio. To finance such a portfolio, the investor makes up a set of IPs for various purposes, which means that they are subject to various unsystematic risks. Thus,
investor seeks to diversify the risk, that is, to avoid simultaneous changes in the profitability of each project in the same direction. At the same time, the smaller is the project in the portfolio, the higher is the risk level. The method of diversification with respect to minimizing non-systemic risks has proved to be very effective provided that a fairly large innovative portfolio is drawn up.

The limit for diversification is the level of risks inherent in this market as a whole, that is, the risks that in theory have been termed systematic.

Systematic risks are such risks that are inherent in work not with individual projects, but with certain sets of projects, to a greater or lesser extent for each of the projects included in such a collection. Systematic risks are also called "market risks". Such a name is received systematically because they are influenced by the whole market or a significant part of it. Accordingly, the greatest attention to systematic risks should be paid to those investors who invest in individual projects prefer to form an innovative portfolio.

Systematic risks are caused by possible uncertainties in the economic situation in the market, by general trends typical for the market as a whole. In the case of systematic risks, the diversification method does not work, and it is extremely difficult to avoid the risk of incurring losses in the course of making capital investments. As examples of such risks, without exhausting their diversity, we can mention the follows:

- exchange rate risk which is inherent to IP investments done by foreign enterprises and which is directly related to currency fluctuations;
- inflation risk – an unexpected increase in inflation leads to forced changes in the IP and can significantly affect the price of projects;
- political risk - unexpected, especially dramatic, changes in the political situation inevitably affect the market, often very unfavourably.

3. Solution method
As a model that assumes the division of risks into systematic and non-systematic and allows to take into account the effect of diversification of the innovative portfolio, it is proposed to use the market model [13].

Based on the market model, the overall risk of the j innovation project, measured by its \( \sigma_j^2 \) variance, can be divided into two components: market (systematic) risk and inherent (non-systematic) risk.

Thus, the risk of j innovation project will be defined by the statement:

\[
\sigma_j^2 = \beta_{jG}^2 \sigma_G^2 + \sigma_{ej}^2,
\]

where \( \beta_{jG}^2 \sigma_G^2 \) is the market risk of the j project;
\( \sigma_{ej}^2 \) - inherent risk of the j project;
\( \sigma_G^2 \) - market index yield variance;
\( \beta_j \) - slope coefficient showing the sensitivity of the project's profitability to changes in market index yield variance.

\( \beta_{jG} \) coefficient is calculated in the following method:

\[
\beta_{jG} = \sigma_{jG} \sigma_G^2.
\]

where \( \sigma_{jG} \) is covariance between the yield of the j project and the market index yield.

The market risk is connected with IP market portfolio and \( \beta_j \) value of the IP. The value of the market risk of the projects with big \( \beta_j \) value is bigger. In the framework of the market model such projects
have greater yield expectations. Thus, IP with big market risk values will be expected to have bigger yields.

Inherent risk is not connected with $\beta_j$. Thus the raise of the inherent risk does not cause the raise of the expected yield. So, according to the market model the investors will be awarded for the market risks, however their own risks will not be compensated.

The use of the market model makes it necessary to define the market index. It is suggested to use industry index received on the basis of the statistics instead of the market one [14].

The overall risk of $j$ portfolio which is measured by its $(\sigma_p^2)$ variance, will be determined [13]:

$$\sigma_p^2 = \beta_{pG}^2 \sigma_G^2 + \sigma_{ep}^2,$$

where $\beta_{pG}^2 \sigma_G^2$ is the market portfolio risk;

$\sigma_{ep}^2$ is the inherent portfolio risk.

The market portfolio risk:

$$\beta_{pG}^2 \sigma_G^2 = \left[ \sum_{j=1}^n x_j \beta_{jG} \right]^2 \sigma_G^2, \tag{3}$$

where $x_j$ is the investment share directed to the realization of $j$ innovation project;

$n$ is the amount of projects allowed by the level of yield.

Diversification leads to market risks averaging, as $\beta_{pG}$ of the portfolio is the average value of $\beta_{jG}$ projects included into the portfolio.

Taking into consideration (2) formula (3) will look like [13]:

$$\beta_{pG}^2 \sigma_G^2 = \left[ \sum_{j=1}^n x_j \beta_{jG} \right]^2 \sigma_G^2 = \left[ \sum_{j=1}^n x_j \sigma_{jG} / \sigma_G^2 \right]^2 \sigma_G^2 = \sum_{j=1}^n x_j^2 \sigma_{jG}^2 / \sigma_G^2.$$

It is suggested to calculate the inherent risk of the portfolio [13] taking into account the assumption of uncorrelated profitability of individual projects included in the portfolio:

$$\sigma_{ep}^2 = \sum_{j=1}^n x_j^2 \sigma_{ej}^2.$$

The use of the market model implies the possibility of reducing the overall risk of the investment project portfolio due to the effect of diversification. It happens due to the reduction of the inherent portfolio risk while the market risk of the portfolio remains approximately the same.

Speaking about the innovation project portfolio, the systematic risk is influenced by macroeconomic situation in the country, it is not reducible and it is not related to specific innovation projects.

A non-systematic risk is caused by the economic situation of the enterprise implementing innovation activities and by the efficiency of the innovation project portfolio management. It is associated with specific IP, it is diversifiable and declining. Therefore, further we will consider only the inherent risk of the IP portfolio. In addition, the assumption of uncorrelated returns of IP included in the portfolio does not correspond to reality, i.e. the formula for calculating the inherent risk of the IP portfolio should be adjusted:

$$\sigma_{ep}^2 = \left[ \sum_{j=1}^n x_j \sigma_{ej} \right]^2 = \sum_{j=1}^n x_j^2 \sigma_{ej}^2 + 2 \cdot \sum_{j=1}^n \sum_{l=1}^n x_j x_l \sigma_{ji} \tag{4},$$
where $\sigma_{ji}$ is yield covariation of $j$ and $i$ projects.

To obtain interval estimates of the portfolio of innovative project risks, we will use the device proposed in [15] to analyse and manage the risks of portfolio investments. As initial data for covariance and project risks, we use the so-called triangular fuzzy numbers with the triangular-type membership function.

To transform formula (4) into a form suitable for using fuzzy initial data, we use the segment method [16] and formulas (1-3).

For each fuzzy number in the initial data structure we obtain confidence intervals $[\sigma_{ji1}, \sigma_{ji2}]$ for a given level of $\alpha$ membership. Then, by substituting the corresponding boundaries of the intervals in (4) according to the rules given above, we obtain:

$$\sigma_{ep}^2 = \left[ \sum_{j=1}^{N} x_j^2 \sigma_{ej1}^2 + 2 \sum_{j=1}^{N} \sum_{i=1}^{N} x_j x_i \sigma_{ji1}, \sum_{j=1}^{N} x_j^2 \sigma_{ej2}^2 + 2 \sum_{j=1}^{N} \sum_{i=1}^{N} x_j x_i \sigma_{ji2} \right]$$ (5)

Thus, by setting the level of $\alpha$ membership by formula (5), we can receive interval risk assessments of various portfolios of innovation projects.

4. Conclusion
In the enterprise portfolio, some projects may increase in value as a result of their realization in favourable conditions. Other innovation projects may fall in price as a result of selling them in unfavourable conditions. This means that the more the portfolio is diversified, the less is the inherent portfolio risk and, consequently, the overall risk of the innovation program. Diversification significantly reduces its own risk.

The methodology of forming a portfolio of innovative projects, taking into account the specifics of the innovation activity of defence enterprises, can be presented as follows.

1. Inclusion of basic projects related to the production of state defence order into the portfolio.
2. Exclusion of those projects, whose share in the overall financial performance of the enterprise is negligible from the set of considered innovative projects. The boundaries with the interval tend to decrease (shift to the left) as projects are added to the portfolio. This trend is terminated after the sixth project is added to the portfolio.
3. Exception from the set of conversion projects of those that are not connected with the basic ones, already included in the portfolio, in the direction.
4. Formation of an admissible set of innovative projects at a given level of profitability.
5. The solution of the problem (1), (2) for the basic projects included in the portfolio, and projects from the admissible set, i.e. solving the problem of minimizing the risk of the portfolio. With small dimensions, which, as a rule, take place in practice, the problem is solved by a complete search, for the case of significant dimensions a special interactive system has been developed that allows solving the problem by the method of dynamic programming.

The methodologies were approved on the basis of data on innovation projects of the Roscosmos enterprise of JSC Central Design Bureau "Geofizika". These data are given in table 1.

| Table 1. Project data. |
|------------------------|
| Projects | Required investments volume, thous. rub. | Expected yield, % | Inherent project risk, thous. rub. |
|-----------|------------------------------------------|------------------|-------------------------------|
| Project 1 | 6,250.00                                  | 14.15            | 183.08                        |
| Project 2 | 5,920.00                                  | 14.84            | 181.17                        |
The results of point and interval risk calculations assessments of innovative project portfolios are given in table 2.

Table 2. Point and interval risk calculations assessments of innovative project portfolios.

| Amount of projects in the portfolio | Portfolio composition | Inherent risk (point assessment) | Inherent risk (interval assessment) |
|-----------------------------------|-----------------------|----------------------------------|------------------------------------|
| 1                                 | 12                    | 5,820.16                         | [57.03; 58.57]                     |
| 2                                 | 12-11                 | 3,063.62                         | [29.71; 31.52]                     |
| 3                                 | 12-11-10              | 2,469.1                          | [23.81; 25.74]                     |
| 4                                 | 12-11-10-8            | 2,064.79                         | [19.62; 21.24]                     |
| 5                                 | 12-11-10-8-6          | 1,798.61                         | [17.06; 18.81]                     |
| 6                                 | 12-11-10-8-6-9        | 1,545.28                         | [14.15; 16.47]                     |
| 7                                 | 12-11-10-8-6-9-5      | 1,597.60                         | [15.04; 16.94]                     |

As it can be seen from the table, the optimal portfolio will consist of 6 projects: 12-11-10-8-6-9.

Thus, the above methodology is oriented to a point (average) risk assessment of innovation. More often it is more convenient for the experts to give interval estimates in assessing the risks of innovation in the stages of the innovation process: the risk of this innovative project at this stage of the innovation process is approximately equal to the number $a$ and is uniquely in the interval $[a_{\text{min}}, a_{\text{max}}]$. Therefore, the authors used a software system that allows to work with interval risk assessments developed in [2].

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