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# Determining the sequence of project implementation for the program of improving the efficiency of business processes

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**Abstract**

This article is devoted to the problem of determining the sequence of project implementation in a program of improving business processes of an organization. The relevance of the study is related to current conditions, where the quality of business processes is essential not just for the success, but also for the survival of an organization. Improvement of business processes is a costly program that involves certain projects. The projects of the program cannot be started at the same time due to limited budget and human

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resources. Thus, we face the task of determining the sequence of stages of program implementations. The solution of this task is one of the most important problems of business informatics. This paper proposes a new criterion for prioritizing projects. It takes into account the fact that funds for projects are generated during the implementation of business processes. The criterion also takes into account the pace of spending the project budget and the need for participation of key employees of the organization. The implementation of the program is divided into a few stages. At each stage, the problem is solved by determining a set of projects whose sum of priorities is maximum and whose resource requirements do not exceed the constraints developed at that stage. The relevance of the article is initiated by looking at the need of enterprises that ensure the airworthiness of civil aviation airplanes. This work is of interest for project program managers of production and service companies, as well as for a wide range of researchers.

**Keywords:** business process, project, program, priority, criterion, sequence of projects implementation

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## Introduction

Business processes (BPs) are essential for Enterprise Architecture because organizational and IT structures should be built upon them [1]. BPs need continuous improvement. Moreover, in modern conditions, the period of invariability of BPs is decreasing.

Two approaches to BPs improvement can be distinguished: efficiency improvement (optimization) and reengineering. In the first case, individual BP elements are improved [2]. Based on qualitative and mathematical analysis, "as is" (AS-IS) and "to be" (TO-BE) models are created [3–5]. Reengineering involves creating a TO-BE model without regard to the current state [6–8]. BP modeling notations are an evolution of the network approach to modeling workflows that has been widely used in project management. They allow one to explicitly indicate the possibility of different BP implementation scenarios. This is not the case in the network project model. All work specified in the project plan must be completed. This is the basis of the critical path method [9]. The project is unique by definition, and the manager must plan it without scenarios. This is an obvious contradiction that causes difficulties. The ability to create and store multiple plans does not solve the problem [10]. The GERT method [11, 12] also did not lead to a practical result. The problem of scenarios in project management remains open.

In this article, the BP optimization program is considered. The development of a methodology for the formation of such a program and its management is a pressing issue for enterprises in various sectors of the Russian national economy. In connection with the current situation, this issue is particularly relevant for enterprises ensuring the maintenance of airworthiness of civil aviation aircraft [13]. For each BP, the implementation of the transition from AS-IS to TO-BE is a separate project. Together, these projects form a program aimed at achieving the goal of optimization of the company's BPs. The following two main questions arise:

- Which projects should be included in the program?
- In what order should the projects be executed?

These issues are related to financial and resource constraints. Even if we decide to optimize only the main BPs that generate revenue, there may not be enough resources to launch all the initiated projects at the same time. It is necessary to prioritize the projects. In this case, it is necessary to take into account the importance of the BPs for the company. It is also necessary to consider that the financial resources for the implementation of projects come from the income generated by the BPs. Let us clarify whether this problem has been solved so far.

Project management is the most regulated area of management [14]. Qualification requirements for project managers are regulated [15]. Project management activities are also regulated [16–19]. These and earlier project management standards indicate that projects should be aligned with the strategic goals of the organization. In accordance with this, the work [20] proposes to determine the priorities of projects by the degree of their relevance to the strategic goals of the organization. For this purpose, first of all, it is necessary to determine the priorities of goals. This approach is based on Saaty's Analytic Hierarchy Process (AHP) method [21]. The source data for determining the priorities of goals is the matrix of pairwise comparisons. The comparison is made on a qualitative linguistic scale, where each linguistic value corresponds to a specific numerical value. In this way, the matrix of pairwise comparisons can be translated into digital form. The priorities of the goals are calculated as an eigenvector corresponding to the principal eigenvalue of the resulting matrix. The AHP method does not take into account the links between the goals. At the same time, these connections are clearly displayed on the strategy map. The strategy map is an element of the Balanced Scorecard concept [22, 23]. Its use is recommended to ensure consistency when filling in the matrix of pairwise comparisons.

The approach proposed by Vargas [20] is implemented in MS Project Server [24]. The method for calculating the priority vector is not specified by the developers. However, its simple approximate calculation proposed in [21] can lead to errors in calculating priorities affecting the ordering of goals. It is necessary to adhere to a highly accurate procedure for determining the main eigenvalue of the matrix and the corresponding eigenvector [25].

Later, a number of modifications of the method proposed by Vargas [20] were proposed. Thus, in the work [26] it was proposed to take into account the risk level of projects when comparing them. Risk is an integral element of the project. This follows from the uniqueness of the project. Works devoted to project risks can be divided into two groups. The first proposes methods that allow you to determine, or better yet, predict the moment when deviations in terms and/or finances become irreversible [27–29]. The second group of works is devoted to organizing timely control of the correctness of the work [30–32]. Both areas are called project diagnostics [33]. In technical diagnostics, a direction similar to the first of them is related to failure prediction [34]. A direction similar to the second is the choice of control points [35].

The method proposed by Vargas [20] does not explicitly use numerical characteristics of either goals or projects. The work [36] suggests assessing the priority of a project based on the sum of weighted points. When calculating the points, "project sustainability assessment indicators" are used. They are divided into groups: "Economic indicators," "Ecological indicators," "Social indicators." The economic indicators include, in particular, the NPV (net present value) and IRR (internal rate of return) of the project. The group of ecological indicators includes, among others, specific energy consumption in kind and the use of energy from renewable sources. The social indicators include: creation of new jobs, level of expenditure on labor protection. Then a portfolio (set) of projects is sought, in which the sum of weighted points is maximum, and the restrictions on allocated resources and the number of projects are met. In this case, the simplex method is used.

The approaches outlined in [20] and [36] can be considered the main ones when solving the problem of forming a portfolio or program of projects based on their priorities. At the same time, [20] deals only with determining project priorities. [36] not only proposes a method for calculating project priorities, but also solves the problem of initial portfolio formation. Initial in the sense that it determines which of the initiated projects should be included in the project and which should not due to existing restrictions.

The problem that our article is devoted to postulates that all projects for improving the selected BPs must be implemented, albeit in several stages. Both at the initial (first stage) and at subsequent stages, the funds (budget) for implementing the projects are formed from the income generated by the BPs. This fact must be taken into account explicitly when determining project priorities. There is no such thing in the literature today.

Thus, the following points are relevant:

- development of a method for calculating the priorities of projects aimed at improving the organization's business process, taking into account that the project budget is formed from the business process's income;
- determining the sequence of implementation of projects of the BP optimization program taking into account the existing financial and resource constraints, provided that all projects must be completed.

As a starting point, let us consider the case where there are no interrelations between the projects that are carried out to optimize the BP. Such a situation is quite typical for enterprises that ensure the maintenance of airworthiness of civil aviation aircraft [13].

## 1. Statement of the problem

The company has $n$ BPs that directly generate income. Currently, the income generation intensity of BP with number $i$ ($i = 1, 2, ..., n$) is $v_i$ monetary units per unit of time. For the sake of concreteness, we will assume that we are talking about thousands of rubles per day. An initial budget of $B^1$. This budget is formed from the income that these BPs previously brought in. It was decided to improve them (optimize them). For this purpose, BP modeling was conducted. As a result, it was determined what needs to be done to transition each BP from the AS-IS state to the TO-BE state. For each $i$-th BP, it was calculated how much the intensity of income generation will increase as a result of the transition from AS-IS to TO-BE. Let us denote this value as $d_i$. We will also assume that we are talking about thousands of rubles per day.

For each BP with number $i$, a project $P_i$ initiated, the implementation of which will ensure the required transition to a new improved state. Accordingly, the value $d_i$ can be considered as an indicator of the effectiveness of project $P_i$. A total of $n$ projects is initiated. It has been established that there are no dependencies between the projects. The cost (budget) of project $P_i$ is equal to $C_i$. The planned time of its implementation is equal to $T_i$. The company employs $m$ key specialists. Each project requires the participation of at least one of them. Key specialists are engaged in BP. Key specialist $j$ ($j = 1, 2, ..., m$) can allocate only a certain share $s_j$ of his daily working time to work on projects. In what follows, we will call $s_j$ the project resource of key specialist $j$ or simply a resource. The resource can be defined both in shares and in percentages of the total working time of the specialist. It is known that project $i$ requires a resource of $s_{ij}$ from key specialist $j$. In this case, $s_{ij} \leqslant s_j$.

It is decided that all projects should be implemented. If at the first stage the initial budget and/or resources are not enough to simultaneously launch all $n$ projects, then the remaining projects will be launched as income from the above BPs accumulates and resources are freed up key specialists.

It is necessary to determine the order in which projects will be launched.

## 2. Solution

### 2.1. Priorities of projects to improve BP

When developing performance management systems, it is necessary to create special indicators [37]. As indicated in the work [37], this is due to the fact that the indicators of economic benefits used in investment analysis are indirect and implicit. We will synthesize an expression for calculating project priorities that is adequate to the formulated conditions. In this case, we will proceed from the following.

1. The higher the efficiency of a project, the higher its priority.
2. If the cost of a project is high, then its inclusion in the portfolio reduces the chances of other projects entering this portfolio.
3. Of two projects of equal cost, all other things being equal, the one with a higher intensity of budget development is less preferable.
4. All other things being equal, a project that requires fewer total key personnel resources is preferable.

Let's construct an expression for calculating the project priority as a dimensionless value. The numerator should reflect positive factors. The denominator should reflect negative factors. Following point 1, we put $d_i$ in the numerator project efficiency. Let's consider what should be in the denominator. In accordance with points 2 and 3, the denominator should contain the intensity of the project budget development:

$$c_i = C_i / T_i . \quad (1)$$

In accordance with paragraph 4, it is necessary to take into account the resource intensity of projects. It is logical to define the resource intensity of a project as the sum of the resources of key specialists required for its implementation:

$$R_i = \sum_{j \in M_i} s_{ij}. \quad (2)$$

where $M_i$ – a set of numbers of key employees whose resources are needed by the project $P_i$.

Let us agree to characterize the relative resource intensity of the project $P_i$ the ratio of the total volume of resources of key specialists required for its implementation to the total volume of resources that can be used to implement projects:

$$r_i = \frac{R_i}{\sum_{j=1}^{n} s_j}. \quad (3)$$

The relative resource intensity of a project determined in this way shows what share the given project requires from the total volume of resources of key specialists allocated to all $n$ projects. The relative resource intensity can also be expressed as a percentage. To do this, it is sufficient to multiply the right-hand side in formula (3) by 100%.

Finally, we obtain the following expression for the project priority:

$$w_i = \frac{d_i}{c_i r_i}. \quad (4)$$

Thus, if the goal of the project is to improve the BP, then it is proposed to adopt as its priority the ratio of the project efficiency to the product of the project's budget development rate and its relative resource intensity. Let us recall that the efficiency of the project is understood as an increase in the intensity of income generation of the BP, the improvement of which the project is aimed at.

### 2.2. Determining the order of launching projects

Since, according to the condition, the budget is less than the total cost of the projects, at the first stage it is proposed to begin implementing a portfolio of $n_1 < n$ projects, the sum of the priorities of which is maximum, and the following restrictions are met: the total cost does not exceed the allocated budget, and the total resource intensity of these projects does not exceed the project resource of any key specialist involved in them.

To solve this problem, we can use the linear programming method. Note that if there are dependencies between projects, the problem is no longer a linear programming problem. Let us introduce $n$ binary variables $X_i$. The value of each $X_i$ is 1 if project $i$ is included in the portfolio, and 0 otherwise. The problem is reduced to maximizing the objective function

$$\sum_{i=1}^{n} w_i X_i \to \max \quad (5)$$

under one budget constraint

$$\sum_{i=1}^{n} C_i \le B^1 \quad (6)$$

and $m$ restrictions on the workload of key specialists

$$\sum_{i=1}^{n} s_{ij} X_i \le s_j. \quad (7)$$

This is a linear programming problem that is solved by the simplex method. As a result of the solution, we will obtain a certain set of projects that are subject to launch at the first stage. Let us designate the set of their numbers as $N_1$. Their total cost is equal to

$$C^1 = \sum_{i \in N_1} C_i. \quad (8)$$

Let us agree to consider the possible beginning of the second stage of project implementation as the moment when at least one project is completed. Let us also agree to consider that if one project is completed and there is a small time lag left until the end of another project, then the beginning of the stage is postponed until the end of the second project. The size of the lag is determined by the program manager, based on the condition that the lag should not exceed the number of working days set by the program curator.

The remainder of the initial budget for the second stage will be

$$\Delta B^1 = B^1 - C^1. \quad (9)$$

Obviously, this budget will not be enough. The company's management must decide to allocate an additional budget. The additional budget is taken from the funds that the BP will generate during the time $t_{12}$ from the beginning of the first stage to the beginning of the second stage.

Note that the funds are taken from the income that the initially profitable BP bring in. Therefore, the fact that the effect of optimization does not occur immediately and does not jump affect only the volume of allocated funds.

It is reasonable to assume that this budget will be proportional to time with a certain coefficient $q_2$:

$$B_e^1 = q_2 t_{12}. \quad (10)$$

As a result, we will find that the budget for the second stage will be

$$B^2 = \Delta B^1 + B_e^1. \quad (11)$$

Reasoning similarly, we can write that the budget of stage number $k$ is determined by the formula

$$B^k = \Delta B^{k-1} + B_e^{k-1}. \quad (12)$$

Here

$$B_e^{k-1} = q_\kappa t_{(k-1)k}, \quad (13)$$

where

$t_{(k-1)k}$ – time from the beginning of stage $(k - 1)$ to the beginning of stage $k$.

Let us determine what the resource constraints will be at the second stage.

At the first stage, the workload of specialist $j$ is equal to the total demand for his resource for all projects launched at the first stage:

$$S_j^1 = \sum_{i \in N_1} s_{ij}. \quad (14)$$

Let us assume that the second stage begins after the completion of project number $f$, from among the projects of the first stage. The completion of this project will free up the resource $s_{fj}$ from specialist $j$. Accordingly, at the second stage the available resource of this specialist will be equal to

$$S_{2j} = s_j - S_j^1 + s_{fj}. \quad (15)$$

If the second stage begins after the completion of several projects, the set of numbers of which is $N_{1F}$, then the available resource of specialist $j$ will be equal

$$S_{2j} = s_j - S_j^1 + \sum_{i \in N_{1F}} s_{ij}. \quad (16)$$

Reasoning in a similar way, we obtain the following. If at the beginning of stage $k$ the projects with a set of numbers of , and the stage begins upon completion of the projects with a set of numbers of $N_{kF}$, then the available resource of specialist $j$ will be

$$S_{kj} = s_j - \sum_{i \in N_k^*} s_{ij} + \sum_{i \in N_{kF}} s_{ij}. \quad (17)$$

The problem of determining projects that were not started at previous stages and which will be launched at stage $k > 1$ is reduced to a linear programming problem, similar to how it was done earlier for stage 1. In this case, the summation in the objective function should be carried out only over the set of numbers $N^k$ of those projects that were not started at previous $(k - 1)$ stages:

$$\sum_{i \in N^k} w_i X_i \to \max. \tag{18}$$

The budget constraint for stage $k$ is

$$\sum_{i \in N^k} C_i \leq B^k, \tag{19}$$

where

$B^k$ – budget of stage $k$, determined by formula (12).

At all stages, the number of resource constraints is equal to $m$. For specialist $j$ at stage $k$, it has the form

$$\sum_{i \in N^k} s_{ij} \leq S_{kj}, \tag{20}$$

where

$S_{kj}$ – the resource of specialist $j$ available at the beginning of stage $k$, determined by formula (17).

Note that it is possible that an attempt to start the next stage after completing one or even several projects may be impossible due to insufficient resources. In this case, it is necessary to wait for the completion of the following projects. Let us apply the obtained results to solving a real problem.

### 3. Example

The company's strategic goal is "To optimize the main BPs." Ten such BPs have been identified. Ten projects have been initiated to achieve the goal. Five key specialists should be involved in their implementation. Following the style adopted in the company, we will say that the allocated resource of each specialist is 100%. Accordingly, the resource intensity of the projects will be set as a percentage, as is done in *Table 1.*

The characteristics of the projects that determine their priorities are given in *Table 2.*

Initially allocated budget $B^1$ = 10 00 000 rubles is three times less than the total cost of the projects that need to be implemented. In addition, the total resource requirements of the projects exceed 100% for each of the specialists. Therefore, the projects will be launched

*Table 1.*

**Projects' need for specialist resources (%)**

| Projects | Specialists | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| 1 | 29 | 8 | 31 | 41 | 50 |
| 2 | 44 | 11 | 1 | 39 | 22 |
| 3 | 36 | 38 | 27 | 36 | 43 |
| 4 | 1 | 18 | 21 | 8 | 7 |
| 5 | 15 | 16 | 2 | 2 | 27 |
| 6 | 24 | 7 | 21 | 18 | 33 |
| 7 | 15 | 45 | 48 | 45 | 5 |
| 8 | 50 | 7 | 43 | 41 | 33 |
| 9 | 18 | 29 | 13 | 32 | 4 |
| 10 | 10 | 19 | 28 | 48 | 17 |

*Table 2.*

**Project characteristics**

| Projects | Relative resource intensity | Planned implementation time (days) | Cost (thousand rubles) | Budget utilization rate (thousand rubles/day) | Efficiency (thousand rubles/day) | Priority |
|---|---|---|---|---|---|---|
| | $r_i$ | $T_i$ | $T_i$ | $c_i$ | $d_i$ | $w_i$ |
| 1 | 0.318 | 159 | 3 665 | 23 | 22.5 | 3.07 |
| 2 | 0.234 | 74 | 648 | 9 | 3.9 | 1.90 |
| 3 | 0.36 | 126 | 6 333 | 50 | 32.5 | 1.80 |
| 4 | 0.11 | 144 | 6 896 | 48 | 50 | 9.49 |
| 5 | 0.124 | 73 | 1 071 | 15 | 5.2 | 2.86 |
| 6 | 0.206 | 52 | 5 590 | 108 | 32.9 | 1.49 |
| 7 | 0.316 | 129 | 691 | 5 | 6.6 | 3.90 |
| 8 | 0.348 | 36 | 1 418 | 39 | 10.4 | 0.76 |
| 9 | 0.192 | 84 | 3 822 | 46 | 20.1 | 2.30 |
| 10 | 0.244 | 66 | 4 076 | 62 | 20.2 | 1.34 |

in stages. It was decided that for each stage $k > 1$ to the remaining budget will be added an amount proportional to the duration of the previous stage with a constant coefficient $q = 100\,000$ rubles.

Since all projects are aimed at achieving one strategic goal, it can be said that they form a program of projects. It is necessary to determine the order of implementation of this program.

Following the proposed approach, we define the projects that should be launched at the first stage using the simplex method. We find that these are projects with numbers $N_1 = \{2; 4; 5; 7\}$. Their total cost is $C^1 = 9\ 306\ 000$ rubles. We proceed to the second stage. It can be started after the completion of project 5. However, given that project 2 should be completed only one day later, a decision is made to start the second stage after its completion. Thus, the duration $t_{12} = 74$ days. The budget of the second stage will be in accordance with formula (11) $B^2 = (10\,000\,000 - 9\,306\,000) + 100\,000 \cdot 74 = 8\,094\,000$ rubles.

We determine the resources of specialists using formula (17). We again solve the linear programming problem with binary variables whose numbers belong to the set $N^2 = \{1; 3; 6; 8; 9; 10\}$. We find that project 1 should be launched at the second stage.

The program will require six stages to be implemented, details of which are provided in *Table 3*.

*Figure 1* shows the roadmap of the considered program for optimizing the company's business process.

*Table 3.*

**Stages of program implementation**

| Stage | Budget (million rubles) | Specialist resources (%) | | | | | Launched projects | Projects, after the completion of which the stage begins | Duration of stage (days) |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | | | |
| $k$ | $B^k$ | $S_1^k$ | $S_2^k$ | $S_3^k$ | $S_4^k$ | $S_5^k$ | $N_k$ | $N_{kF}$ | $t_{(k-1)}k$ |
| 1 | 10 | 100 | 100 | 100 | 100 | 100 | 2; 4; 5; 7 | | 74 |
| 2 | 8.094 | 84 | 37 | 31 | 47 | 88 | 1 | 2.5 | 55 |
| 3 | 9.929 | 70 | 74 | 48 | 51 | 43 | 6; 9 | 7 | 84 |
| 4 | 8.917 | 53 | 63 | 56 | 27 | 46 | 3 | 4; 6; 9 | 20 |
| 5 | 4.584 | 71 | 92 | 69 | 59 | 50 | 10 | 1 | 66 |
| 6 | 7.108 | 64 | 62 | 73 | 64 | 57 | 8 | 10 | 40 |

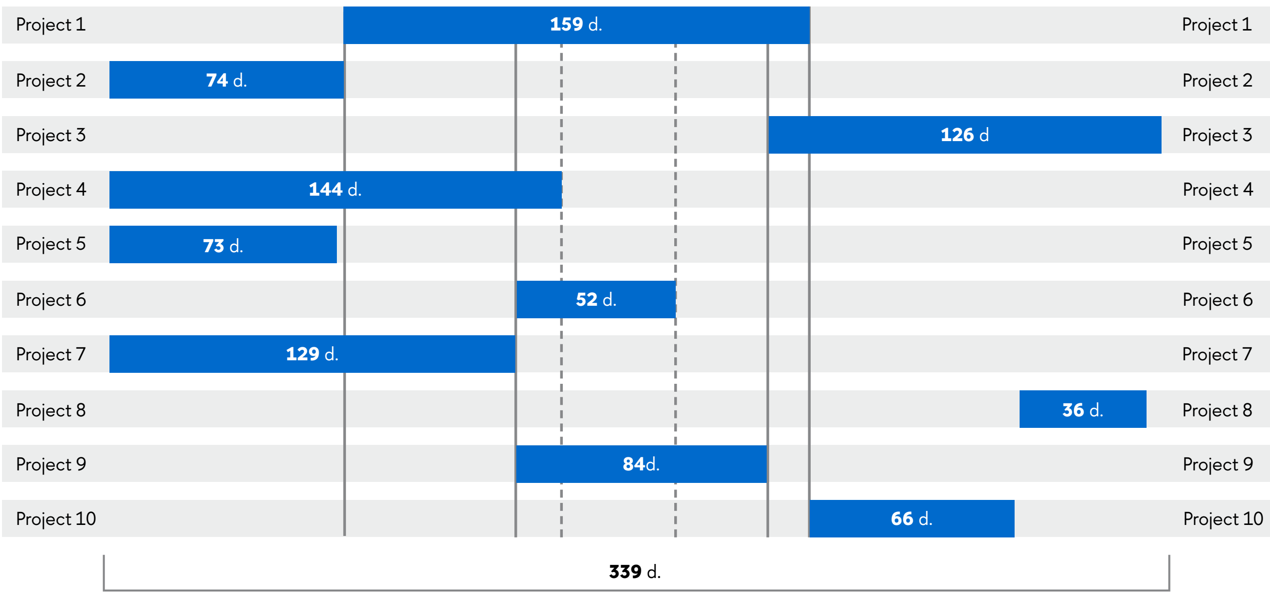


*Fig. 1.* Roadmap of the company's business process optimization program.

## Conclusion

According to the authors, the following are new in this work:

- expression for calculating the priority of projects, reflecting the fact that the projects are aimed at optimizing the business processes that generate the budget for their implementation;
- a method for step-by-step determination of the order of implementation of the entire program aimed at optimizing the business processes that generate the company's income.

The work was initiated to meet the current need of enterprises that ensure the airworthiness of civil aviation aircraft. The results obtained are also applicable in other sectors of the national economy.

The article is of interest to managers of project programs of manufacturing and service companies, as well as to a wide range of researchers and postgraduate students of technical and economic specialties. The further development of the approach is the consideration of the situation of the presence of dependencies between the projects of the program. ■

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