INVESTMENT PLANNING OF INNOVATIVE ACTIVITY

INTRODUCTION
The current pace of innovative transformation of the economy entails the restructuring of financial and investment processes that ensure the management of innovations in order to maintain the level of efficiency of their application in new conditions. Planning and forecasting methods also cannot remain unchanged and need to be constantly updated to meet the requirements for tools operating in the modern economy as much as possible. In this regard, the development of methods and tools for mathematical modeling of financial and investment aspects of innovation management is of great importance for innovative enterprises, being a prerequisite for the emergence of significant competitive advantages (KHOTINSKAYA; SHOKHIN, 2014).

MATERIALS AND METHODS
The basis for giving a standardized form to the processes of the innovation life cycle is their visualization by using technological networks, which requires the development of an appropriate mathematical apparatus that provides the manager with convenience for perception and natural immersion in the digital environment. The analysis of such tools (KURBEL, 2013) allows us to determine the adjacency matrix as the most appropriate form of representation (VAN STEEN, 2010; HARTSFIELD; RINGEL, 1994). Thus, the technological network will be defined using a matrix $D = \|d_{ij}\|_{I,J}$ of a special kind. The representation of the technological network in matrix form is convenient from the point of view of its digitization and subsequent analysis carried out using the ranking of the technological network, the algorithm of which is described in (ZOTOV, 2018a). Further filling the ranked network is filled with information about the project (ZOTOV, 2018a), and is used as the main tool for managing the innovation process.

METHODOLOGY: ASSESSMENT OF THE RESOURCE SUFFICIENCY OF THE INNOVATION PROCESS
The creation or acquisition of innovations are complex processes, the implementation of which requires the participation of a team of specialists of various profiles, the creative nature of whose work (MAKSIMOV, 2013; PODOL'SKII; POLYARUS; IVANOV, 2017) and the accompanying lack of standards, however, do not exempt from the need for financial and resource planning of the innovation process (MARTYNOVA, 2015; LUKMANOV, 2016). In this case, it is of interest to determine the dependence of the probability of successful execution of a technological operation on the amount of resources allocated (MANAS, 2014). First of all, we mean labor resources, since for an innovative enterprise, the main cost item is the remuneration of employees.

Suppose that the above probability is given as a function of the volume of the resource $Q$ allocated for performing this technological operation, i.e. $P = P(Q)$, which is non-decreasing, and its change will be proportional to the volume of the allocated resource, i.e.

$$\Delta P(Q) = \Phi \times \Delta Q$$

(1)

Here $\Phi$ is a certain functional, the value of which depends both on the degree of approximation of the resource provision $Q$ of the probability of successful execution of the technological operation to the maximum level $P_{max}$, and on the volume of this resource. Therefore

$$\Phi = \Phi(Q, P_{max} - P(Q))$$

(2)

Assuming that for both arguments the dependence (2) is directly proportional and denoting the quotient product of the proportionality coefficients of the arguments by $\alpha$, we obtain the following equation:

AUTHORSHIP
Vladimir Mikhailovich Zotov
Assistant Professor, Department of History and Sociology, University of Mohaghegh Ardabili, Ardabil, Iran.

ORCID: https://orcid.org/0000-0002-5462-7461
E-mail: zotov.v.m@mail.ru

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\[ \Phi = \alpha \ast Q \ast (P_{\text{max}} - P(Q)) \]  

(3)

Thus, the dependence (1) will take the final form:

\[ P(Q) = 1 - e^{-\frac{\alpha}{Q^2}} \]  

(4)

It is obvious that the probability \( P(Q) \) grows slowly at small values of the volume of the resource used \( Q \), increases sharply from the moment a certain volume \( Q' \) is reached and stops growing when a certain volume \( Q'' \) is reached, asymptotically approaching the level \( P_{\text{max}}=1 \).

Each technological operation of the process of creating or acquiring an innovation is \( O_i \in T(I) \), where \( T(I) \) is a technological network describing the process (ZOTOV, 2016) and characterized by the eigenvalue of the coefficient \( \alpha_i \), and the resource levels \( Q_i' \) and \( Q_i'' \).

Let's consider the use of equation (4) in practice. It is obvious that if there is an input value \( Q_{ij} \), \( j = 1, J \) to perform the operation \( O_i \), \( i \in [1, I] \), the coefficient \( \alpha_i \); \( i = 1, I \) should be defined as a previously known tabular variable, the value of which is determined using statistical data related to previous innovative projects.

The use of such an approach makes it possible to abandon the rationing of technological operations, as required by the classical scheme of resource planning (MAKHOVIKOVA; KANTOR; DROGOMIRETSKII, 2011). Due to the creative nature of the main content of the innovation process, the most appropriate is the use of heuristic methods that answer the question "what will happen if...?". The purpose of dependency (4) is to provide an answer to the question about the probability of successful execution of the technological operation \( O_i \), which is part of the technological network \( T(I) \), provided that a resource in the volume \( O_i \) is allocated for this operation.

Determining the initial values of the coefficients \( \alpha_i \); \( i = 1, I \) requires the creation of an expert group, while an innovative project that was recently completed and is well known to the entire expert team is taken as a standard. The procedure for determining the initial values of the coefficients \( \alpha_i \); \( i = 1, I \) is carried out in three stages.

During the first stage, the average values of the minimum, most probable and maximum volumes \( \bar{Q}_i^{\text{min}}, \bar{Q}_i^{\text{mp}} \) and \( \bar{Q}_i^{\text{max}} \) and the corresponding values of the probabilities \( P_i^{\text{min}}, P_i^{\text{mp}} \) and \( P_i^{\text{max}} \) are determined.

During the second stage, the reference values of the complexity of technological operations \( Q_i^* \) and the corresponding values of the probabilities of their successful completion \( P_i^* \) are calculated.

During the third stage, according to the formula

\[ \alpha_i = \frac{2 \ln(1 - P_i^*)}{(Q_i^*)^2}, i = 1, I \]  

(5)

obtained from (4), is the calculation of the initial values of \( \alpha_i \); \( i = 1, I \), that provides the correct formulation of the problem and the successful distribution of a given amount of resources for individual operations.

**RESOURCE PLANNING OF INNOVATION ACTIVITY**

In modern conditions, the work of the company's service that provides innovation management has to respect principles of project management (BLINOV; UGRYUMOVA, 2015), and the project of creating or acquiring an innovation becomes the object of management. Let's consider an approach to planning the resources necessary for the implementation of such a project. The project of creating or acquiring an innovation can be described using a ranked technological network, in this case it becomes necessary to allocate the entire available resource \( Q \) to individual operations of the technological network \( O_i \); \( i = 1, I \) in such a way as to achieve the greatest probability of successful completion of the project.

The complex resource allocated to ensure the implementation of the project is a vector
\[ Q = (Q^1, Q^2, ..., Q^n, ..., Q^m), \]

where \( Q^m \) - the volume of the \( m \)-th type of resource, \( m \) is the number of types of resources.

The task of resource planning for the creation or acquisition of an innovation is the equivalent of the task of distributing the available volume of the resource to the operations of the technological network \( T(i) \) (ZOTOV, 2018b). The integral criterion that such a distribution is optimal should be the maximum probability of implementing all operations of the initial technological one. At the same time, the main limiting condition is the amount of available labor resource \( Q \), as an additional condition, a high probability of successful completion of all previous operations is determined.

Based on the above, the formulation of the resource allocation problem can be formulated as follows: it is necessary to determine the set \( \{Q_i, i = 1, T\} \) that satisfies the above constraints and maximizes the integral probability that all technological operations will be completed successfully.

The solution of such a problem can be found by using the dynamic programming method (GHARAJEDAGHI, 2007), the algorithm in this case includes both a preparatory stage and a repeated stage of calculations.

The results of the preparatory stage form the basis for providing the calculation of the values \( a_i, i = 1, T \) which, in turn, will be the initial data for the first stage of the algorithm computational stage.

In the future, using the dynamic programming method, using a package of standard programs (block 4), the initial variant of resource allocation \( Q \) is obtained for the operations of the technological network \( T(i) \) \( \{Q(O) = \{O_1, O_2, ..., O_i\}\} \) and the value of the integral probability that the above operations will be successfully completed.

In block 5, the initial variants of the resource distribution \( Q_i, i = 1, T \) are obtained for the operations of local technological networks \( T(i), i = 1, T \) and the values of integral probabilities \( \rho(Q_i), i = 1, T \) corresponding to such distributions.

This completes the preparatory stage of the algorithm, the resulting resource allocation option is taken as the basis for evaluating subsequent options during the execution of the computational stages of the algorithm.

Block 6 provides for the initiation of signs of correct correctness and incompatibility, as well as the launch of the \( k \) iteration counter (block 7). Next, the values \( a_i, i = 1, T \) are determined, which are the basis for determining the values of \( P(0_i) \) during the next iteration of the calculation stage (block 8).

In block 9 will receive a distribution \( Q(k) = \{O_1^k, O_2^k, ..., O_I^k\} \), and the probability \( P^k \), block 10 will receive \( Q_i^k = \{q_1^k, q_2^k, ..., q_N_i^k\} \) and \( P_i^k, i = 1, T \).

In block 11, we will check the feasibility of the condition \( P^k > P_{min} \). If the condition is met, the optimal resource allocation is achieved. Let’s remember the data for the resource plan (block 24) and check the \( nes \) value (block 25). If, in retrospect, the original tasks were incompatible (\( nes \neq 0 \)), this means determining the current version of the resource plan by gradually increasing the allocated volume of resource \( Q \), which means that the optimal distribution is obtained for the minimum possible value of volume \( Q \). At this stage, the calculations are completed, the optimal resource plan is created (block 17) and the algorithm is exited.

If the condition \( P^k > P_{min} \) is not met, this is a sign that the resource plan obtained at this iteration is not optimal. If the sign of correction is not zero, this indicates that the current version of the resource plan was determined by a gradual decrease in the allocated amount of resource \( Q \), it means that the resource allocation was optimal at the previous iteration of the calculation stage. At this stage, the calculations are also completed, the optimal resource plan is initiated (block 17) and the algorithm is exited.
Figure 1. Algorithm for resource allocation

Source: Search data.

If the initial volume of the resource was not adjusted, we have to check the degree of proximity between the obtained values of the current and previous integral probabilities (block 13): if they differ by more than a given value of \( \varepsilon \), then we have to proceed to block (14), if the...
difference is more significant, then we have to check the possibility of increasing the volume of the resource to a certain limit value $Q$ (block 15). If this possibility is feasible, we remember the values $\alpha_i, i = 1, I$ at the last iteration (block 19); we determine the new value of the volume $Q$ (block 20); we remember the $nes$ attribute (block 21) and increase the value of the iteration counter $k$ by 1 (block 22). Next, we assign the coefficients $\alpha_i, i = 1, I$ to values determined at the last iteration (block 23), and proceed to block 9.

If checking the conditions of the problem for incompatibility shows the absence of an analog in retrospect, this means getting the optimal resource plan right away, which is often associated with a significant overestimation of the initial resource volume. In this case, it is necessary to check the possibility of reducing the initial volume of the resource. To this end, we remember the values $\alpha_i, i = 1, I$ at the last iteration (block 26), form a new value $Q$ (block 27), remember the sign $cor$ (block 28), increase the value of the counter $k$ by 1 (block 29), and go to block 9. Then the calculation stage is repeated either until the optimal resource plan is obtained (exit through block 25), or until the obvious impossibility of implementing the project is determined, taking into account the current volume of the resource (exit through block 16).

**CONCLUSION**

The practical significance of the developed model of financial and resource planning lies in the fact that the problem statement and the solution algorithm can be implemented not only in the field of innovation management of the company, but also in other applied areas whose production processes can be described through the use of network models. At the same time, both the formulation and the algorithm for solving the problem can be adapted to any type of network models. Thus, the developed model will become part of the financial investment tools as an auxiliary mechanism that provides financing for investment and innovation processes.

**REFERENCES**

BLINOV, A.O.; UGRYUMOVA, N.V. Process management in creation of the effective organization. *Finansy: teorija i praktika*, 2015, 4, p. 38-44 (in Russ.).

GHARAJEDAGHI, J. *Managing chaos and complexity: a platform for designing business architecture*. Minsk: Grevtsov Publisher Publ., 2007, 480 p.

HARTSFIELD, N.; RINGEL, G. *Pearls in graph theory: a comprehensive introduction*. Mineola, N.Y.: Dover Publications, Inc., 1994, 259 p.

KHOTINSKAYA, G.I.; SHOKHIN, E.I. The role of financial tools in enhancing the competitiveness of Russian business. *Finansy: teorija i praktika*, 2014, 3, p. 64-75 (in Russ.).

KURBEL, K.E. *Functions, business processes and software for manufacturing companies*. Heidelberg: Springer, 2013, 359 p.

LUKMANOV, A.R. Development of a feasibility study for an innovative project. *Finansy: teorija i praktika*, 2016, 20 (2), p. 51-55 (in Russ.).

MAKHOVIKOVA, G.A.; KANTOR, E.L.; DROGOMIRETSKIY, I.I. *Enterprise planning: lecture notes*. Moscow: Ekhonomika Publ., 2011, 267 p. (in Russ.).

MAKSIMOV, N.N. Theoretical foundations of innovation. *Molodoi uchenyi*, 2013, 10, p. 340-351 (in Russ.).

MANAS, J. *The resource management and capacity planning handbook: a guide to maximizing the value of your limited people resources*. McGraw-Hill Education, 2014, 256 p.

MARTYNOVA, E.V. Features evaluation of innovative development company. *Finansy: teorija i praktika*, 2015, 2, p. 61-69 (in Russ.).

PODOL'SKIY, A.G.; POLYARUS, A.N.; IVANOV, S.V. Methodological apparatus for assessing the performance of subdivisions of organizations that create scientific and scientific-technical...
products for military purposes. *Informatsionnye tehnologii v proektirovani i proizvodstve*, 3, p. 3-11, 2017 (in Russ.).

VAN STEEN, M. *Graph theory and complex networks: an introduction*. Maarten Van Steen, 2010, 300p.

ZOTOV, V.M. Algoritum for ranking the industrial network. *Innovatsii i investitsii*, 2018a, 10, p. 197-200 (in Russ.).

ZOTOV, V.M. On the issue of modeling the intellectual property management process. *Upravlencheskie nauki*, 2016, 3, p. 109-117 (in Russ.).

ZOTOV, V.M. Resource planning of the innovation process. *Ehkonoma i upravlenie: problemy, resheniya*, 2018b, 6 (9), p. 55-61, (in Russ.).

**Investment planning of innovative activity**

*Planejamento de investimentos de atividade inovadora*

**Planificación de inversiones de actividad innovadora**

**Resumo**

O objetivo do estudo, neste caso, é desenvolver métodos para modelagem de processos que visem garantir o planejamento de investimentos de atividades inovadoras do empreendimento. A base metodológica da pesquisa é a adaptação das redes tecnológicas aos métodos de planejamento financeiro e de recursos. Em paralelo, o aparelho matemático correspondente foi desenvolvido. Ficou claro que as atividades do departamento da empresa que lidam com a gestão da inovação têm que se basear nos princípios da gestão de projetos. A pesquisa baseada na análise do processo teve como objetivo criar ou adquirir uma inovação em uma empresa no contexto dos recursos necessários para a implementação bem-sucedida de tal processo. O resultado determinou e descreveu um padrão matemático descrevendo a dependência da probabilidade de que uma operação tecnológica seja realizada com sucesso na quantidade de investimento (recursos) alocados para esta operação. As matrizes de adjacência tornaram-se a forma mais adequada de representação de modelos de processos inovadores.

**Palavras-chave:** Processo de investimento. Projeto de inovação. Kit de ferramentas de investimento. Modelagem em economia. Abordagem de processo.

**Abstract**

The purpose of the study in this case is to develop methods for modeling processes aimed at ensuring investment planning of innovative activities of the enterprise. The methodological basis of the research is the adaptation of technological networks to the methods of financial and resource planning. In parallel, the corresponding mathematical apparatus was developed. It became clear that the activities of the company’s department dealing with innovation management have to base on the principles of project management. The research based on the analysis of the process aimed at creating or acquiring an innovation at an enterprise in the context of the resources necessary for the successful implementation of such a process. The result determined and described a mathematical pattern describing the dependence of the probability that a technological operation will be performed successfully on the amount of investment (resources) allocated for this operation. Adjacency matrices became the most appropriate form of representation of models of innovative processes.

**Keywords:** Investment process. Innovation project. Investment toolkit. Modeling in economy. Process approach.

**Resumen**

El propósito del estudio en este caso es desarrollar métodos para modelar procesos destinados a garantizar la planificación de la inversión de las actividades innovadoras de la empresa. La base metodológica de la investigación es la adaptación de las redes tecnológicas a los métodos de planificación financiera y de recursos. Paralelamente, se desarrolló el aparato matemático correspondiente. Quedó claro que las actividades del departamento de la empresa que se ocupan de la gestión de la innovación tienen que basarse en los principios de la gestión de proyectos. La investigación basada en el análisis del proceso dirigido a crear o adquirir una innovación en una empresa en el contexto de los recursos necesarios para la implementación exitosa de dicho proceso. El resultado determinó y describió un patrón matemático que describe la dependencia de la probabilidad de que una operación tecnológica se realice con éxito en la cantidad de inversión (recursos) asignada para esta operación. Las matrices de adyacencia se convirtieron en la forma más adecuada de representación de modelos de procesos innovadores.

**Palabras-clave:** Proceso de inversión. Proyecto de innovación. Conjunto de herramientas de inversión. Modelización en economía. Enfoque de proceso.