Tool for Assessing the Risks of R&D Projects Implementation in High-tech Enterprises

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Abstract. The article gives a tool for assessing the risks of R&D projects implementation in high-tech enterprises including aerospace industry. The tool is algorithms and calculation formulas that help to make risk assessments at each stage of project implementation. Special attention is attached to the analysis of the most common risks that arise in the course of R&D projects implementation. These risks are divided into three groups: risks that affect the project R&D projects deadlines; risks, affecting the R&D projects financing; risks, associated with the technological characteristics of the projected facility features. This can be fully applied for innovative projects in aerospace industry including development of new materials and composite technologies. The calculation algorithms of the techniques are adapted for computer calculations and the use of statistical data instead of expert estimates contributes to the increase of accuracy and objectivity of calculations.

1. Introduction

A high-tech enterprise including aerospace industry may face various risk factors under a modern market economy and an unstable political situation in the world. Such factors can adversely affect the financial condition of enterprises, influence the R&D projects implementation deadlines. For knowledge-intensive industries (including aerospace), to which the enterprises of high-tech industry are fully applied, many risks are connected, first of all, with external factors [1,2]. In the aerospace industry such risks typically include the delay of financing, the changes in construction plan, the negative experimental results in the trial use of new materials and technologies. Also play serious role system risks which are connected with the mistakes and disagreements among partners in consortiums typical for aerospace industry organization.

The diagnosis of probable risk factors for high-tech industry enterprises is one of the most important components of economic analysis [3,4]. Enterprise’s management considers its results, while operating the financial policy. Therefore, it is necessary to have techniques that allow to assess possible risks, identify unfavorable factors for the enterprise's activities, further develop a set of anti-risk measures, based on available facilities and resources and calculate the predicted efficiency of these activities (for example, in [5]). Aerospace industry is among the first which started the use of the project management systems as new competences [6] (including software tools) and even was one
of the main drivers for PM standards, but the practice showed that the risk assessment tools should be improved.

The sources of the emergence of risk factors for knowledge-intensive enterprises of the aero, rocket and space industry are diverse. For example, the overall economic situation in the country, the unstable political situation in the world, the effect of export sanctions, the activities of competing enterprises abroad. In relation to an enterprise, such risk factors are external, and their management can be difficult due to the complex predictability or insurmountable nature. Other risk factors that are internal in relation to the enterprise, on the contrary, can be well-predicted, their management can be reduced to the timely removal of "pain points" in the internal activities of an enterprise. For example, such factors may be an inexpedient increase of document agreement deadlines within an organization, insufficiency of organization's circulating assets, which are necessary to pay for certain needs, ensuring correct work operation, inadequacy of purchased equipment to the declared technical characteristics. Industry risk can also be connected with the scientific problems when the experimental results do not coincide with the attended metrics and qualities, what is especially typical for new materials.

2. Methods
The process of risk analysis involves the consideration of many external and internal factors with the help of special economic and mathematical methods that allow obtaining estimates of the level of risk and calculate the efficiency of anti-risk measures, on the basis of which risk management will be carried out.

To assess the impact of risk factors on the stage of R&D projects implementation deadlines, let us use the following ratio:

\[ R_T = \frac{T_{\text{fact}} - T_{\text{plan}}}{T_{\text{plan}}}, \]  

where \( T_{\text{fact}} \) is the value of the actual time of a project stage implementation, \( T_{\text{plan}} \) is the planned time of a project stage implementation.

Let us consider the risk of a project cost exceeding the same way:

\[ R_P = \frac{P_{\text{fact}} - P_{\text{plan}}}{P_{\text{plan}}}, \]  

where \( P_{\text{fact}} \) is the value of the actual cost of a project stage implementation, \( P_{\text{plan}} \) is the planned cost of a project stage implementation.

If the project stages (a group of some \( n \) project stages) are implemented consistently, then we will consider the following value as a risk assessment, related to a project implementation deadline:

\[ R_T = \frac{(T_{\text{fact}}^1 - T_{\text{plan}}^1) + \ldots + (T_{\text{fact}}^n - T_{\text{plan}}^n)}{T_{\text{plan}}^1 + T_{\text{plan}}^n}, \]  

If the project stages (a group of some \( n \) project stages) are implemented simultaneously, in parallel and independently of the mutual implementation results, we will consider the following value as a risk assessment, related to a project implementation deadline:

\[ R_T = \max_i \frac{(T_{\text{fact}}^i - T_{\text{plan}}^i)}{T_{\text{plan}}^i}, \]  

where \( i = 1, \ldots, n \) corresponds to a project stage, implemented in parallel.

For risk factors that affect the project cost, let us use the following forecast value, regardless of the consecutive or parallel nature of the project stages implementation:

\[ R_P = \frac{(P_{\text{fact}}^1 - P_{\text{plan}}^1) + \ldots + (P_{\text{fact}}^n - P_{\text{plan}}^n)}{P_{\text{plan}}^1 + P_{\text{plan}}^n}. \]
The proposed method for risk assessment can be a part of a more general risk management system that can be implemented in an enterprise or an entire industry. Risk management in the economy is understood as a specific sphere of economic activity that requires deep knowledge of an industry, which is represented by an enterprise, knowledge in the analysis of modern business (an enterprise can implement commercial projects, double-purpose projects, purchase components from third-party suppliers), knowledge of special methods of analysis, assessment and management of risks, as well as in the field of insurance (since insurance and self-insurance are powerful tools of risk management).

The main task of an enterprise administration when managing risk is to find an option that would ensure an optimal balance of risk and project objectives achievement (related to income, financial, etc.). The management process is a systematic work of risk analyzing, developing and taking appropriate measures to minimize it. The risk management process generally corresponds to the chart shown in Figure 1. Risk assessment is an integral part of the quantitative risk analysis stage.

![Figure 1. General chart of risk management](image)

Creating a technique for R&D projects risk assessment of Rocket and Space enterprises, we will rely on international risk management standards: ISO 31000: 2009 "Risk management. Principles and guidelines", ISO / IEC 31010: 2009 "Risk management - Risk assessment techniques". These standards stipulate the basic general methods that must be applied when assessing risks.

The initial data for the calculation of the risk assessment algorithm for the R&D projects implementation are the specific risk factors that are most common in the enterprises activities.

The factors, influencing the terms of a project implementation are the following:
- An inexpedient increase in the term of documents coordination both with a customer and intra-company \( F_i^1 \);
- Procurement time increases the project deadline, if there is an increase in the time required to conduct competitive procurement procedures, the time, necessary for the procurement coordination
and justification to a customer, organization's internal services or a supplier cannot deliver products on
time for whatever reason ($F_1$).
- Co-executor within the organization (another thematic subdivision) cannot deliver his part of the
work on time for whatever reason ($F_2$);
- A contractor, engaged at work works cannot deliver his part of the work on time for whatever
reason ($F_3$);
- Lack of opportunity to deliver part of the work on time due to insufficient prepayment from a
customer ($F_4$);
- Insufficiency of circulating assets of an organization, necessary to pay for various demands,
ensuring proper work delivery ($F_5$).

The factors, affecting the project cost are the following:
- Increase in the cost of equipment or materials, necessary for work delivery ($F_6$);
- Increase in the cost of work, performed by a contractor ($F_7$);
- Increase in the cost, paid by an organization from the circulating assets, which affect the ability to
deliver work ($F_8$);
- Lack of full prepayment from a customer ($F_9$);
- The necessity for extra costs for work delivery due to newly discovered structural and
technological features of the projected facility ($F_{10}$).

3. **Algorithms for assessing the risks of R&D projects implementation in high-tech enterprises**

1. **Algorithm for assessing risks that affect a project deadline**

   To assess the risks that affect the project deadline, we will use the method, recommended by
ISO/IEC 31010-2011 "Risk management. Methods of risk assessment", which is related to the
construction of a matrix of consequences and probabilities. The specific character of the risk
technique, considered in this section is that an increase in the project implementation time is the only
considered consequence of these factors.

Supposing, the considered stage of a project requires the estimation of the possible excess of the
project implementation terms. In other words, it is necessary to determine the $T_{fact}$ value of a project
cost. Let the risk management group of an enterprise identify possible risk factors, which may have a
negative impact on the R&D projects implementation at this stage. Let us first consider the case when
the distinguished risk factor is the only one. In this case, the value $T_{fact}$ of time for a project stage
implementation can be determined by the following formula:
\[ T_{\text{fact}} = T_{\text{plan}} + \Delta T; \]

\[ \Delta T = k \cdot T_{\text{plan}}; \]

\[ k > 0, \]

where \( k \) is a specified coefficient.

The value of the \( k \) coefficient can be learnt in two ways: by using statistical data or by an expert method. Let us consider both of these methods.

The method, based on statistical data resides in analyzing the previous experience of projects implementation, marked by the negative impact of certain risk factors. Basing on the statistical data for the considered risk, we can comprise series that can help to determine the mathematical expectation of exceeding the project implementation time:

Let us consider the average value of the excess

\[ \Delta T_{cp} = \frac{1}{n} \sum_{i=1}^{n} t_i \]

as a probable estimate of the excess of a project stage implementation time, constructed according to statistical data.

Thus, the following estimate is correct:

\[ E(T_{\text{fact}}) = T_{\text{plan}} + E(T_{cp}). \]

Another method is to obtain an expert estimate of a project stage implementation time excess by filling the pairwise comparison matrix. As objects for comparison, the expert is offered to pairwise assess the possible excess of project stage implementation time, expressed as a percentage of the planned time. Herewith, the eigenvalue vector of such matrices will be a priority vector.

To compare two objects, using the pairwise comparison method, the following rating scale, offered by T. Saati is often used. So, let there be given 2 objects A and B (exceeding time) and a comparison criterion. We will fill in the integer values of estimates from 1 to 9 according to the following rule:

- Estimate 1 is filled in if object A and object B are equally preferable.
- Estimate 3 is filled in if object A is slightly preferable than object B. Consequently, the estimate 1/3 corresponds to the situation when A is slightly less preferable than B.
- Estimate 5 is filled in if object A is significantly more preferable than object B. Consequently, the estimate 1/5 corresponds to the situation when A is significantly less preferable than B.
- Estimate 7 is filled in if object A is obviously more preferable than object B in relation to the comparison criterion. Consequently, the estimate 1/7 corresponds to the situation when A is obviously less preferable than B.
- Estimate 9 is filled in if the significance of the object A is absolutely more preferable than the object B. Consequently, the estimate 1/9 corresponds to the situation when A is absolutely less preferable than B.
- Estimates 2, 4, 6, 8 (1/2, 1/4, 1/6, 1/8) are used to facilitate trade-offs between arguments that differ slightly between the two basic numbers.

Let us give an example of the matrix of pairwise comparisons of a project stage implementation time exceeding as a result of the negative impact of a risk factor \( F_1 \) (Table 1).

|       | 5%  | 10% | 15% |
|-------|-----|-----|-----|
| 1     | 1   | 1/3 | 1/2 |
| 3     | 1   | 2   |     |
| 2     | 1/2 |     | 1   |
| 2     | 1/2 |     | 1   |

The vector of priorities of this matrix of pairwise comparisons is \((0.122, 0.424, 0.227, 0.227)\).
In order to obtain \( k \), corresponding to the considered situation, it is necessary to obtain the sum of the products of the considered relative exceedings for the corresponding component of the priority vector. For our example, the result is \( k = 5\% \cdot 0.122 + 10\% \cdot 0.424 + 15\% \cdot 0.227 + 20\% \cdot 0.227 = 12.795\% \).

Let \( T_{\text{plan}} = 100 \), then, using the formula, we obtain \( T_{\text{fact}} = 100 + 0.128 \cdot 100 = 112.8 \).

If the negative effect of several risk factors, affecting the project implementation time are predicted, the formula for obtaining the final value of the R&D project stage implementation time excess takes the following form in the case of simultaneous influence of factors:

\[
T_{\text{fact}} = \max_i (T_{\text{plan}} + \Delta T_i).
\]

where \( i \) corresponds to the risk factor \( F_i \).

2. Risks, related to an increase in the project cost.

For risks, related to the change in the project cost, the disquisitions on their evaluation are similar to the case when risk factors affect the R&D projects deadlines.

In this case, the \( P_{\text{fact}} \) value of time for a project stage implementation can be determined according to the following formula:

\[
P_{\text{fact}} = P_{\text{plan}} + \Delta P;
\]

\[
\Delta P = k \cdot P_{\text{plan}};
\]

\[k > 0,\]

where \( k \) is a certain coefficient.

To assess such risks, it is also advisable to use methods, based on statistical data or methods of expert evaluation.

If the negative effect of several risk factors, affecting the project cost are predicted, the formula for obtaining the final value of the R&D project stage implementation time excess takes the following form in the case of influence of factors on the same project stage:

\[
P_{\text{fact}} = \sum_{i=1}^{n} (P_{\text{plan}} + \Delta P_i);
\]

where \( i \) corresponds to the risk factor \( F_i^\text{2} \).

3. Risks, related to the technological characteristics of the projected facility features.

The features of the risk factors of this group is the ability to manage them at the prediction stage. Let us hereafter assume that the negative impact of these factors is the increase of a project cost. In this case, it is advisable to predict the impact of risk factors, taking into account the possible financial costs on anti-risk measures. Using simulation modeling, it is possible to calculate the optimal amount of money, spent on the anti-risk measures. To do this, we can use the algorithms, offered in the previous subsection.

In this case, the economic effect \( B \) from the measures implementation will be equal to the amount of savings:

\[
B = (P_{\text{fact}} - P_{\text{plan}}) - D,
\]

where \( D \) is the sum of expenses on anti-risk measures.

4. Conclusion

The work offers the technique of the estimation of R&D projects risks in hi-tech enterprises including aerospace industry. The technique contains algorithms and calculation formulas, used to estimate risks at each stage of the R&D project implementation. The creation and implementation of an efficient R&D management and control system is possible due to the improving of methods for assessing the projects investment attractiveness and risks, as well as the development of a corporate R&D management system in the rocket and space industry.
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