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# Optimization Modeling of Innovation Project Portfolio Resource Efficiency for Engineering Enterprises

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## Abstract
The issue of industrial sector efficiency improvement is very relevant nowadays. The qualitative development of competitive advantages among domestic enterprises of instrument-making and engineering is possible nowadays mainly due to the effective use of available resources, the faster growth of labor productivity and enterprise innovative activity increase. At that it is important to pay a special attention to the development of an effective mechanism for innovative project competitive portfolio of production design and technological preparation (PDTP), since it is the quality, the duration and the cost of PDTP that largely determine the innovativeness and financial profitability of products. The article presents an economic-mathematical model of production capacity optimization, which allows to increase the efficiency of labor resource use and to optimize the time of new product development at machine-building enterprises (the load model for interchangeable resource groups). The model aims to minimize the total cost of documentation development, subject to simultaneous loading of employees in several projects within the matrix management structure. Thus, the competent planning of project portfolio financial efficiency concerning design and technological preparation in the modern dynamically developing world is one of the main attributes for a successful innovation and investment policy of an enterprise. The calculation of the proposed model serves the strategic and the tactical goals of an enterprise: it is necessary during the change of project participant composition and number and should be taken into account during personnel policy and enterprise overall strategy development.

**Keywords:** Resource efficiency; New product development project; Optimization model; Project efficiency; Employee loading.

## 1. Introduction
A difficult economic situation, a political uncertainty on the world arena cause an objective need to improve production and introduce the measures that contribute to the intensive development of the national economy and improve the efficiency of enterprise resource use. The problem of resource potential implementation is of particular importance for the types of economic activity that form the structural framework of the territory economy in the long run, such as engineering enterprises.

According to the experts from the RIA Rating, the Russian machine-building industry increased its output by 3.4% in 2017. Partially, this result is due to the low base factor, since the production of many types of engineering products in 2016 reached a multi-year minimum (Review the result of, 2017). Also, RIA Rating experts point out the growth of engineering product exports, which, according to the Federal Customs Service, increased by 24.6% in physical terms and 15.5% in monetary terms during the year (Review the result of, 2017). Thus, there is a positive, but unstable dynamics in the engineering industry. A qualitative leap in competitive advantage increase is possible through an effective use of available resources, a faster growth of labor productivity and an increased innovation activity in the industrial sector. Thus, there is an objective need to create an effective mechanism for innovation (Korsakov et al., 2017).

The goal is to develop a model of design-technological project portfolio efficiency, taking into account the simultaneous loading of project team members in several projects within the framework of the production organization matrix structure.

The review of the works by domestic and foreign researchers has revealed a huge variety of different techniques and approaches to investment portfolio development and optimization. For example, during the selection of projects Turner J.R, Nalesnaya E.E. and others are guided by quantitative and qualitative assessment of the relationship between portfolio profitability and risk (Nalesnaya, 2017; Turner and Müller, 2003), and the connection of the performed projects with the achievement of the strategic and the tactical goals of a company is studied by Matyushok S.V. and others (Kaplan and Norton, 1995; Matyushok et al., 2014). Leonard-Barton D. covers the problems of competent allocation of production resources in his works (Leonard-Barton, 1992), the issues of labor valuation and effective time management are disclosed in the works by Puech L. and others (Puech and Durand, 2017).

In order to obtain a synergistic effect, it is important to combine and harmonize the recommendations of domestic and foreign scientists on the development of an effective project portfolio at the stage of strategic and tactical planning of an enterprise innovation and investment activity.

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# 2. Methods

As domestic practice shows, the innovation activity of enterprises is reduced noticeably at the final stages of the scientific and technological process. If we analyze the dynamics of patent issuance on the results of intellectual property by Rospatent in 2017, we can identify the following ratio: 32.9% of patents are accounted for inventions, 8.7% - for industrial models and only 4.3% of patents are accounted for industrial designs.

Numerous studies carried out by analytical services state a weak correlation between implemented projects and the company development strategy.

Besides, the implementation of future plans is hampered by the production conditions and the irrational (and sometimes uncontrolled) use of resources.

The issue of project resource efficiency improvement during the product development stage should be addressed in a comprehensive manner, including the implementation of the following measures:

- the reduction of production costs and the development time of new products due to unification, typification and standardization of products;

- the minimization of time loss for the development of new products, taking into account the continuity of single knowledge base accumulation and use on the projects implemented at an enterprise;

- the reduction of costs due to the quality study of product design and technological component, taking into account the cost of components and the complexity of new product manufacturing and assembly during the stage of design and technological documentation development with the minimization of rejection likelihood at the stage of assembly and adjustment;

- the reduction of unit fixed costs due to an earlier marketing of new products and production increase.

During project management at Russian instrument-making enterprises, it is also important to take into account the specifics of projects (Ildarkhanova and Safiullin, 2017):

- labor resources are the main limiting factor during the implementation of new product development projects;

- the matrix or linear-functional organizational structure prevails at domestic instrument-making enterprises implementing new projects (or modernization projects);

- enterprises are characterized by the simultaneous implementation of a large number of differentiated PDTP projects;

- they implement short-term (the implementation period of up to one year) and medium-term (up to three years) projects;

Thus, the key tool for project resource efficiency improvement at the stage of design and technological preparation of production is the correct distribution of employee workload and the distribution of responsibility, taking into account the qualifications of staff, ensuring the necessary level of knowledge transfer (mentoring); the motivation of project activity participants, as well as the increase of project planning and monitoring role. Taking into account the abovementioned requirements, the author proposed an optimization model to increase the resource efficiency of new product development projects at instrument-making enterprises during the stage of design and technological documentation development.

# 3. Results and Discussion
## 3.1. Problem Formulation

The following data is known:

$t_{hij}$ – the hour complexity of a single document development of the type h by an employee of i-th position of j-th category.

$c_{ij}$ - the average cost of one hour of work by one employee of the i-th position and j-th category in rubles.

Let $x_{hij}$ – is the required number of developed documents of the form h by an employee i of that position j of that category, pcs. It is required to find non-negative values of $x_{hij}$ variables, that ensure the minimum total cost of documentation development when the production plan is fully implemented.

*Optimality criterion*: minimum total costs for the development of documentation within the project portfolio.

Thus, the economic and mathematical model of new product resource efficiency improvement for new project development based on the optimization of project team member load is the following one (formula 1):

$$Z_{min} = \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{h=1}^{H} c_{ij} \cdot t_{jih} \cdot x_{jih} \qquad (1)$$

The limitation on the number of developed documents within the framework of projects included in the portfolio is presented in formula 2, where $A_h$ is the total number of required documents of type h within the project portfolio. Formula 3 shows the restriction of the project team members by load, where $B_{ij}$ is the settlement fund of i-th position and j-th category employee operation time in hours. $B_{ij}$ is calculated by the formula 4. Formula 5 is the qualification limit, where d is the minimum required degree of participation during documentation development. The degree of participation is measured in percent. The left side of the expression in the constraint system shows the resource volume used optimally, and the right side shows the available volume of the same resource. The condition of a negative value impossibility for the number of developed documents is indicated in formula 6.

*the limit on the number of documents being drawn up:*

$$\sum_{h=1}^{H} x_{jih} = A_h \quad (h = \overline{1,H}) \tag{2}$$

*1) the limit on the load of project team members:*

$$\sum_{i=1}^{I} \sum_{j=1}^{J} t_{jih} \cdot x_{jih} \leq B_{ij} \quad (i=1,2,...I, j=1,2,...J) \tag{3}$$

$$B_{ij} = K_{ij} \cdot W_g \cdot (1-p), \quad ( P = \overline{1,100} ), \tag{4}$$

where, $K_{ij}$ – is the number of employees of the i-th position of j-th category; p - the loss of working time in %.

*2) the limit on the qualifications of performers:*

$$x_{jih} \leq A_h \cdot d \quad h = \overline{1,H} \tag{5}$$

*3) the condition of non-negativity:*

$$x_{jih} \geq 0 \tag{6}$$

The system of restrictions on the number of documents created in the framework of projects included in the portfolio, involves the calculation of the amount of documents of this type, developed by all possible performers, and the total number should correspond to the number of documents required by plan. The system of restrictions on the loading of project team members is the calculation of employee load of a particular position and category depending on the number and the labor intensity of the documents they develop. At that the calculated load value of a group of workers of a similar profession and category working under the project program should not exceed the statutory amount of time calculated as the product of the number of employees of this qualification and position in the group, the total annual time fund, adjusted for the loss of working time. The system of limitations on qualification shows the minimum degree of a particular category and position employee participation during a document development.

The proposed linear programming model makes it possible to use the "Search for Solution" function in Microsoft Excel to calculate the optimal load of executors taking into account the current production program aimed at cost minimization.

## 4. Conclusions

During the model development, they took into account the restrictions on the number of created documents within the projects included in the portfolio, on the load of project team members and on the qualifications of project participants. The model of resource efficiency improvement allows to increase the financial efficiency of a project portfolio through the rational use of enterprise resources, and can also be a working tool for a quantitative justification of labor costs for innovation and investment activities of enterprises. The model can be used as an auxiliary tool for project personnel planning during the determination of the most demanded competencies; the setting of training priority, staff qualification development; the calculation and the recalculation of personnel requirements in the cases of project portfolio change.

In order to use the mathematical model, it is necessary to establish labor standards for technical experts. The work of this model is hampered by the fact that the workforce is creative and not always amenable to rationing during the development of new products. The expert methods of labor rationing, used at domestic enterprises, do not have the necessary degree of objectivity. The model requires the additional detailing of work and the coordination of projects by terms taking into account priorities;

This model was tested at one of the engineering enterprises of the city of Kazan, and the results of the study showed, that the qualitative analysis of the project portfolio in terms of its resource efficiency at the planning stage, and the organization of project portfolio monitoring process at the execution stage, allows you to save more than 20% on project labor costs relative to the same indicators of the previous year, to increase the salary of the company employees by 5-10% due to the possibility of participation in a greater amount of projects.

## 5. Summary

Investment activity and financial attractiveness of instrument engineering domestic enterprises is largely determined by the efficiency of new product production, starting with the process of design and technological documentation development, and ending with the delivery of the product into mass production.

The purpose of optimization model application for resource efficiency improvement at instrument-making enterprises is the redistribution of responsibility between project participants to increase competence and innovative potential of project participants, to optimize project implementation time and minimize the costs of new product design and development. At the same time, the assessment of business process efficiency main indicators should be carried out systematically, and new goals should be established and the standards for labor-intensive work should be adjusted based on the results of the assessment. It is important to understand that the proposed measures for resource saving, management system and technology development will get a synergistic effect only if the project portfolio for new product development is aimed at enterprise strategic goal implementation and its innovative activity increase in general.

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