MATHEMATICS

Mathematical model of value-oriented portfolio management of high-tech enterprises projects

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Abstract. The necessity of optimization of the mathematical apparatus for the formation of project portfolios of science-based enterprises based on the value-oriented approach is considered. The mathematical model of value-oriented management of project portfolios of the science-based enterprise is developed on the basis of the improved information model of project portfolio formation and the economic-mathematical model integrated into it. There have been introduced an additional indicator of innovative value in portfolio projects and a restriction on the allowable aggregate risk of project portfolios, which leads to the selection of the portfolio with the highest integral value.

Keywords: *project portfolio, portfolio management, value-oriented approach, science-based enterprises.*

Introduction. Changes in the global economy require qualitatively new methodological approaches to the analysis and management of the development of science-based high-technology industries, which would serve as guarantors of the state's competitiveness and stability. Modern portfolio management focuses on the formation of a project portfolio on the basis of values [1]. The main concept of the value-oriented approach is the formation of a project portfolio with the highest added value. It integrates a variety of values and transforms them into a system of objectives leading to the creation of a new value enriched with uniqueness, distinctive features and innovations, which satisfies all participants of the project portfolio under development. This approach involves revision of the projects and programs included to the project portfolio of science-based enterprises in order to establish priorities according to the strategic values and accounting for uncertainties of the turbulent environment.

Brief overview of related publications. The analysis of scientific publications has showed that the problem of forming an optimal project portfolio, which allows achieving strategic goals of the organization, is considered in a number of research studies [2-5]. Each of which deals with particular features of portfolio management and offers appropriate methods and models for their formation. The authors of publication [6] emphasize the disambiguation of two groups of the project portfolio formation techniques for organizations. The first group involves selection of projects for the portfolio on the basis of expert commentary [2, 3], while the second group employs decision support systems [4, 5]. It should be noted that application of each of the approaches is determined by the volume and quality of the source information and the conditions under which the management decision on the portfolio formation is made.

Extending usage of the project approach to the sphere of non-material production necessitated evaluation of the project's success beyond its quantitative characteristics. Value-oriented project management suggests using the "project value" criterion when assessing the project's effectiveness [7]. In publication [8], S. D. Bushuiev defines value as the benefit which all stakeholders obtain from the project implementation. The author suggests defining the project value as a complex indicator which consists of the value of the process, the product, and the organization implementing the project. According to Professor V. A. Rach [9], who introduces the concept of "harmonized value", two aspects of the value harmonization should be considered: harmonization with strategic goals of the organization implementing the project and harmonization of the values realized by all stakeholders of the project. According to the authors of publication [10], the value approach is the main concept of project portfolio formation; it involves maximization of the growth of organizational values. It is this circumstance that necessitates the development of a new value-oriented project management methodology based on the integrity of the object of management and the uncertainty of changes in the environment [11].

There have been recently developed a number of models of project portfolios using different mathematical apparatus: single- and multi-criteria models; deterministic, stochastic or fuzzy models; linear, nonlinear, dynamic, and graphical models [4, 6, 10, 12-18]. In addition, artificial intelligence tools have been widely implemented, such as neural networks, genetic algorithms, and the compositional approach. Publication [7] presents an informational model of formation of a project portfolio of international activity of higher educational institutions, which employs the economic-mathematical linear programming model.

Analysis of the **materials** from literary sources shows that the existing mathematical apparatus is flawed and does not take into account the peculiarities of portfolio management at science-based enterprises. Therefore, research and modernization of portfolio management for science-based enterprises on the basis of the value-oriented approach is an urgent question, which needs to be elaborated and optimized.

The article aim is to develop a mathematical model of the value-oriented portfolio management for science-based enterprises, which allows assessing the integrated value of a project portfolio in order to optimize the achievement of strategic goals of the enterprise.

Basic material and research results. Portfolio management of a science-based enterprise focuses on providing analysis of its projects in order to establish value priorities, coherence and compliance of portfolio management with the organization's strategy. Publication [19] highlights the basic strategic values of a science-based enterprise, and publication [20] renders the characteristics of project portfolios and the specifics of their management. The author also forms the value field of a science-based enterprise, defined as an interrelated system of the value orientation sets (motives, tools, methods, techniques, objects and products of human activity, their personal meanings and objectives). It is characterized by a synergistic effect and is constantly evolving towards the enterprise strategy and its components. The value field is based on the main values of science-based enterprises that constitute a hierarchical (pyramidal) system and proceed to the value-oriented strategies of the respective levels, being influenced by the external and internal environment.

By their specific features, science-based enterprises implement a large number of diverse projects, organizing them into portfolios. The main task of administrators and managers is the formation of an optimal portfolio from a wide variety of project options.

The process of formation of the portfolio for a science-based enterprise includes 7 stages (Fig. 1).

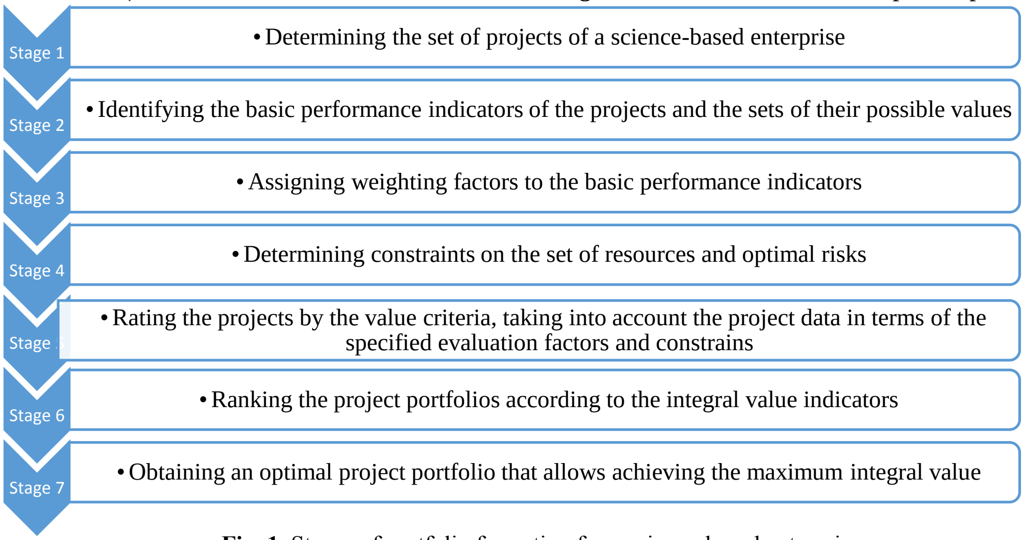

Fig. 1. Stages of portfolio formation for a science-based enterprise

In order to solve the problem successfully and achieve the strategic goals of the enterprise, let us build a functional model for the process of project portfolio formation for a science-based enterprise (Fig. 2).

The process of transforming the model inputs into outputs takes place due to the use of an economic-mathematical model for project portfolio formation [7].

The set $Q = \{q_1 ; ... ; q_k ; ... ; q_l\}$ includes a number of alternative variants of the projects of the science-based enterprise $k = \overline{1;l}$). Implementation of each of the projects is aimed at achieving the strategic goals of the enterprise and concerns the following areas: production, science, innovation, economy, policy, ethics, as well as social, regional and cluster components. The set of the basic values of the science-based enterprise forms its value field, which is taken as the basis for the set of basic performance indicators of the project $B_k = \{b_{k1}; ...; b_{ki;...}; b_{kn}\}$, $(i = \overline{1;n})$. In turn, the degree to which the results of each project are achieved is rendered by the obtained values of these indicators $Y_{ki} = \{y_{ki1}; ...; y_{kij;...}; y_{kim}\}, (j = \overline{1;m})$.

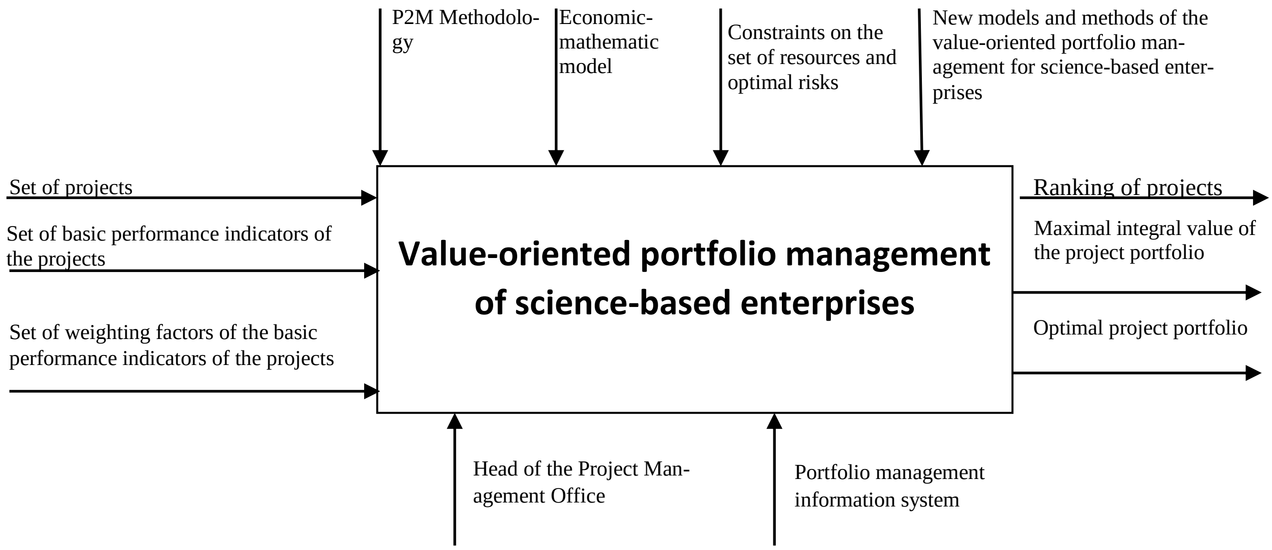

Fig. 2. Functional model of the process of project portfolio formation for a science-based enterprise

According to P2M [1], the most feasible and effective methods for determining the value are the balanced score-card method and the five and two method, which are useful for the development of primary evaluation indicators. “Five” stands for five E’s: *efficiency*, *effectiveness*, *earned value*, *ethics*, and *ecology*. *Efficiency* of resource use in projects is determined by the ratio of benefits received from the project to the amount of resources used. *Effectiveness* represents the level of satisfaction of the parties concerned before and after the project and describes the sector of benefits on the basis of certain performance criteria. *Earned value* is a universal criterion for measuring the project progress, which binds the idea of the project to its schedule and costs (resources). *Ethics* is the program community’s response to the overall acceptability and social orientation of the program idea, its compliance with social and corporate rules and satisfaction of the ethical expectations of the participants. *Ecology* is a criterion of the organization’s sustainable growth or the program’s continuous progress with due regard for environmental protection. Meanwhile, “two” stands for two A’s: *accountability* and *acceptability*. *Accountability* is determined by how much the management is responsible for the project’s / program’s results, including intermediate results obtained by stakeholders, as well as transparency, visibility and publicity in informing the community about the current status of the project / program. *Acceptability* is determined by a number of conditions adopted by stakeholders with regard to the project’s cost indicators related to the amount of capital invested, guarantees of return on investments, and approved plans for allocating the program’s flow of funds in time.

Taking into account the specific features of science-based enterprises and the peculiarities of managing their projects, it is necessary to supplement the above with the *indicator of innovative value* of the portfolio projects.

Since the basic performance indicators of the project vary in their nature, let us calculate their values by means of expert commentary measured in points in order to simplify their further conversion to the indicator of the project’s value. It is also necessary to consider the importance of each of the indicators in achieving the strategic goals of a science-based enterprise by assigning their weighting factors, which may vary depending on the project:

$$W_k = \{w_{k1}; \dots; w_{ki;\dots}; w_{kn}\}, (k = \overline{1;l};\ i = \overline{1;n}),$$
$$\sum_{i=1}^{n} w_{ki} = 1.$$

It is proposed to evaluate the project’s success with the help of an additive indicator of its value, which can be presented as the following formula:

$$V_k = \sum_{i=1}^{n} w_{ki} \cdot y_{kij}, \left(k = \overline{1;l}\right),$$

where w_{ki} is the weighting factor of the *i*-th performance indicator for *k*-th project, and y_{kij} is the *j*-th value of the *i*-th performance indicator for *k*-th project.

Thus, the results obtained from the value indicators of the projects can be taken as a basis for their rating. The project with the highest value will receive the highest rating score $R_{k,}\left(k = \overline{1;l}\right)$.

Formation of an optimal project portfolio, which allows achieving the maximum integral value, is possible via solving the problem rendered by *the economic-mathematical model*.

The target function of the model is the integral value of a project portfolio, which is selected from the set of alternative portfolio variants $P = \{p_1; \dots; p_h; \dots; p_e\}, (h = \overline{1;e})$. The integral value is calculated as the sum of the values of individual projects included in the portfolio:

$$IV_h = \sum_{k=1}^{l} V_k \cdot x_{hk} \to max$$

The model’s control parameters are x_{hk}, $\left(h = \overline{1;e};\ k = \overline{1;l}\right)$, which demonstrate the possibility of the *k*-th project’s inclusion to the *h*-th portfolio. The control parameters are expressed as the Boolean variables $x_{hk} = \{0; 1\}$, (1 stands for the case when the *k*-th project is included to the *h*-th portfolio, 0 – when not).

Since any project activity is carried out with limited resources, it is necessary to consider this constraint $\alpha = \{\alpha_1; \dots; \alpha_f; \dots; \alpha_d\}, \left(f = \overline{1;d}\right)$ for each type of resources involved in the project, such as material, financial, managerial, labor, informational ones. The available information on the required provision of resources for the project activity of a science-based enterprise is taken as a basis for developing a matrix of resource demand. The total amount of resources of the *f*-th type required for the *h*-th portfolio should not exceed a specific threshold value $\sum_{k=1}^{l} r_{kf} \cdot x_{hk} \le \alpha_f, \left(h = \overline{1;e};\ f = \overline{1;d}\right)$.

Uncertainties and errors in projects and portfolios are regarded as their risks. The risks should not exceed the threshold values that lead to destructive phenomena in management; correspondingly, the model should take into account the risks and have appropriate limitations. Therefore, let us introduce the constraint *Risk*$= \{R_1; \dots; R_g; \dots; R_s\}, (g = \overline{1;s})$ for each type of risks existing in the project portfolio. The indicator of the risk of the *g*-th type in the *h*-th portfolio should not exceed a certain threshold value

$\sum_{k=1}^{l} R_{kg} \cdot x_{hk} \le R_g, (h = \overline{1;e};\ g = \overline{1;s})$.

Solving the linear programming problem with the use of the simplex method enables obtaining the optimal project portfolio $P_h^{opt}, (h = \overline{1;e})$, which allows achieving the maximum of its integral value IV_h^{max}.

Since the optimization linear programming problem can have more than one optimal solution, it is possible to form several alternative variants of optimal portfolios. Thus, the boundaries of management decisions will be expanded through creation of a portfolio ranking, allowing one to choose the best option from the available alternatives.

Conclusion. Therefore, a project portfolio of a science-based enterprise is formed from a set of projects and should only include those that allow realizing the maximum integral value for achieving its strategic goals and minimizing the risks of these portfolios. Formation of an optimal portfolio is possible through the use of the proposed model of the process of project portfolio formation for a science-based enterprise, as well as the economic-mathematical model. Since the presented model is deterministic and does not take into account the instability of the conditions under which the strategy of the enterprise is implemented, it is planned to further develop a model of risk management of project portfolios for science-based enterprises in the fuzzy form.

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Математична модель ціннісно-орієнтованого управління портфелями проектів наукомістких підприємств

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Аннотация. Рассмотрена необходимость оптимизации математического аппарата при формировании портфелей проектов наукоемких предприятий на основе ценностно-ориентированного подхода. Разработана математическая модель ценностно-ориентированного управления портфелями проектов наукоемких предприятий на основе усовершенствованной информационной и, интегрированной в нее, экономико-математической моделей формирования портфеля проектов**.** Введены дополнительный показатель инновационной ценности в проектах, которые входят в портфель и ограничение по допустимому совокупному риску портфеля проектов, что, впоследствии, приводит к выбору портфеля с наибольшим значением интегральной ценности.

Ключевые слова: *портфели проектов, управление портфелями проектов, ценностно-ориентированный подход, наукоемкие предприятия.*