Risk Reduction Strategy and Risk Management on The Basis of Quality Assessments

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Abstract. The main issue of the study is the problem of improving the efficiency of risk management of the program. The article proposes a method for determining the quality of risk assessments of a program consisting of several projects. Risk management tasks are set and solved on the basis of risk reduction and risk avoidance strategies. The aim of the study is a systematic integrated approach to the formulation and solution of tasks to improve the efficiency of the risk management program, which allows you to objectively, fully and accurately assess the relationship of economic and technical indicators. Qualitative risk assessment can be carried out by a common method of analogy, the essence of which is to analyse the totality of data on similar projects. Here they conduct a study of impact of adverse factors on them in order to accurately determine the potential risk of new projects. The main difficulty of using the methods is the exact and correct choice of analogues, since there are no formal criteria for determining the degree of similarity of situations. All aggregate socially significant economic indicators of operational measures can become the basis of legislative regulation in the industry. Conclusions: the strategy of risk reduction is that activities are carried out that reduce either the probability or damage or both from medium to low, from high to medium or low.

1. Introduction
Risk management in the program is a section of project management, which includes tasks and procedures to determine the risks of projects included in the program, as well as the development and implementation of effective measures to respond to them [1,2]. Project risk is characterized by two parameters: probability of occurrence of a risk event; influence on the characteristics of the project (the amount of damage).

In practice, as a rule, qualitative assessments of probability and damage (low, medium, high probability, low (small), medium, high (large) damage) are applied. The generalizing characteristic is the degree of influence (rank) of risk, which is understood as the expected damage (the product of the probability of damage). This paper gives a formulation and proposed solution methods the three objectives of the risk management program. [3-5]. The first is to determine the qualitative characteristics of the program with the given qualitative characteristics of the projects included in the program. The second objective is to reduce the impact of the programme to a low level with minimal cost of reducing the risks of the programme projects. The third task is to reduce the impact of the
program risks to a low level in the formation of its subject area by excluding from the program projects with high and medium levels of influence of projects, so that the effect of the program was the maximum [6-8].

2. Materials and Methods

A. Program and projects

Consider a program consisting of \( n \) projects. Each project is characterized by the effect of its implementation \( a_i \), the cost of its implementation \( c_i \) and a qualitative assessment of risk (probability and damage). We will consider a three-point scale for the probability, damage and impact of the project.

Let us denote \( v_1, v_2 \) – boundary values of probability. If the probability \( p \leq v_1 \), then the project has low risk, if \( v_1 < p \leq v_2 \), then the project has medium risk, if \( p > v_2 \), then the project has high risk. Since the probability distribution for projects with low, medium and high risk levels is not known, it is natural to assume that these distributions are uniform. Therefore, we define the basic probability levels as follows:

\[
v_k = \frac{v_k}{2},
\]

\[
v_c = v_1 + \frac{(v_2 - v_1)}{2} = \frac{v_1 + v_2}{2},
\]

\[
v_b = v_2 + \frac{(1 - v_2)}{2} = \frac{v_2 + 1}{2}.
\]

Similarly, we define (in an expert way) the boundary damage levels \( U_1 \) and \( U_2 \) (per unit cost of the project). If the risk is considered low (for damage), the damage \( U_1 \leq U \leq U_2 \). If the risk is average for damage, then \( U_1 < U < U_2 \). If the risk is high for damage, then \( U > U_2 \). Next, define the basic levels.

\[
U_h = \frac{U_1}{2},
\]

\[
U_c = \frac{U_1 + U_2}{2}.
\]

To define a baseline \( U_b \), you must specify the maximum damage \( U_{\text{max}} \). Next, calculate:

\[
U_b = U_2 + \frac{U_{\text{max}} - U_2}{2} = \frac{U_{\text{max}} + U_2}{2}.
\]

Further, to simplify, we take \( U_{\text{max}} = 1 \), that is, we believe that the damage does not exceed the cost of the project (although this does not always occur). Now it is possible to determine the impact of project risks [9-11].

Note that there are nine possible types of projects: (H; H), (H; C), (H; B), (C; H), (C; C), (C; C), (B; H), (B; C), (B; C). Accordingly, we obtain nine possible degrees of influence. For example, for type (H; B) we have the degree of influence \( W = v_1 \cdot U_h \). Similar for other types. The boundary levels of the degree of influence are determined naturally

\[
W_j = v_j \cdot U_j, \quad W_c = v_c \cdot U_c, \quad W_b = v_b \cdot U_b.
\]

Accordingly, the basic levels

\[
W_a = v_a \cdot U_a, \quad W_c = v_c \cdot U_c, \quad W_b = v_b \cdot U_b.
\]

Let us assume that the qualitative characteristics (types) of all projects of the program are given. Task 1. To determine the qualitative characteristics (type) of the program risks.
**Task 2** (risk reduction strategy). For each project of the program, the costs of reducing the probability and damage characteristics are set. Identify a reduction strategy that reduces the impact of the program to a low level with minimal cost.

**Task 3** (risk avoidance strategy). There are $n$ projects – applicants for inclusion in the program and the amount of funding for the program. To determine the set of projects included in the program, so that the effect of the program was the maximum, and the degree of influence of risks of the program were low.

**B. Characteristics of qualitative risk assessment**

Qualitative risk assessment characterizes the degree of importance of risk through the choice of response. The availability of accompanying information makes it easier to prioritize different risk categories.

Qualitative risk assessment involves assessing the conditions of occurrence of risk, determining their impact on the project using standard methods and tools. The use of these methods (tools) helps to eliminate uncertainty, which is often found in projects. Throughout the life cycle of projects, there is a need for continuous risk reassessment.

The result of a qualitative risk assessment is to describe the uncertainties that may arise during the project or cause the risks themselves. Logical maps, which are lists of questions to identify existing risks, are often used to describe. In the course of drawing up such lists, a list of risks is formed, which are subsequently subject to ranking in accordance with the degree of importance and the amount of possible losses.

**C. Qualitative risk assessment of the program.**

All project types are specified. It is necessary to determine the type of program, that is, qualitative risk assessments of probability, damage and impact. Assume that the damages of individual projects are summarized. The degree of influence of the program risks is equal to the sum of the degrees of influence of individual projects (the mathematical expectation of the sum of independent random variables is equal to the sum of the mathematical expectations of these values).

We have damage from the risks of the program:

$$U = \sum_{i=1}^{n} U_i.$$  \hspace{1cm} (7)

Program risk impact:

$$W = \sum_{i=1}^{n} w_i \lambda_i,$$  \hspace{1cm} (8)

$$\lambda_i = \frac{c_i}{\sum_j c_j} = \frac{c_i}{c}.$$  \hspace{1cm} (9)

The probability of risks of the program

$$P = \frac{W}{U}.$$  \hspace{1cm} (10)

Note that the values of $U_i$ and $W_i$ are determined by the project type. For example, if the project type is (C; B), then $U_i = U_b$, $w_i = U_b \times v_c$.

By correlating the obtained values $U$, $W$ and $P$ with the boundary levels, we determine the type of the program.

Example 1. The program consists of 6 projects, the types of which are given below (table. 1).
Table 1. The Program of 6 Projects.

|   | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| i |   |   |   |   |   |   |
| probability | B | C | H | C | H | H |
| damage       | C | C | C | H | H | H |

Let’s take the following values of boundary levels

\[
v_1 = 0.2, \quad v_2 = 0.6
\]

\[
U_1 = 0.3, \quad U_2 = 0.8
\]

\[
W_1 = 0.06, \quad W_2 = 0.48
\]

Define basic levels:

\[
V_u = 0.1, \quad v_c = 0.4, \quad V_b = 0.8
\]

\[
U_u = 0.15, \quad U_c = 0.55, \quad U_b = 0.9
\]

\[
W_u = 0.015, \quad W_c = 0.22, \quad W_b = 0.72
\]

Note that the damage of the projects included in the program is determined by the unit cost of the program. If the risk damage of the project is equal to \( U_c \), where \( c_i \) - the cost of the \( i \)-th project, \( C = \sum c_i \) - the cost of the program, then \( U_c = \lambda_i U \times C \) where \( \lambda_i = \frac{c_i}{C} \) - the unit cost of the \( i \)-th project.

The cost of projects and their specific costs are given below (Tab. 2):

Table 2. Specific costs of projects.

|   | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| i |   |   |   |   |   |   |
| \( c_i \) | 5 | 10 | 15 | 10 | 5 | 5 |
| \( \lambda_i \) | 0.1 | 0.2 | 0.3 | 0.2 | 0.1 | 0.1 |

Calculate the damage from the risks of the program:

\[
U = 5 \times 0.055 + 10 \times 0.55 + 15 \times 0.55 + 10 \times 0.15 + 5 \times 0.15 = 19.5
\]

Calculate the degree of influence:

\[
W = 5 \times 0.8 \times 0.55 + 10 \times 0.4 \times 0.55 + 15 \times 0.1 \times 0.55 + 10 \times 0.4 \times 0.15 + 5 \times 0.1 \times 0.15 = 5.975
\]

Calculate the probability of a risk event:

\[
P = \frac{W}{U} = \frac{5.975}{19.5} \approx 0.36
\]

The boundary level determines the type of program (C; C; C), that is, the program has an average level of risk for all characteristics. Being able to assess the quality characteristics of the program, you can solve the problem of risk management. Consider two risk management strategies: risk reduction and risk avoidance.

D. Opportunities of qualitative risk analyses

Qualitative risk assessment and analysis help to identify and search for possible types of risks, identifying and describing the causes and factors that affect the level of a particular type of risk. In addition, it describes and provides a cost assessment of all possible consequences of the identified risk with the proposal of measures to minimize (compensate). The main objective of a qualitative risk assessment is a qualitative analysis, involving a description of the likely damage, including its valuation and measures to reduce and prevent risk (insurance, creation of a reserve). The qualitative approach does not make it possible to determine the numerical value of the risk of investment projects. For this reason, it can be considered as the basis for subsequent studies using quantitative methods.
E. Qualitative risk assessment methods

The most frequently used qualitative methods of evaluating investment risks include the analysis of the appropriateness of costs, method of expert estimates and method of analogies. The basis of the cost-relevance analysis is the assumption that the cost overruns are caused by the initial underestimation of the cost of the project as a whole (or its components), changes in the design boundaries (due to unforeseen situations), differences in productivity, and increases in the cost of the project compared to the original (for example, due to inflation or changes in tax legislation). During the analysis, these factors are detailed and make a checklist of possible cost increases for each option.

F. Expert method

Qualitative risk assessment can be carried out through expert risk assessments. This method includes methods of forecasting and risk analysis based on the opinions of experts who have experience in the implementation of innovative projects. The most common method is the Delphi method, which consists in the forecast, which excludes direct communication of group members. Here, experts are interviewed individually using questionnaires. The main problem that may arise when using the methods of expert assessments is related to the objectivity and accuracy of the results. It may be associated with poor selection of experts, the possibility of group discussion, the dominance of a certain opinion, etc.

3. Results and Discussion

A. Risk reduction strategy

The risk reduction strategy is that activities are undertaken that reduce either the likelihood or the damage, or both, from medium to low, from high to medium or low.

Depending on the type of project, there are different options for reducing risk. For projects of type (H; C) or (C; H), there is only one option to reduce the risk from medium to low (damage or probability). For projects of type (C; C), there are already three options. The first two options involve reducing the risk to a low level, either in probability or in damage. The third option is to reduce the risk to a low level in both probability and damage. For projects of type (B; H) or (H; B), there are two options for reducing risk from high to medium or low. For projects of type (C; B) or (B; C) there are five options for risk reduction. Two of them are associated with reducing the risk from high to medium or low. One option is to reduce the risk from medium to low. Another two options are to reduce the risk from medium to low while reducing the risk from high to medium or low. Finally, there are eight options for projects of type (B; B). Four options involve reducing the risk from high to medium or low, either in probability or in damage. Another four options are to reduce the risk from high to medium in probability (or damage) while reducing the risk from high to medium or low in damage (or probability).

Each option of risk reduction will be evaluated by the magnitude of the reduction in the degree of influence it provides. This value is equal to the difference between the degree of influence of projects of this type and the degree of influence of projects to which the project belongs after risk reduction. [12]

We will set the task of determining the options for risk reduction for each type of projects included in the program, ensuring the reduction of the degree of impact of the program risks to a low level with minimal costs [13-15].

The problem will be solved in two stages. At the first stage, for each type of project, the problem of determining the dependence of the minimum cost on the value of reducing the degree of influence is solved.

For the formal formulation of the problem will designate \( S_j \) the cost of the implementation of the \( j \) version of the project \( i \in Q \), \( x_j = 1 \), or for the \( i \) project selected \( j \) option to reduce risk \( x_j = 0 \).

Task. Define \( \{x_j\}, i \in Q \), minimizing
\[ \sum_{ij} S_{ij}x_{ij}, \]  
(11)

under constraints
\[ \sum_{j} x_{ij} = 1, \quad i \in Q_k, \]  
(12)
\[ \sum_{i \in Q_k} \sum_{j} x_{ij}b_{ij} \geq B_kc, \]  
(13)

where is \( B_k \) - parameter, \( 0 \leq B_k \leq W_0 - W_f \), \( W_0 \) - existing level of risk impact of the program, \( b_{ij} \) - reducing the impact of program risks (per unit coast), which provides \( j \)-th option project \( i \in Q_k \).

As a result of solving this problem we obtain for each type the dependence of the minimum cost \( S_k(B_k) \) from the value of reducing the degree of influence \( B_k \times C = Y_k \).

At the second stage, the problem of minimizing costs is solved:
\[ \sum_{k} S_k(Y_k), \]  
(14)
under constraints
\[ \sum_{k} Y_k \geq C(W_0 - W_f) = \Delta. \]  
(15)

Example 2. There are six projects in the program with types from example 1. Project 1 has five options for reducing impact, project 2 has three options, and projects 3 and 4 have one each.

Stage I. Solve problem (1) ÷ (3) for project 2. Costs \( S_1 \) and values \( Y_1 \) are given below (table. 3).

| \( j \) | \( S_1 \) | \( Y_1 \) | type |
|---|---|---|---|
| 1 | 6 | 1,1 | CC |
| 2 | 7 | 1,8 | BH |
| 3 | 8 | 1,925 | HC |
| 4 | 12 | 2,125 | HH |
| 5 | 9 | 1,9 | CH |

The last line of the table shows the final type of the project. Note that option 5 can be excluded, since it is dominated by option 3 (at a lower cost, we get a greater reduction in the degree of influence).

Solve problem (1) / (3). The result is shown below (table.4):

| \( j \) | \( S_2 \) | \( Y_2 \) | type |
|---|---|---|---|
| 1 | 4 | 1.65 | HC |
| 2 | 8 | 2.05 | HH |
| 3 | 5 | 1.6 | CH |

In this case, option 3 could be deleted because it is dominated by option 1.

For projects 3 and 4, the task does not need to be solved, since they have only one option. For project 3, this is an option with costs \( S_3 = 3 \) and a value \( Y_3 = 0,6 \), and for project 4, this is option \( S_4 = 2 \) and \( Y_4 = 0,675 \).

Stage II. At this stage, we solve the problem (4), (5) by dichotomous programming. Take the structure of the dichotomous representation of the problem presented in Fig. 1.
Calculate $\Delta = (W_0 - W_i) \times 50 = 2,975$.

For the convenience of computing all the effects of the reduction of the degree of influence is multiplied by 100.

**Step 1.** We consider types 3 and 4. The solution is given below (table 5):

| Option  | Effect | Cost |
|---------|--------|------|
| 1       | 67.5; 2| 127.5; 5 |
| 0       | 0      | 60; 3 |
| 4       | 3      | 1 |

Option (60; 3) is excluded because it is dominated by option (67.5; 2). The results are shown in table 6:

**Combined type I**

| Option  | Effect | Cost |
|---------|--------|------|
| 0       | 0      | 2 |
| 1       | 67.5   | 5 |

**Step 2.** We consider the combined type I and type 2. The solution is given below (table 7):

| Option  | Effect | Cost |
|---------|--------|------|
| 2       | 205; 8 | 272.5; 10 | 323.5; 13 |
| 1       | 165; 4 | 232.5; 6 | 292.5; 9 |
| 0       | 0      | 67.5; 2 | 127.5; 5 |
| I       | 0      | 1      | 2 |

The result is presented in table 8:

**Combined type 2**

| Option  | Effect | Cost |
|---------|--------|------|
| 0       | 0      | 2 |
| 1       | 67.5   | 4 |
| 2       | 3      | 6 |
| 3       | 292.5  | 9 |
| 4       | 332.5  | 13 |

**Step 3.** We consider the combined type 2 and type 1. The solution is given below (table 9):
The optimal solution is determined by the cell (345; 11). It is consistent with reducing the damage assessment of project 1 to a low level and reducing the probability assessment of project 2 to a low level.

B. The strategy of risk avoidance

The essence of the risk avoidance strategy is that a number of high-risk and (or) medium-risk projects are not included in the program, so that the degree of impact of the program risks does not exceed $W_1$.

Denote $x_i = 1$, if project $i$ is included in the program, $x_i = 0$, otherwise, $a_i$ – the effect of the $i$ – th project, if it is included in the program, $R$ – the amount of funding for the program.

Task. Define $x_i$, $i = 1, n$, maximizing

$$\sum_i a_i x_i,$$

under constraints

$$\sum_i c_i x_i \leq R,$$

$$\sum_i b_i x_i \leq W_1,$$

where is $b_i$ - the degree of influence of $i$ type project.

If the project $i \in Q_k$, $k = 1, 9$, than

$$b_i = \alpha_i W_k x_i,$$

Where is $\alpha_i = \frac{c_i x_i}{\sum_j c_j x_j}$, where is $W_k$ - the degree of influence of the $k$ type project (per unit cost of the program), i.e. $k = H$ either C or B.

Inequality (20) takes the form

$$\sum_k c_j w_k x_i \leq W_1 \sum_j c_j x_i,$$

or

$$\sum_k \sum_{i \in Q_k} c_i \Delta_k x_i \leq 0,$$

where is $\Delta_k = W_k - W_1$.

Task (18), (19), (21) is an integer linear programming problem. We describe an approximate algorithm for its solution based on the Lagrange multiplier method.

Let us calculate the Lagrangian:
\[ L(\lambda, x) = \sum_{i \in Q_k} \sum_{x_i} (a_i - \lambda c_i \Delta_k) x_i, \]

where is $\lambda$ - Lagrange multiplier.

Note that for fixed $\lambda$ tasks, the maximization problem under constraint is the knapsack problem. We will solve it approximately on the basis of the "Cost – effect" method. The effectiveness of the project $i \in Q_k$ at a given value is $\lambda$ determined by the expression

\[ q_i(x) = \frac{a_i - \lambda c_i \Delta_k}{c_i} = \frac{a_i}{c_i} - \lambda \Delta_k. \]  

The problem was reduced to the definition at which the minimum value is achieved

\[ N(\lambda) = \max_x L(\lambda, x). \]  

This problem can be solved by a simple search (for example, dividing the segment of possible values $\lambda$ in half), given that the number $N(\lambda)$ is a convex function $\lambda$.

Example 3. Let’s take projects from example 2. Data on the values $a_i$, $c_i$, $\Delta_k$ and $q_i(0)$ are given below (table. 10) (values $c_i \Delta_k$ multiplied by 100).

| $i$ | 1  | 2  | 3  | 4  | 5  | 6  |
|-----|----|----|----|----|----|----|
| $a_i$ | 12 | 21 | 6  | 10 | 14 | 9  |
| $c_i$ | 5  | 10 | 15 | 10 | 5  | 5  |
| $c_i \Delta_k$ | 90 | 60 | -7.5 | 0 | -22.5 | -22.5 |
| $q_i(0)$ | 4  | 3.5 | 3  | 2.5 | 2  | 1.5 |

Take $R = 30$.

Step 1. $\lambda = 0$. The program includes projects 1, 2, 3. Calculate:

$\Delta_1 + \Delta_2 + \Delta_3 + \Delta_4 = 342.5 > 0$.

Step 2. $\lambda = 0.05$. The values $q_i(0.05)$ are shown below (tabl.11):

| $i$ | 1  | 2  | 3  | 4  | 5  | 6  |
|-----|----|----|----|----|----|----|
| $q_i(0.05)$ | -9.5 | -4.5 | 3.375 | 0 | 3.125 | 2.625 |

The program includes projects 3, 5 and 6 at a cost of 25.

Step 3. Take $\lambda = 0.02$.

The values $q_i(0.02)$ are shown below (tabl. 12):

| $i$ | 1  | 2  | 3  | 4  | 5  | 6  |
|-----|----|----|----|----|----|----|
| $q_i(0.02)$ | 0.2 | 0.3 | 3.15 | 2.5 | 2.45 | 2.45 |

The program includes projects 3, 4 and 5 with costs 30 and effect 20. This solution is optimal. Indeed, none of the first two projects can be included in the program.

If the rector and the head of the program decided to go to the average level of risk, the values of $\Delta_k$ change, that is, reduced by $W'_i - W'_i = 0.48 - 0.06 = 0.42$ (per unit cost). In this case, as it is easy to check, all projects will have negative $\Delta_k$ And the program will include the first three projects with effect 39, which is much more than 20 [16,17].
4. Conclusions
The article deals with the problem of determining the qualitative characteristics of the risks of programs [18,19] for the case when the damage and the degree of influence of the risks of the program [20-24] are, respectively, the amount of damage and the sum of the degrees of influence of the risks of the projects of the program. Further research requires a situation where the program consists of dependent projects (network schedule of projects), in which both the probability and damage, and the degree of impact of the program risks are described in a more complex way.

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