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OPTIMIZATION MODELS OF INVESTMENT MANAGEMENT IN THE ACTIVITIES OF INNOVATIVE ENTERPRISES

Lyudmila Ganushchak-Efimenko[1], *Iryna Hnatenko[2], Roman Kozhushko[3], Rafał Rębilas[4], Viktoriia Rubezhanska[5], Tetiana Krakhmalova[6]

[1]Prof. Dr. Kyiv National University of Technologies and Design. Nemyrovycha-Danchenka str. 2. 01011. Kyiv. Ukraine. Phone Number +380675982473. E-mail address glm5@ukr.net

[2]Assoc. Prof. Kyiv National University of Technologies and Design. Nemyrovycha-Danchenka str. 2. 01011. Kyiv. Ukraine. Phone Number +380661076939. E-mail address q17208@ukr.net

[3]Assoc. Prof. Kyiv National University of Technologies and Design. Nemyrovycha-Danchenka str. 2. 01011. Kyiv. Ukraine. Phone Number +380632677657. E-mail address roman_kozhushko@ukr.net

[4]Dr.hab. Akademia WSB. ul. Cieplaka 1C. 41-300. Dąbrowa Górnicza. Poland. Phone Number +4888533022. E-mail address rrebilas@wsb.edu.pl

[5]Dr.Luhansk Taras Shevchenko National University. Gogol str. 1. 92700. Starobilsk. Ukraine. Phone Number +380953081789. E-mail address rubezhiik@gmail.com

[6] PhD Student. Kyiv National University of Technologies and Design. Nemyrovycha-Danchenka str. 2. 01011. Kyiv. Ukraine. Phone Number +380662537540. E-mail address tetiana_krakhmalova@ukr.net

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In a global economic competition, the countries that provide favorable conditions for efficient investment and innovation are winning. At the same time, the problem of sufficient investment support for enterprises, which, in turn, can be solved by economic and mathematical modeling of the investment management process becomes especially relevant. In this regard, the purpose of our study is to develop an algorithm for making the optimal decision on the feasibility of implementing a particular innovation project based on the calculation of optimization models of investment management. To achieve this goal, the following methods of scientific research were used: economic-mathematical modeling, abstract-logical method, graphical method. According to the results of the research, the decision-making algorithm on the feasibility of implementing a particular innovation project can be used by entrepreneurs-innovators to plan, forecast, control production processes, cash, material, and investment flows at the enterprise, as well as to determine the necessary financial capabilities, efficiency, risk innovative project.

Key words: algorithm, innovation enterprise, innovation project, investment management, optimization model.

JEL Codes M21, C5.

1. Introduction

In modern society, the pace of economic growth and the level of development of countries is largely determined by the role of scientific and technological progress in the intellectualization of production.

*Corresponding author

In a global economic competition, the countries that provide favorable conditions for efficient investment and innovation are winning. Innovative activity of enterprises is reduced to development of innovative projects and programs with attraction of a certain volume of investments, which are realized in the form of large cross-sectoral projects for creation, development and dissemination of technologies that contribute to fundamental changes in the technological basis of economy, as well as projects for the development of basic research, scientific and technical support of social programs, international cooperation based on targeted investment (Kuksa, Shtuler, Orlova-Kurilova, Hnatenko, Rubezhanska, 2019).

The problem of sufficient investment support for innovation is relevant for enterprises in many countries in the world where the capital market is still underdeveloped, and innovation is financed only at the expense of the own funds of enterprises, which are often limited (Kuksa, Hnatenko, Orlova-Kurilova, Moisieieva, Rubezhanska, 2019). As a result, such businesses are forced to use profit and depreciation on current needs, thereby subverting their strategic competitiveness. In this regard, it is important to model the investment management process in the activities of innovative enterprises, which allows to carry out preliminary study of the enterprise in order to highlight the features of its operation, to analyze and forecast the economic situation inside the enterprise and beyond, to choose the optimal decision for the implementation of a particular innovative project in the conditions of uncertainty and action of a large number of external and internal factors.

The scientific works of many scientists are devoted to the study of peculiarities of functioning of innovative enterprises, as well as to the development of mathematical models of profit optimization of these enterprises. Thus, Daksa, Yismaw, Lemessa, Hundie (2018) in their scientific work have analyzed the main driving forces for the development of innovative entrepreneurship in developing countries. The study uses survey data to analyze the determinants of innovative development in Ethiopia based on the construction of a multivariate probit model (MVP). Hashi, Stojcic (2013) investigate the innovation process and its impact on firms' ability to compete with each other in national and international markets. Using the probit and tobit regression models, Abdu, Jibir (2017) analyze the following factors which influence on the development of innovative entrepreneurship: attracting investment in research and development, formal training, firm size, competitors' activity, location, specificity of enterprise activity. It has been found that investing in research and development, staff development to a sufficient extent is of paramount importance for successful innovation. In Mahendra, Zuhdi, Muyanto's article (2015) the impact of the activities of major institutions and access to finance on innovation production by Indonesian enterprises is examined. Aseev, Hutschenreiter, Kryazhimskiy, Lysenko (2005) revealed the optimal function of managing the investment portfolio of an innovative enterprise and presented the numerical results of the optimal investment management in the financial portfolio of the enterprise and its potential creditors. Murnieks, Sudek, Wiltbank (2015) on the basis of hierarchical linear modeling of 1988 investment valuations of 40 different philanthropists-investors analyzed the relationship between investors' estimation of business qualities of entrepreneur-innovator and their decision to invest in development of a certain enterprise. Wu, Wang, Chen (2017) conducted a study of the impact of specific investments, governance mechanisms and behavior on the effectiveness of Chinese cooperative innovation projects. Migliori, De Massis, Maturo, Paolone (2020) examine the relationship between family management and the propensity to invest in innovation in family firms on the example of 1093 Italian small and medium-sized family firms. In Krušinskas, Benetytė (2015) carried out a modification of the artificial neural network (ANN) model for enterprises investing in technological innovation as well as define the basic elements of the effectiveness of risk management factors affecting investment in technological innovation. Kostuchenko, Pogorelov, Assyra (2016) examined the principles of investment management in terms of cognitive modeling and investigated the issue of increasing the investment attractiveness of innovative underground construction.

Paying tribute to the aforementioned scientific works, it is worth noting the need to further study the features of calculation and use of mathematical models of investment management in the

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process of economic activity of innovative enterprises. In this regard, the purpose of our study is to develop an algorithm for making the optimal decision on the feasibility of implementing a particular innovation project based on the calculation of optimization models of investment management.

The object of the research is the innovation activity of the enterprises, the subject of the research is the modeling of the process of investment management in the innovation activity of the enterprises.

In the course of the research the following methods of perception economic phenomena knowledge and processes to solve the problems posed in the work were used: economic-mathematical modeling – to calculate optimization models of investment management in the activity of innovative enterprises; abstract-logical method – for formulation of conclusions and realization of theoretical generalizations concerning formation of structure of decision-making algorithm on realization of certain innovative project; graphical method – for visual presentation of theoretical and analytical material on reflection of structure of decision-making algorithm on realization of innovative project on the basis of calculation of optimization models of investment management.

The algorithm of decision making, proposed by the results of scientific research, can be used by innovative entrepreneurs for planning, forecasting, control of production processes, cash, material, and investment flows in the enterprise, as well as for determining necessary financial capabilities, efficiency, riskiness of realization certain innovative project.

2. Research results and discussion

Adequate provision of innovative enterprises for investment plays an important role in the effective functioning of these business entities. In this case, investment security management is a complex process that is implemented through the following functions: analysis, forecasting, planning, organization, motivation, accounting and control. The interconnection and interaction of these functions and stages of the management process determine the integrity of the enterprise management system as a whole (Hnatenko, Kuksa, Naumenko, Baldyk, Rubezhanska, 2020).

We believe that the most important investment management tool is modeling, which allows analyzing and forecasting the economic situation inside the enterprise and beyond, sales markets and markets for material and technical resources. In the process of modeling, a preliminary study of the object is carried out in order to highlight its essential characteristics, design the model, analyze the adequacy of the model to real economic processes and adjust it. In general, the problem of modeling relates to multicriteria problems of finding the optimal solution in the conditions of uncertainty and action of a large number of external and internal factors by determining the adequacy of the available resources of the enterprise necessary for the implementation of a specific innovation project.

The use of optimization models of investment management in the activity of industrial innovative enterprises will be considered in more details:

1. An optimization model without the involvement of a loan with full raw materials and equipment available. This model allows to calculate the production program of an innovative enterprise, provided that the company has stocks of raw materials, goods and equipment needed for manufacturing innovative products. It is assumed that the enterprise produces innovative products in different volumes, which are set by a certain set of production programs $X = \{x^1, \dots, x^N\}$, where $x^k = (x_1^k, \dots, x_n^k)$, but a production program k = (1, ..., N) specifies production volumes for all products of the species i (i = 1, ..., n), where n – the number of types of products produced.

The following designations are used in this model:

Z_{const} - fixed costs;

a_i - the price of the unit of production of the species i;

b_i - variable costs of producing a unit of production of a species i;

$c_i = a_i - b_i$ - margin income in the production of products i;

l_{ij} - rate of consumption of the resource i, that is, the volume of the resource of the species j (j = 1, ..., M, where M - number of resource types), required to produce the unit of production of the species i;

L_j – stock of resource of the species i;

t_{if} - load time of the equipment unit of the species f (f = 1, ..., K, where K - number of types of equipment) to produce a unit of production of the species i;

k_f - the number of units of equipment of the species f;

t_f - effective uninterrupted operation time of type f equipment, that is, the calendar time of the operational phase minus retrofitting time, routine maintenance and other types of work during which type f equipment cannot be used in the production process.

Thus, the function that maximizes the profit of the enterprise will look like (1):

$$\sum_{i=1}^{n} c_i x_i - Z_{const} \rightarrow max. \tag{1}$$

Restrictions are on resources and equipment (2):

$$\sum_{i=1}^{n} l_{ij} x_i \leq L_j \,, j = \overline{1, M};$$
$$\sum_{i=1}^{n} t_{if} x_i \leq k_f t_f \,, f = \overline{1, K};$$
$$x_i \geq 0, x_i \in Z, \tag{2}$$

where Z – the set of integers.

This model uses one assumption: an enterprise loan is repaid at the expense of income from its innovation activity.

2. A credit-driven optimization model to increase production with partially available raw materials and equipment. This model can be used in a situation where additional resources are involved in increasing the output. As in the previous model, an enterprise can, for a limited period of time, produce products in volumes specified by alternative production programs of the plural $X = \{x^1, \ldots, x^N\}$, where $x^k = \left(x_1^k, \ldots, x_n^k\right)$.

It will be assumed that the company attracts a loan in volume V for the purchase of additional material resources of production L_j^+ and equipment γ_f.

The following designations are used in the model:

V - the volume of the loan attracted at α percent;

β_j - the unit price of a resource of a species j (j = 1, ..., M);

γ_f - unit price of the equipment of the type f (f = 1, ..., K);

L_j^+ - the stock of resource of species j;

$k_f + \gamma_f$ - the number of equipment units of the species f.

The profit maximization feature of an innovative enterprise will be as it is shown in Formula 1.

Restrictions on resources and equipment (3):

$$\sum_{i=1}^{n} l_{ij} x_i \leq L_j + L_j^+, j = \overline{1, M};$$
$$\sum_{i=1}^{n} t_{if} x_i \leq \left(k_f + \gamma_f\right) t_f, f = \overline{1, K} \tag{3}$$

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Restrictions on the amount of credit purchases (4):

$$\sum_{i=1}^{M} \beta_i L_j^+ + \sum_{f=1}^{K} y_f \gamma_f \leq V \tag{4}$$

Restrictions on integer values (5):

$$x_i, y_f, L_j^+ \geq 0, x_i, y_f \in Z \tag{5}$$

The solution of the optimization problem will allow to determine the most optimal production program x = (x_1, ..., x_n), as well as purchase volumes of additional raw materials and equipment.

3. A credit-driven optimization model for product differentiation of partially available raw materials and equipment. This model assumes that the company plans to expand production and launch new products n + 1, ..., n_1. At the same time additional types of equipment are involved in additional financial resources K + 1, ..., K_1 and material resources M + 1, ..., M_1.

The following designations are used in the model:

V - the volume of the loan attracted at α percent;

β_j - the unit price of a resource of a species j (j = M + 1, ..., M_1);

γ_f - unit price of the equipment of the type f (f = K + 1, ..., K_1);

L_j^+ - purchase volume of the resource of the species j = M + 1, ..., M_1;

y_f - volume of equipment purchase f = K + 1, ..., K_1.

The profit maximization feature of an innovative enterprise will be as it is shown in Formula 1.

Restrictions on resources and equipment (6):

$$\sum_{i=1}^{n_1} l_{ij} x_i \leq L_j + L_j^+, j = \overline{1, M};$$
$$\sum_{i=1}^{n_1} l_{ij} x_i \leq L_j^+, j = \overline{M+1, M_1};$$
$$\sum_{i=1}^{n_1} t_{if} x_i \leq (k_f + \gamma_f)\, t_f, f = \overline{1, K};$$
$$\sum_{i=1}^{n_1} t_{if} x_i \leq (k_f + \gamma_f)\, t_f, f = \overline{K+1, K_1} \tag{6}$$

Restrictions on the amount of credit purchases (7):

$$\sum_{i=M+1}^{M} \beta_i L_j^+ + \sum_{f=K+1}^{K} y_f \gamma_f \leq V \tag{7}$$

The condition of repayment of the loan from the profit (8):

$$\sum_{i=1}^{n_1} a_i x_i - V(1+\alpha) \geq 0 \tag{8}$$

The restriction on integers will have the form shown in Formula 5.

The solution of this optimization problem will allow to find a new production program, considering the product differentiation, the purchase of new types of raw materials and equipment.

The abovementioned optimized investment management models play a decisive role in the decision-making process regarding the feasibility of implementing a particular innovation project. It should be emphasized that this process requires a clear algorithm of actions to ensure the achievement of the following goals:

- adequate reflection of the activity of the innovative enterprise in the main spheres of its activity (production, financial, investment);
- mathematical formalization of the influence of management decisions in different management subsystems;
- determining the adequacy or lack of financial resources for innovation activities (development and implementation of innovative products / services) in a specified period;
- optimization of management decisions and mobilization of internal reserves, which allow to restore and strengthen the financial capabilities of the enterprise.

The main purpose of this algorithm is to integrate various tools into a single business decision-making technology, aimed at ensuring the fulfillment of the enterprise-inventor of its liabilities to investors and customers in the relevant market of goods / works / services (Figure. 1).

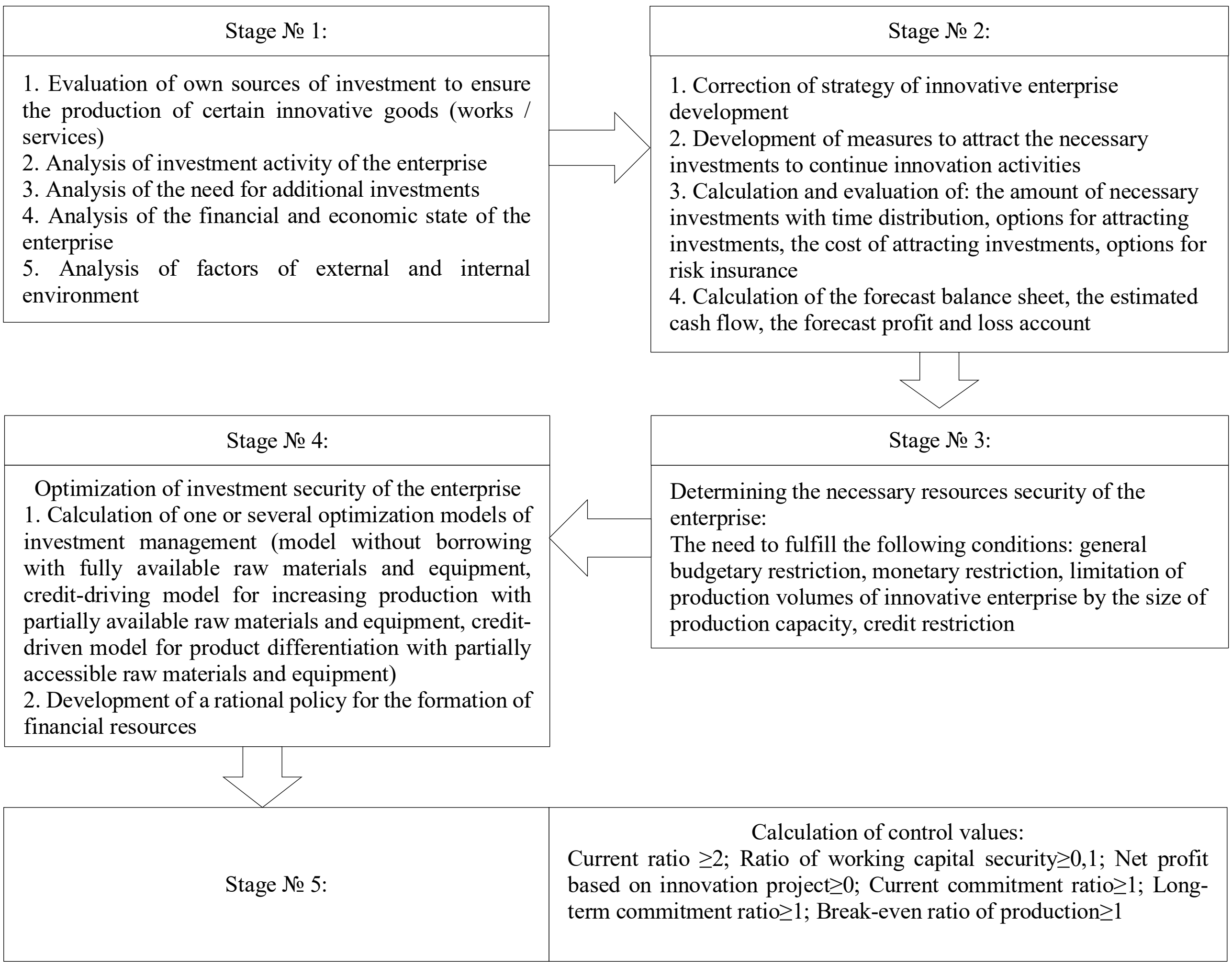

Figure 1. The architectonics of the algorithm for decision-making on the feasibility of a particular innovation project implementation

In the first stage of the analysis the identification of the technical, economic and financial status of a certain innovative enterprise is carried out, the influence of factors of the external and internal environment, problem areas are identified, and recommendations are made for their elimination. This assesses the availability, structure and efficiency of own resources, investment activity of the company and the need for additional investment.

In the second stage, the main planned indicators are calculated and the forecast balance, profit and loss statement, cash flows of the enterprise are calculated on their basis. In this case, it is possible to adjust the strategy of development of an innovative enterprise considering the basic conditions for conducting business activity. Thus, the proposed algorithm will allow to consider the influence of the choice and implementation of a management decision on the results of a specific investment project for the development and sale of innovative goods, works / services.

In the third stage, the enterprise is provided with financial resources, considering the measures planned for implementation based on forecast information.

The volumes of actual production of an innovative enterprise (*Qf*) depend on the quantity, quality and price of the necessary material, labor, financial and other resources.

The following restrictions are checked based on the forecast documents (plan for development and realization of the innovative product (performance of works / services), forecast balance sheet, cash flow and profit and loss statement):

1. The overall budget restriction, i.e. the sum of all receipts (*Ic*) should be not less than the amount required to cover all the expenses of the enterprise (*Oc* – cash outflows) taking into account the transitional balance of the previous period at each step of the calculation and in the whole for the period (9):

$$\sum_{n=1}^{T}\sum_{i=1}^{n} Ic_i^{(t)} \geq \sum_{n=1}^{T}\sum_{j=1}^{m} Oc_j^{(t)}, \tag{9}$$

where $1 < i < n; 1 < j < m$;

i – sources of cash receipts;
j – types of cash outflows.

2. Monetary restriction, that is, at every step of the calculation the entrepreneur-innovator must have "ready cash" (*M*) not less than his needs to cover his payroll (O_{sal}), material expenses ($O_{mat.c.}$), tax payments (O_{tax}) and other costs (Oc_{oth}) (10):

$$M \geq O_{sal} + O_{mat.c.} + O_{tax} + Oc_{oth} \tag{10}$$

3. Restricting the production volume of an innovative enterprise by the size of production capacity *(PC)* for a specific period (11):

$$O_{pl}^{(t)} \leq PC^{(t)} \tag{11}$$

4. Credit restriction, that is, an enterprise cannot attract loans *(Cr)* for more than a maximum amount of cash limits *(Lc)* per borrower in all banks *(b)* with which the researching innovation enterprise operates (12):

$$\sum_{b=1} Cr_b \leq \sum_{b=1} Lc_b \tag{12}$$

5. Reserve restriction that determines the planned amount of required spare resources (R_{pl}) to eliminate unforeseen disruptions to the production process.

If the conditions are not met, then it is necessary to go back to the second stage of the algorithm and choose another strategy for investing innovative activities.

The fourth stage develops a rational policy of formation of financial resources on the basis of optimization models (or one model) of investment management aimed at maximizing the profit of the enterprise by minimizing the costs of servicing own, borrowed and other funds involved in the development and sale of innovative goods, works / services.

In the fifth stage, control values of the parameters are compared, which are compared with the normative or recommended values. We propose to use the following indicators as these parameters: current ratio, working capital ratio, net income, current and long-term liabilities, break-even ratio.

In general, the number of benchmarks should not be large, because only in this case it is possible to create the preconditions for the efficiency and complexity of the analysis, avoid excessive complexity and eliminate the inconsistency of the conclusions. The selected indicators reflect the economic advantage of a certain innovation project (net profit based on the innovation project), the positive impact of the project implementation on the financial situation at the enterprise (current liquidity ratio and the ratio of own working capital assets), financial assets of the enterprise (ratios of current and long-term liabilities, break-even ratio).

If the values of the benchmarks meet the requirements shown in Fig. 1, then it is decided to implement an innovative project, if not - it is necessary to return to the second stage of the algorithm and correct the appropriate measures, especially those ones concerning the pace of project implementation and the dynamics of attracting investors' funds.

It should be emphasized that the risk level, like some other factors, influences the investor's decision to invest in a certain innovative project. Quantitatively, the risk of an investor is characterized by its objective estimation of the probable magnitude of the maximum and minimum income. However, the greater the range between these values with equal probability, the higher the risk. In practice, many methods can be used to determine risk. In this algorithm we propose to use a rather simple statistical method, which involves determining the degree of risk by calculating the income dispersion indicators (*Dpr)* and the standard deviation in income (*SDpr*) by the formulas (13-14):

$$D_{pr} = h_1 * (Pr_{max} - Pr_0)^2 + h_2 * (Pr_{min} - Pr_0)^2 \quad (13)$$

$$SD_{pr} = \sqrt{D_{pr}} \quad (14)$$

where h_1, h_2 – the probability of obtaining maximum and minimum income, respectively;
PR_{max} - the maximum amount of income or return rate;
PR_{min} - the minimum amount of income or return rate;
PR_0 - the expected (desired) amount of revenue or return rate.

Calculations can be even more complicated if, based on expert judgment, to determine the likelihood of different income options based on calculated options for production of innovative products, works, services (optimal and most real - actual) and financing options (pessimistic, most real – actual, optimistic). The most important thing in this algorithm is not the complexity and accuracy of risk calculations for the investee, but the determination of the limits of risk acceptability for investors. If the investor considers that the risk is acceptable for him, then he will participate in the financial support for the implementation of the innovative project, guided by different decision-making criteria.

Thus, the proposed algorithm for deciding on the feasibility of implementing a specific innovation project, based on the calculation of optimization models of investment management in the innovation activity of enterprises, can be used for planning, forecasting, controlling production processes, cash, material, and investment flows in innovative enterprises. At the same time, the calculations make it possible to draw relevant conclusions not only about the financial capacity, efficiency, riskiness of the implementation of a specific innovation project, the use of investment

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mechanisms and instruments, but also about the correctness, profitability, and prospects of relations between the participants of the investment process as a whole.

3. Conclusion

Enterprises' innovation management is one of the main means of ensuring their effective development, which is determined by the ability of businesses to create new products, transformation into the production of more sophisticated ideas, etc., which becomes possible only in the conditions of sufficient availability of financial investment resources. Investment activity is a prerequisite for the individual circulation of funds of each individual innovation enterprise. In turn, manufacturing activities related to novation and innovation create the preconditions for new investment. Thus, investment management in the activity of innovative enterprises plays a decisive role in ensuring their effective functioning in the conditions of fierce competition in the relevant markets for products (works / services).

In the course of the research, based on the calculation of optimization models of investment management, an algorithm for making the optimal decision on the feasibility of implementing a specific innovation project was proposed, which, imitating the variants of the managerial influence of the enterprise management, depending on the specific activity of a certain enterprise and investment income options, allows to combine various management tools into a single business decision-making technology aimed at ensuring the fulfillment of its obligations by the enterprise-innovator to investors and consumers.

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