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Network Models for Solving the Problem of Multicriterial Adaptive Optimization of Investment Projects Control with Several Acceptable Technologies

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Abstract. This paper discusses the problem of multicriterial adaptive optimization the control of investment projects in the presence of several technologies. On the basis of network modeling proposed a new economic and mathematical model and a method for solving the problem of multicriterial adaptive optimization the control of investment projects in the presence of several technologies. Network economic and mathematical modeling allows you to determine the optimal time and calendar schedule for the implementation of the investment project and serves as an instrument to increase the economic potential and competitiveness of the enterprise. On a meaningful practical example, the processes of forming network models are shown, including the definition of the sequence of actions of a particular investment projecting process, the network-based work schedules are constructed. The calculation of the parameters of network models is carried out. Optimal (critical) paths have been formed and the optimal time for implementing the chosen technologies of the investment project has been calculated. It also shows the selection of the optimal technology from a set of possible technologies for project implementation, taking into account the time and cost of the work.The proposed model and method for solving the problem of managing investment projects can serve as a basis for the development, creation and application of appropriate computer information systems to support the adoption of managerial decisions by business people.

THE RELEVANCE OF RESEARCH

It is known that successful entrepreneurial activity in a competitive environment requires the use of the most modern business management tools. Project management at the moment is one of the most effective ways to develop and implement changes and innovations.

In the current conditions of the development of the national economy the problem of the most effective investment of capital in various investment projects with a view to its multiplying is topical.

Investment activity is more or less inherent in almost any enterprise. However, the reasons for the need to attract investment may be different. This may be the need to update the existing material and technical base, increase the volume of production and sales activities, and develop new types of products, and gain a relatively larger share of the target market, etc.

In the conditions of functioning of a market economy, there are many opportunities for investing money allocated for the implementation of various projects. At the same time, many domestic enterprises usually have limited free financial resources, which they could send to invest in effective projects. Therefore, the task arises, the result of which should be optimization of the investment portfolio.

Investment decisions, like any other type of management activity, are based on various formalized methods and informal procedures.

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To attract investors it is necessary to develop new models, methods and technologies of investment control. One of such approaches can be the development and creation of models and methods that allow to optimize the control of investment projecting.

This article continues a series of articles by authors on optimizing the control of investment projecting processes. Optimization of control of these processes can be carried out, for example, using network economic and mathematical modeling, the application of which is systematically studied in the authors' works [12, 13, 14].The development of these methods will solve various problems of control complex operations, as well as the development and implementation of network planning and control systems in various areas of the economy.

The tasks of investment projecting necessitate a scientific approach that would enable us to orient ourselves in a complex set of emerging difficulties, and this applies equally to small, medium and large [15, 20, 21].

The novelty of this work is the development and creation of a new economic-mathematical model for the task of optimizing the control of investment projecting processes for an economic entity in the presence of several technologies based on the methods of network modeling and results of the authors' works [12-14], and a method for solving this task is proposed.

The presence of several technologies for the realization of the investment projecting may be due to the existence of different sets of works / projects operations, which depend on the application (food services, construction, transport, trade, communications, medicine, *etc.*) and the conditions for carrying out these works. Depending on this, the implementation of the relevant processes of investment projecting should take into account the existence of such an opportunity.

In the presence of several technologies for the implementation of investment projecting processes as an economic and mathematical model in this paper, it is proposed to use the appropriate network model that allows to optimize both the choice of available technologies and the investment projecting processes under consideration.

RESEARCH TECHNIQUE

We present an economic-mathematical model for formalizing the task of optimizing the control of investment projecting processes in the presence of several technologies and the corresponding method for its implementation.

1. A tuple is introduced $U = \{U_1, U_2, ..., U_m\}$ that describes the conditions-restrictions for the implementation of a particular investment project on: initial data; technological solutions; output data ($m \in N$; N is the set of all natural numbers).

2. We introduce an array of technologies $P(U) = \{P_1, P_2, ..., P_n\}$ that implement the investment project and satisfy the given conditions U $(n \in N)$.

3. For each ith technology $P_i \in P(U)$ $(i \in \overline{1,n} = \{1,2,...,n\})$, an array of work-operations $R(P_i) = \{R_1(P_i), R_2(P_i), ..., R_{n_i}(P_i)\}$ is introduced, the implementation of which allows implementing this technology $(n_i \in N)$.

4. For each array of work-operations $R(P_i) = \{R_1(P_i), R_2(P_i), ..., R_{n_i}(P_i)\}$ $(i \in \overline{1,n})$ introduce a set of quality criteria $F_i = \{F_1^{(i)}, F_2^{(i)}, ..., F_r^{(i)}\}$ that assesses the results of the implementation of the processes for the investment project $(r \in N)$, where $F_i : R^{3 \times n_i} \to R^1$ $(i \in \overline{1,r})$.

5. Each jth work-operation $R_j(P_i) \in R(P_i)$ $(j \in \overline{1,n_i})$ corresponds to an array of data − a matrix $A_{ij} = \left\| a_{kl}^{(ij)} \right\|_{\substack{k \in \overline{1,p_{ij}} \\ l \in \overline{1,3}}}$ $(p_{ij} \in N)$ whose values of the three elements of each kth row are respectively equal to the duration, cost, and quality of the possible kth version of the implementation of this jth work-operation, then is the number of rows of this matrix is equal to the number p_{ij} of different variants of the implementation of the operation-operation under consideration.

6. Based on the available data and methods of network economical and mathematical modeling [5, 6, 11-13], the condition for choosing the optimal technology is formulated $P^{(e)} = P_{i^{(e)}} \in P(U)$, $i^{(e)} \in I^{(e)} \subseteq \overline{1,n}$ for the vector quality criterion $F_i = \{F_1^{(i)}, F_2^{(i)}, ..., F_r^{(i)}\}$ that is evaluating the results of implementation of investment projecting

processes (for example, in the form of minimizing the scalar criterion, which is the convolution of the vector quality criterion under consideration with the help of the scalarization method [6, 7, 9, 10]).

7. On the basis of the methods of network economical and mathematical modeling [12-14], available data, the generated quality criterion and the optimality condition, the corresponding task of optimizing the control of the investment projecting processes under consideration is formulated. Namely, among all the acceptable technologies $P(U) = \{P_1, P_2, ..., P_n\}$ that allow to implement the considered investment projecting processes, it is required to find at least one technology $P^{(e)} = P_{i^{(e)}} \in P(U)$, $i^{(e)} \in I^{(e)} \subseteq \overline{1,n}$ that satisfies the chosen optimality condition.

8. The formulated optimization problem is solved using the methods of network economical and mathematical modeling for investment projecting processes.

9. From the solution of the optimization problem it follows that the matrix $B^{(e)}_{i^{(e)}} = \left\| b^{(e,i^{(e)})}_{kl} \right\|_{\substack{k \in \overline{1,n_{i^{(e)}}} \\ l \in \overline{1,3}}}$ contains all the data that is necessary to describe all the operations required to implement a specific optimal technology $P^{(e)} = P_{i^{(e)}} \in P(U)$ $(i^{(e)} \in I^{(e)})$.

10. Then, for a set of work-operations $R(P^{(e)}) = R(P_{i^{(e)}}) = \{R_1(P_{i^{(e)}}), R_2(P_{i^{(e)}}), ..., R_{n_{i^{(e)}}}(P_{i^{(e)}})\}$ that corresponds to the generated optimal technology $P^{(e)} = P_{i^{(e)}} \in P(U)$ $(i^{(e)} \in I^{(e)})$, in accordance with the rules of building a network model, the task of network modeling is solved - the formation of the appropriate optimal network model $WM^{(e)} = WM^{(e)}_{i^{(e)}} \in WM$ from an array of admissible network models $WM = \{WM^{(e)}_i\}_{i \in \overline{1,n}}$.

11. For the generated network model $WM^{(e)} = WM^{(e)}_{i^{(e)}}$ and data from the matrix $B^{(e)}_{i^{(e)}} = \left\| b^{(e,i^{(e)})}_{kl} \right\|_{\substack{k \in \overline{1,n_{i^{(e)}}} \\ l \in \overline{1,3}}}$, which contains all the data necessary for describing all operations $R(P^{(e)}) = R(P_{i^{(e)}}) = = \{R_1(P_{i^{(e)}}), R_2(P_{i^{(e)}}), ..., R_{n_{i^{(e)}}}(P_{i^{(e)}})\}$ that implement the optimal technology $P^{(e)} = P_{i^{(e)}} \in P(U)$ $(i^{(e)} \in I^{(e)})$, the task of constructing a critical path-the formation of a critical or optimal time $T^{(e)} = T^{(e)}_{i^{(e)}}$ for the implementation of the investment project under consideration – is solved.

12. The output of the optimization of the control of the investment projecting process under consideration is the data set ($P^{(e)}$, $R(P^{(e)})$, $F^{(e)}$, $WM^{(e)}$, $T^{(e)}$), where $P^{(e)} = P_{i^{(e)}} \in P(U)$ - the optimal technology; $R(P^{(e)}) = R(P_{i^{(e)}}) = \{R_1(P_{i^{(e)}}), R_2(P_{i^{(e)}}), ..., R_{n_{i^{(e)}}}(P_{i^{(e)}})\}$ - the optimal set of operations that implements the optimal technology $P^{(e)}$; $WM^{(e)} = WM^{(e)}_{i^{(e)}}$ - optimal network model; $T^{(e)} = T^{(e)}_{i^{(e)}}$ – the optimal time for the implementation of the investment project, $(i^{(e)} \in I^{(e)})$.

13. In the end, we obtain an optimal network model for implementing investment projecting processes, taking into account the availability of several technologies for its implementation.

We describe the methodology of adaptive control of investment projecting. When implement an investment project within the framework of the optimal network model $WM^{(e)}$, at a time interval $\overline{0,T^{(e)}} = \{0,1,...,T^{(e)}\}$ where $T^{(e)}$ is a natural number, at the time $\tau \in \overline{0,T^{(e)}}$ a deviation from the calendar schedule corresponding to the optimal time $T^{(e)}$ is realized of the optimal set of works $R(P^{(e)}) = R(P_{i^{(e)}}) = \{R_1(P_{i^{(e)}}), R_2(P_{i^{(e)}}), ..., R_{n_{i^{(e)}}}(P_{i^{(e)}})\}$. Then the set $R_\tau(P^{(e)}) \subset R(P_{i^{(e)}})$ forms a new network model $WM^{(e)}_\tau \subset WM^{(e)}$.

For the network model $WM_\tau^{(e)}$, a new critical path is formed, the optimal time $T_\tau^{(e)}$ and schedule for the remainder $R_\tau(P^{(e)})$ of the project. We note that the inequality holds: $T^{(e)} \le T_\tau^{(e)}$.

This procedure for correcting the control of the investment project is repeated every time there are deviations from the generated calendar schedule and allows for the organization of adaptive control of the process under consideration.

Consider the application of the proposed method for optimizing the control of investment projecting processes on a meaningful practical example. Given that a large number of investments are associated with the opening of various cafes, restaurants, bars, *etc.*, we will choose the area of public catering for the implementation of the proposed method.

The proposed economic-mathematical model for optimizing the control of investment projecting processes using network modeling methods [12-14] involves the allocation of the main works of the network model and the construction of tables describing the corresponding work-ribs, their coding and duration. Each work (process) corresponds to a table with the selected options for the values of the parameters necessary for its execution.

For example, consider a project, part of which is the introduction of a new menu in three catering establishments in the canteen, a fast food cafe and a restaurant, and take three acceptable technologies for its preparation at each of these enterprises. Here is the definition of the price of selling a dish in a restaurant (Table 1).

TABLE 1. Determination of preliminary sale price of a unit of production

No. in order	Product	Cost of 1 kg of product, rub.	Amount of product per unit of output, gram	Energy costs per unit of output, rub.	Transport costs per unit of production, rub.	Chef's salary per unit of output, rub.	Unit cost of production, rub.	Trade margin rub.	Unit price, rub.
1	Product 1	200	100	8	8	65	124.8	25.2	147.2
2	Product 2	110	50						
3	Product3	350	50						
4	Product4	80	10						

The duration and cost of the preparation of the dish are different for each food technology. The works, their coding, the duration of execution and the cost for each technology are presented in Tables 2-4.

TABLE 2. Description of works for the first technology

No. in order	Code of work	The content of the work	Duration, days	Cost, rub.
1	A_1	Calculation of the cost of products included in the dish	2	20
2	A_2	Calculation of labor costs and other expenses, including electricity and transport costs, per unit of production	2	20
3	A_3	Calculation of value added tax or trade markup	1	10
4	A_4	Determination of the full cost of a dish	1	10
5	A_5	The price of the dish is compared with the price of competitors and determine whether it is attractive to customers	1	1

The network model of the process under consideration for the first technology is shown in Figure 1a. Figure 1b shows a network model with calculated time parameters [12, 13].

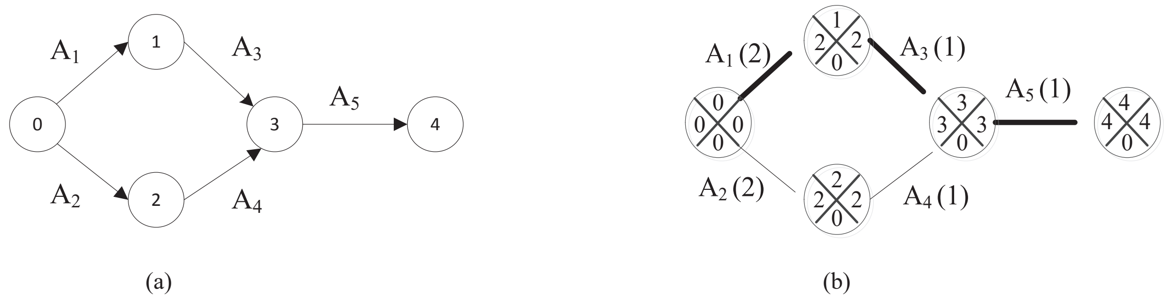

FIGURE 1. Network model for the first technology: (a) – formed network model; (b) – network model with calculated time parameters

TABLE 3. Description of works for the second technology

No. in order	Code of work	The content of the work	Duration, days	Cost, rub.
1	B_1	Calculation of the cost of products included in the dish	2	20
2	B_2	Calculation of labor costs and other expenses, including electricity and transport costs, per unit of production	2	25
3	B_3	Calculation of value added tax or trade markup	1	15
4	B_4	The price of the dish is compared with the price of competitors and determine whether it is attractive to customers	1	10
5	B_5	Determination of the full cost of a dish	1	10

The network model of this process for the second technology is shown in Figure 2.

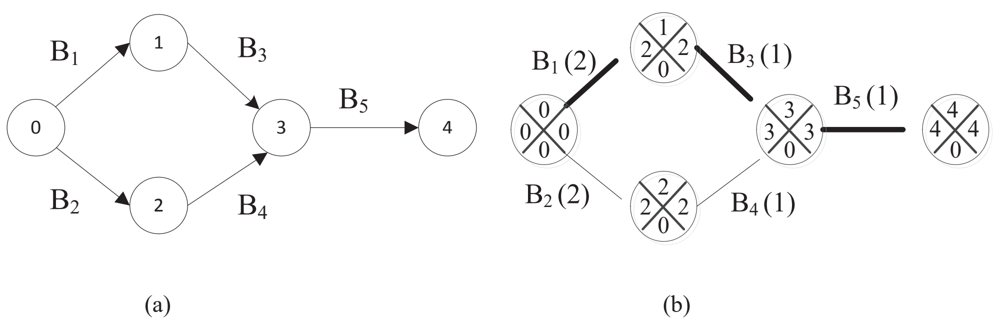

FIGURE 2. Network model for the second technology: (a) - formed network model; (b) - network model with calculated time parameters

TABLE 4. Description of works for the third technology

No. in order	Code of work	The content of the work	Duration, days	Cost, rub.
1	C_1	Calculation of the cost of products included in the dish	2	30
2	C_2	Calculation of labor costs and other expenses, including electricity and transport costs, per unit of production	2	30
3	C_3	Calculation of value added tax or trade markup	1	20
4	C_4	The price of the dish is compared with the price of competitors and determine whether it is attractive to customers	2	20
5	C_5	Determination of the full cost of a dish	1	20

The network model of this process for the third technology is shown in Figure 3.

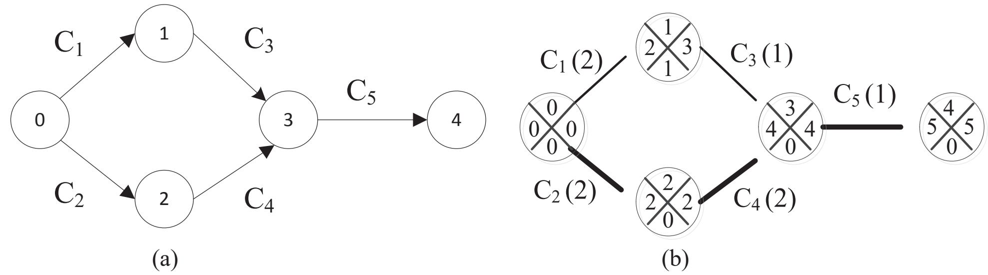

FIGURE 3. Network model for the third technology: (a) – formed network model; (b) – network model with calculated time parameters

Thus, the optimal path is calculated for all three technologies, and it can be noted that even at such a small stage of the project, which is considered in the example, there are differences that depend on the technology adopted at a particular enterprise.

We will optimize the generated network models of investment projecting by the cost parameter. The boundary values of the durations of work a_{ij} and b_{ij}, their cost c_{ij}, the cost coefficients for the acceleration of works h_{ij}, as well as the results of optimization of network models by the cost parameter are given in Table 5. The calculation formulas can be seen, for example [13].

TABLE 5. Optimization of network models by the cost parameter

Code of work	The work (*i, j*)	Duration of work, days			Cost of work, thousand rub.			h_{ij}	ΔC
		a_{ij}	t_{ij}	b_{ij}	c_{min}	c_{ij}	c_{max}		
For the first technology									
A_1	(0, 1)	1	2	3	20	20	25	-	-
A_2	(0, 2)	1	2	3	20	20	30	5	5
A_3	(1, 3)	1	1	2	10	10	15	-	-
A_4	(2, 3)	1	1	2	10	10	15	5	5
A_5	(3, 4)	1	1	1	0	1	10	-	-
Total						61			10
For the second technology									
B_1	(0, 1)	1	2	4	20	20	30	-	-
B_2	(0, 2)	1	2	4	20	25	30	3.33	6.66
B_3	(1, 3)	1	1	3	10	15	20	-	-
B_4	(2, 3)	1	1	3	10	10	20	5	10
B_5	(3, 4)	1	1	2	10	10	20	-	-
Total						80			16.66
For the third technology									
C_1	(0, 1)	2	2	3	30	30	35	5	5
C_2	(0, 2)	2	2	3	30	30	35	-	-
C_3	(1, 3)	1	1	2	20	20	25	5	5
C_4	(2, 3)	2	2	5	20	20	30	-	-
C_5	(3, 4)	1	1	2	20	20	25	-	-
Total						120	-	-	10

Let us analyze the data obtained in the table. The cost of the initial version of the work of the selected stage of the project for the first technology on the basis of the generated network model is equal to the sum of the values of all the works determining it: $C = \sum_{ij} C_{ij}$ = 61 rubles. The cost of implementing the project after optimization by the cost indicator: $C' = C - \Delta C$ = 61 – 10 = 51 rubles. The cost decreased by 17%.

The cost of the selected stage of the project for the second technology was 80 rubles. After optimization: 80 – 16.66 = 63.34 rubles. Decreased by 21%. The cost of works of a similar stage of the project for the third technology was 120 rubles. After optimization: 120 – 10 = 110 rubles. Decreased by 8.4%.

Thus, as a result of optimization of control based on network models for the considered investment projecting technologies, work plans have been created that allow performing the entire complex of necessary works of the selected stage of the project: for the first technology – for 4 days and a minimum cost of 51 rubles; for the second technology - for 4 days and the minimum cost of 63.34 rubles; for the third technology – for 5 days and the minimum cost of 110 rubles.

Next, it is necessary to choose the optimal variant of the preparation of the dish, taking into account their duration and cost. The optimal option is to choose the project with the first technology – the implementation of all the work for 4 days and the cost of preparing the dish 51 rubles. When using, for example, the third technology, the duration of work for the implementation of the process under consideration is increased by 1 day, and their cost increases by 2 times and is equal to 110 rubles.

ANALYSIS OF THE RESULTS

The main results of the proposed new method of network economical and mathematical modeling of the solution of the problem of optimization of investment projecting processes in the presence of several technologies are the following:

- the analysis of scientific approaches to the optimization of control of investment projecting processes under consideration was carried out, which showed the relevance of the research topic and the need for new developments based on economic and mathematical modeling;
- in the work the tasks necessary to achieve the set goal have been determined, and a new network economic and mathematical model for solving the optimization problem under consideration has been developed and a methodology for solving it has been proposed;
- developed model provides a more graphic representation of the content of processes in general and of each work separately;
- it is shown that the methods of network control through the graphic representation not only provide a visual representation of the investment projecting processes, but also allow them to carry out their diverse research - first, to more clearly identify the interrelationships of the project implementation stages, and second, to determine the optimal order of these stages In order, for example, to reduce the time and cost of completing the whole complex of processes and works;
- optimization of the developed network economic and mathematical model based on the possibility of transforming the model from one form to another, and the main indicators of optimization are time and costs of funds for the implementation of all processes and works of the project;
- the applied importance of the developed economic-mathematical model and the method of solving the problem of optimization of investment projecting processes on a concrete practical task is demonstrated.

CONCLUSIONS

This article proposes a new network economic and mathematical model and a general scheme of the method for solving the problem of optimizing the control of investment projecting processes in the presence of several technologies.

The use of network economic and mathematical models and methods for optimizing the control of the investment projecting process allows us to realize the main goal of management - the implementation of all project activities in the shortest possible time while reducing costs. If there are several technologies, *i.e.*, Works or blocks of work for a particular project in different relationships, then the optimal time for project implementation as a whole will be the smallest of their durations.

Using the proposed approach to solving the problem of optimizing the control of the investment projecting process on the basis of network economical and mathematical modeling is a reliable justification for the quality of investment projects, which facilitates the adoption of well-considered decisions by investors.

In conclusion, we note that the practical application of new economic and mathematical models and methods for optimizing investment design processes in the changing environment of the business environment contributes to the effective development of business. When optimizing the work of investment design for a particular company, the effectiveness of its functioning and positioning in the market is increased. Consequently, the study carried out in this article is important and relevant for this field of economics.

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