

The cost management of civil and agro-industrial construction project in the scope of information model

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Abstract. The necessary conditions for the existence of an effective cost management system of investment and construction projects are established in the article. Stated aim of the study is to develop methodological provisions of the cost engineering using information modeling technologies. The methodological blocks for parameterization, goal-setting and algorithmization of the information model of an investment and construction project are developed by the author. A list of aggregative cost parameters and an aggregative cost function of an investment and construction project, which is based on aggregative cost parameters, are presented. The processes of budgeting, control and managerial decision-making were considered by the author as functional blocks. The tasks of project budgeting in the scope of an information model, the comprehensive budget model of an investment and construction project and its system parameterization are presented in the article. The main provisions of project cost control and a list of basic cost indicators for control purposes are considered. The requirements of information modeling compatibility with the current subject activity and other software are determined. The author has developed the main provisions of project change management in the scope of information model and recommendations for rational making management decision. An algorithm for a decision-making regarding the realization of an investment and construction project is presented. The prospects of adaptive management of investment and construction projects particularly cost is determined and the vector model of the project behavior under the management action is developed. The main customer requirements to the information model of the investment and construction project are presented. The advantages of using the 5D model in the cost management system for the implementation of an investment and construction project are revealed.

1 Introduction

Construction is a complex, open, dynamic and multifunctional activity that requires a systematic management of various indicators of an investment and construction project at

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all stages of its life cycle. In particular, it applies to the composite construction cost indicator, because common problem is over-expenditure on the average by 25-30%.

The cost of the final construction object increases for several reasons: poor quality of construction and estimate documents, project defects, increase in the resources' cost included in the estimate, low level of organization of the construction process and logistics, losses caused by defects and downtime, etc. The traditional problems are aggravated by threats and great turbulence of the outside world in modern emergency conditions. It leads to the need to introduce fundamental management innovations.

The usage of a comprehensive, flexible, dynamic methodology for modeling the value creation of an investment and construction project with regular system provision with the information about the cost elements of the project is a necessary condition for the existence of an effective cost management system for investment and construction projects [1-11]. This scientific and practical problem reflects the challenges of the present moment, fragmentary results of research in this direction are presented in a few publications [12-14]. It should be emphasized that the investment stage of construction implementation, at which the value of the investment and construction project is directly created, remains unexplored.

The purpose of this publication is to develop methodological provisions of cost engineering using modern digital technologies. The following tasks were identified for solving:

- to present the system components and processes for cost management of implementing an investment and construction project,
- to develop the basic processes of the 5D model, with the help of which the investment and construction project is implemented,
- to adapt the provisions of project controlling taking into account compatibility with information modeling technologies.

2 Research methodology

This article has been prepared based on a complex of various research methods. Both classical management theory and engineering methods of project management are accepted as the initial methodological basis. The provisions of the systematic approach, information modelling and system management were used. The actualization of the proposed method of the investment and construction projects' management involves the usage of the intelligent automatic control principles.

3 Results and discussion

It is possible to identify cost-forming processes and process components of project management at the main stages of an investment and construction project [7, 15-18]. For example, the investment stage involves the following basic processes of the cost management of an investment and construction project: budgeting, organization of data flows, control of cost indicators, monitoring of the current status of the project, monitoring of resource prices, assessment of budget implementation and its forecasting, decision-making on cost optimization, mutual settlements between construction participants, assessment and analysis of actual costs when there is facility commissioning. These processes are combined in the concept of project controlling.

The cybernetic scheme of managing the cost of the project implementation at the investment stage is presented in Figure 1.

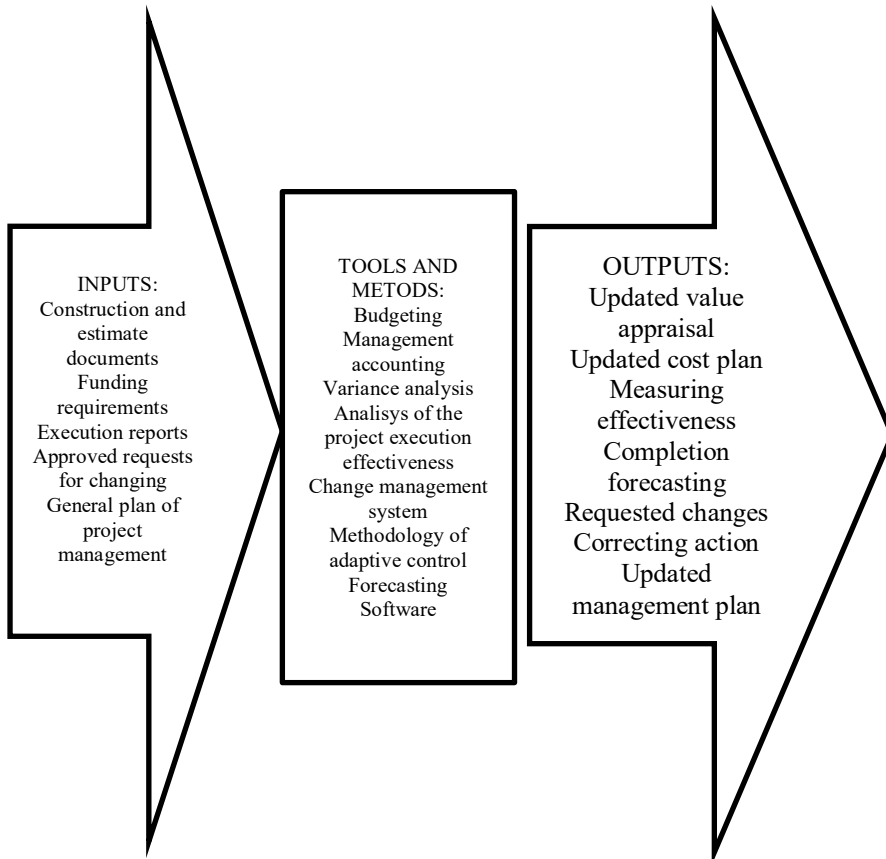


Fig.1. System components and cost management processes of the investment and construction project implementation

It is necessary to develop general provisions of project controlling – project management with the mandatory usage of cost engineering methods and information modeling technologies – to manage the cost of investment and construction projects at the implementation stage. The information model of the investment and construction project reflects all the necessary technical, manufacturing, economic and other capital construction object components, which have a specific stratification and correct relationship. In particular, the 5D stratum is a set of cost indicators of an investment and construction project in an actual functional relationship with other components of the information model.

For example, the rules of the information model formation are normatively defined in SR 333.1325800.2020 «Information modeling in construction» [19]. The types, structure and content of the information model depend on the goals and tasks of the investment and construction project, the type of capital construction object, the tasks of using information modeling, as well as customer requirements and the current legislation about the structure and content of technical and other documentation for the relevant stage of the investment and construction project life cycle.

The following tasks of the cost management of the investment and construction project implementation in the scope of an information model should be formulated:

- development and regular updating of the investment and construction project budget model,
- work schedule considering the work sequence, normative requirements and resources' availability,
- forming the bill of work volumes in the 4D and 5D model format with the distribution of construction and installation work deadlines and supplies of materials and equipment,
- resource planning, supply and procurement control,
- reports creation about the performed work and updating of model data in real time,
- rapid regular determination of the degree of the completion and the capital construction project readiness,
- monitoring the investment, budget, works, spending cash and its circulation on the project,
- rapid variance analysis, variance assessment with critical risk identification of the project,
- digital maintenance of post-completion documentation,
- visualization of regular operational statistics on the project,
- development of corrective measures in the detection of project deviations,
- forming the regulations and monitoring their implementation,
- optimization of the construction process with the application of the modern technologies, methods and work regulations.

The information model as a tool for project controlling must be provided with a methodological and functional base to solve the tasks. The blocks of parameterization, goal-setting and algorithmization as tools for solving economic and managerial tasks will be considered from the basic methodological provisions, taking into account the basic professional introductory on the formation and management of information flows.

The first methodological block of an investment and construction project information modeling is the determination and formalization of input parameters. Various purposes of using the information model can be implemented under the mandatory conditions of rules' regulation for the development and implementation of a set of parameters in the model. Moreover, the process of goal-setting and formalization of modeling tasks also require rational parameterization in the scope of the model.

According to the current trends of project activity, it is possible to emphasize the aggregated cost parameters of an investment and construction project in the modern practice of project analysis:

- project costs (Cos),
- sources and factors of funding (Fin),
- resource provision of the project (Res),
- budget of the investment and construction project (Bud),
- project risks in value terms (Ris),
- time factor and its impact on the project cost (Tim).

Then it is necessary to consider the cost of the investment and construction project (Pr) as compound function of various factors' complex.

$$Pr = F(\text{Cos}, \text{Fin}, \text{Res}, \text{Bud}, \text{Ris}, \text{Tim})$$

The presented functional dependence is further disaggregated and developed into an objective function of a multi-criteria optimization problem in the cost management system of an investment and construction project. According to this basis, it is effective to create estimate documents at any stage, to budget and control the cost indicators of an investment and construction project in the scope of the information model, based on automatic calculations and algorithmic actions of the software.

A such service information blocks as the structure of cost items, the classifier of structural elements, materials' reference books, the classifier of valuations, complex and working processes within the system of diary and network scheduling, key analytical features of budgeting, planning and control can be connected after setting the parameters of the model. Work with reference books is necessary for the following functional processes: calculation, formation of a work list, resource planning, diary scheduling, analytical procurement of control and plan-fact analysis, preparation of decision-making, etc.

The usage of parametric modeling can significantly speed up the processes of collecting, handling and analyzing information, especially at the stage of the investment and construction project implementation. If information model is correctly developed and parameters are set correctly, most of these processes occur qualitatively in automatic mode.

Presenting comments on the methodological conditions of parameterization of the information model, it is necessary to note the following model perspectives. The managing of the investment and construction project cost as a subsystem of general project management in combination with other quantitative and qualitative parameters reasonably requires the usage of situational assessment and management based on the results of project development [7]. Mentioned methodological approach has particular importance at the investment stage of construction implementation, which is considered in this publication.

It is suggested that

- the management model based on the assessment of the situation, determination of the status and trajectory of the project development will more accurately allow us to observe different quantitative and qualitative changes, develop a forecast taking into account these changes and regulate the project development;

- model assessment of the trajectory of the investment and construction project development is suggested to do generalized on the basis of dynamic characteristics of the situation and status assessment, which shows the current state and degree of approximation to the planned project result;

- managerial impact is possible in a number of aspects with respect to the current intermediate subjective result described during determining the status of the project: firstly, on approaching the desired result with a minimum tolerance, secondly, on correction the desired result.

The next methodological block includes algorithmization of both control processes and model processes, and provides the implementation of project controlling functions in the scope of information model. As it has been mentioned earlier, the subject group of project cost management processes includes budgeting, tracking its implementation, cost control, and preparation of management decisions.

The first functional block in the information model of an investment and construction project is the development of a budget model. The budget model of the project is a system of budget indicators in the necessary dimensions, which includes financial and resource analysts. A comprehensive budget model of an investment and construction project is built based on the interrelationships between the elements of financial and resource planning (Figure 2).

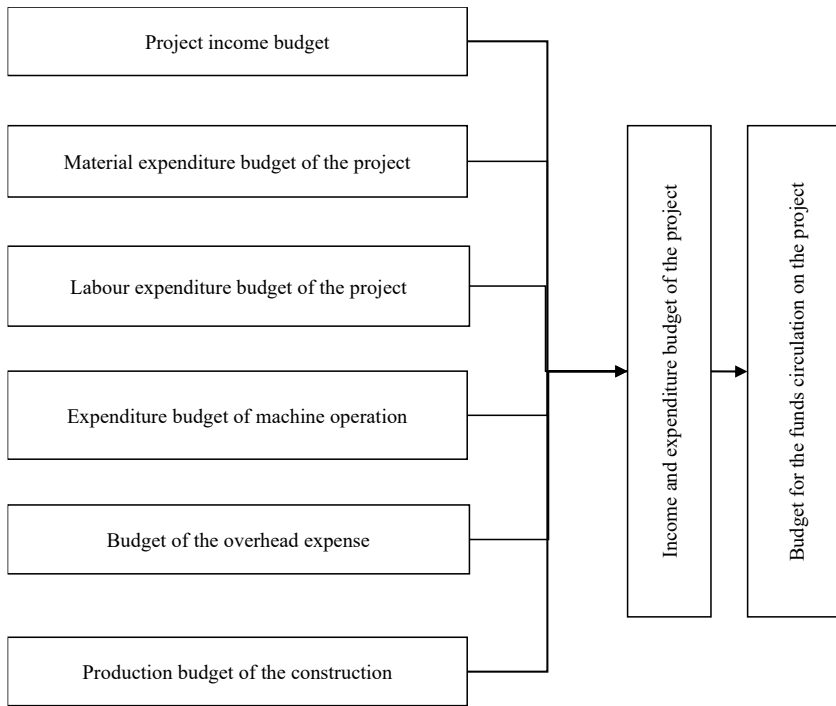


Fig.2. Complex budget model of investment and construction project

The budgeting rules are developed taking into account the fact that expenditures, as a fundamental budgetary factor, characterize the costs planned during the production and depend on a number of other factors: resource ratios, the percentage of subcontracts, invoice payment policy, periods of materials’ supply, constructions, basic equipment, etc.

Formalization, structuring and analytical filling of budget forms is carried out taking into account the system parameters of this information submodel and the requirements of the management subject. Table 1 presents the system parameters of the budget model of the contractor’ subjective phase [20].

Table 1. System parameterization of the budget model of the investment and construction projects

Local budget	Input information	Calculations	Output information
Project income budget	Planned work scope and its cost distributed over time	Performed work income	Planned income
Direct material budget	Production plan, requirement per the unit of work, stock of materials, unit cost of the material	Material requirements, direct material costs	Price of the materials’ procurement
Budget of the direct labor costs	Work plan, labour input per unit of the work, hourly cost rates	Staff requirements, direct labour inputs	The cost of payment for the work
Direct expenditure budget of machine	Production plan, requirement per the unit of work, stock of materials, machine-hour cost	Requirement for machines and mechanisms, direct expenditures for the	The price of the machine operation

operation		machines and mechanisms	
Overhead budget	Production plan, salary budget, structure	Overhead costs in their structure	Overhead cost
Production budget of the construction	Components of the direct expenditures, work scope	Total and unit cost	Production cost
Income and expenditure budget	The work scope, revenue, direct expenditure and overhead	Total income and expenditure of the project, different types of profits	Operating income, project net profit
Cash flow budget	Revenue, received advances, loans, expenses	Income, disbursements, balance of the cash flows for the project	Net cash flow for the project

During the developing the budget in the scope of the information model of the project, it is important to take into account the following tasks:

- assessment and forecasting of the availability and circulation of funds for a specific project;
- checking the financial realizability of the project;
- determination of the payback period, estimation of profit for the period of project implementation;
- analysis of the appropriateness of borrowing the funds;
- determination of the terms and volumes of the required borrowed funds;
- monitoring and adjustment of the financial project plan, taking into account its actual progress.

The preparation and implementation of control of the investment and construction project are considered as the second functional unit in the information model (table 2). Implementation of control is an iterative process performed regularly and systematically during the project implementation, which is programmed into algorithmic processes of project information model.

Table 2. Basic iterations of the realization control of the investment and construction project

Stage	Processes
Preparation	selection for observation of the most important characteristics of the project implementation: timetable, project budget, etc.
	creation of the accounting indicators' system of the project implementation with reasonable detalization
	development of analytical indicators' system of the project implementation, allowing to evaluate the project implementation and deviations based on the control purpose
	establishment of order, periodicity and patterns of database formation on the basis of accounting indicators, which is based on the timetable and project budget
	correlation of control processes with existing accounting policy and subjective accounting system
	regulation and organization of control processes of investment and construction project, formation of structure and organization of information flows
Realization	collecting the information about the project implementation progress in the fields, identification and evaluation of deviations from the planned indicators
	analysis of the reasons that led to the deviation of the actual results

	from the planned one and the indicators, which show the "critical deviations" from the calendar planning and budget
	finding the methods of project execution normalization in the context of individual functional blocks with the study of resources and capabilities of the subjective project cost formation
	development and promotion of the reasonable proposals to adjust project execution processes
	delegation of responsibility, implementation and implementation control of corrective measures, fixing of deviations' causes and their prevention in the future

A set of budgeted and controlled (in the future) accounting and analytical indicators is developed according to the main criteria: the share in the cost, the possibility of evaluation and manageability. Controlled *зщщщщщ* indicators of the investment and construction project cost may include indicators of the following list, disaggregated with a certain degree of detalization.

- Total and unit cost of the contract work.
- Material costs: the total and unit cost of materials; the requirement of basic materials per unit of work.
- Expenditures for direct labor: direct labor costs per unit of work; hourly cost rate.
- Expenditures of the machine operation
- Overhead costs.
- Marginal or net profit.

Accounting of controlled indicators must be provided with information and in documentation, without contradicting the existing business and management accounting policy at the company. It is necessary to emphasize the need to comply with the principle of compatibility of the information model with the current activities of the subject and with other software.

The system of traditional document management is adapted in the scope of the information model on the basis of certification, the formation of registers and reports to track the status of an investment and construction project. Documentation support can be expanded due to the following sources of information: the project of work, work logs, bills of control results, etc. It transfers management to the subjective level and expands the capabilities of project management.

As a result, reports on the state of the investment and construction project contain planned and actual values of the resources' cost for the work execution. It allows calculating absolute and relative deviations. It is necessary to emphasize the specifics of the model reporting process as a key point for identifying deviations and triggering that activates the algorithm of the cost managing of an investment and construction project.

Moreover, the control in the scope of the information model of the investment and construction project can execute the additional functions :

- exchange of information, collection and storing of data on project phases based on various services,
- additional remote analysis of contractors and suppliers, prevention of defects,
- systematization of inspections, data synchronization,
- inspection of compliance with the plan of construction and installation works,
- early identification of potentially difficulty construction stages, etc.

The task of the next functional block is to manage detected project deviations or changes. It includes the following processes:

- identification and evaluation of changes-causes;
- analysis of the project state after the occurred changes-causes;
- generation of alternative management solutions to normalize or rationalize the state of the project;

- assessment of possible consequences and selection of the most effective solution;
- development of a request for the necessary change-consequence;
- control and accounting of project changes.

A management decision is a reasonable conclusion about the need to act in the specific way to achieve the project results. Any decision is made in conditions of a variety of goals, a variety of tools and methods of achieving goals, a variety of factors that create different conditions or risks in which activities are carried out.

The rational decision-making process includes situational analysis, identification of problems, formation of a set of possible solutions, formation of criteria for evaluating solutions, evaluation of solutions and selection of the best solution, planning, implementation, implementation monitoring, result evaluation. If it is necessary, these iterations are performed simultaneously, iteratively, with a return to the execution of the previous stages.

The usage of information models makes it possible to evaluate more options with the definition of a set of indicators, which are the basis for comparing and optimizing investment expenditures, at the stage of preparation and consideration of management decision options. According to the adaptive management methods, the choice of the most effective option in the given conditions can be carried out on the basis of the existing practical experience included in the precedent base [8]. The prospect of adaptive management occurs in the scope with the information model of an investment and construction project.

Mathematically, the adaptive management can be considered as an operational adjustment of the coefficients of the investment and construction project' mathematical model based on the processing of received data on various changes in the adaptation algorithm. According to this base, the mathematical model is clarified and controlling influences on the control object are formed in the control algorithm with the obligatory receiving a response within the feedback. Repeatable iterative actions are consolidated in a management program based on algorithmic adaptation processes, a management algorithm and information support. It allows archiving, accumulating information to form a knowledge base of intelligent automatic control in the future.

The concept and control set of an investment and construction project and, in particular, a complex cost indicator are determined by the subject during the setting modeling tasks. The accepting the adaptive management based on precedents as a reasonable logical consequence of project controlling is suggested in this publication [7,8].

The practical realization of the methodological and functional blocks will become a permanently functioning algorithm of making decision for the implementation of an investment and construction project in all parameters, including a comprehensive indicator of the project cost. This algorithm (Figure 3) corresponds to the concept of situational management based on results. Besides, it uses an adaptive management mechanism based on precedents.

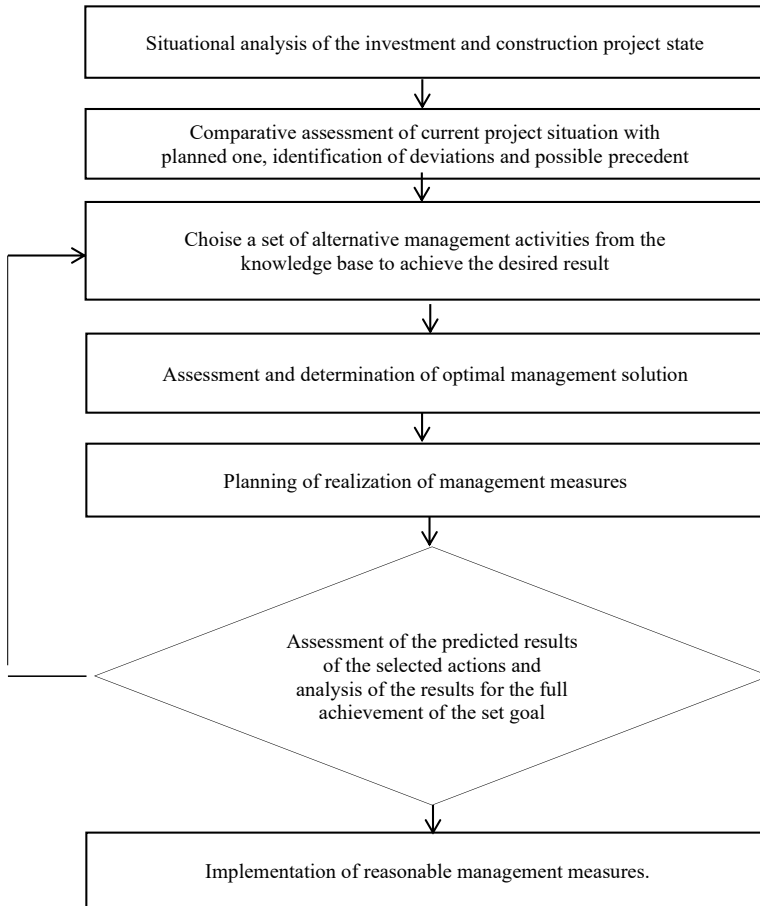


Fig.3. Basic decision-making algorithm for the implementation of an investment and construction project

According to the chosen concept, the vector model of the investment and construction project behavior under the influence of the control vector is formed as follows (Figure 4).

It is so important to formulate the customer's requirements for information models correctly and accurately, which are fixed in technical requirement, at the stage of setting the modeling task to effectively use the considering management innovation:

- goals and tasks of information modeling usage;
- work stages and control points of the information output;
- requirements for the content of the digital information model and the volume of modeling;
- requirements for the levels of elements' development of the digital information model;
- requirements for the content and formats of the project results' output;
- requirements for the quality of the digital information model;
- requirements for approval procedures, methods and formats of data exchange, mutual net resources;
- requirements for the provision of key project metrics;
- other requirements.

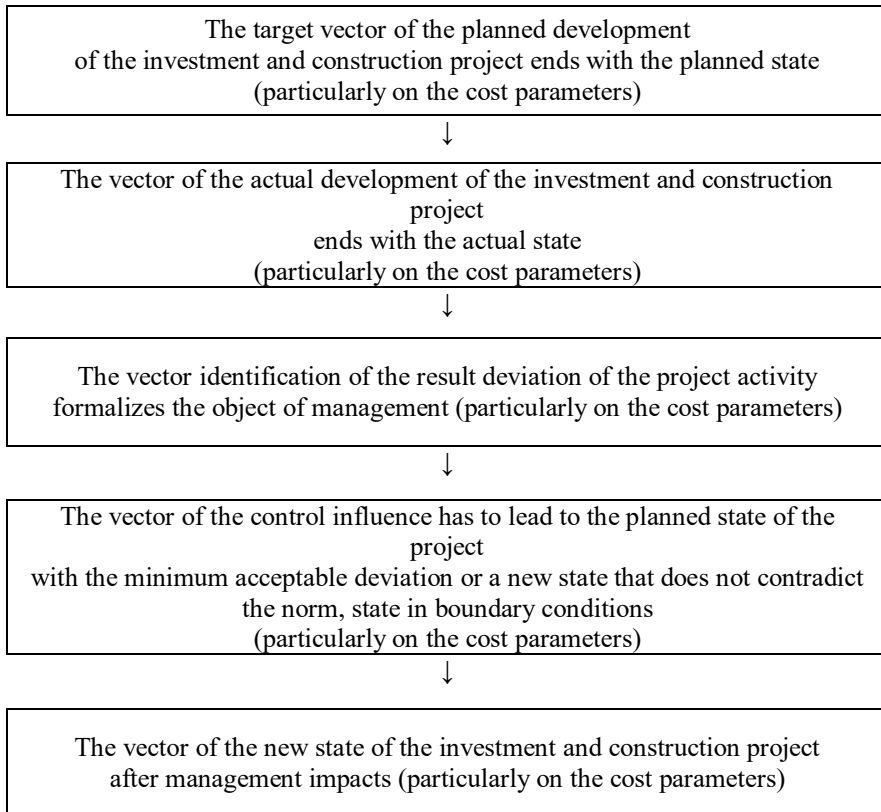


Fig.4. Vector model of investment and construction project management

If it is compared with traditional methods of financial management of investment and construction projects, the advantages of the 5D model in connection with the 4D model are as follows:

- increasing the speed and efficiency of working with information,
- reduction of labor intensity and time for calculating cost indicators,
- rationality when performing complex multiparametric calculations,
- extended variability of calculations and analytical procedures,
- speed and flexibility of calculations,
- a clear link to the production conditions,
- the possibility of move to planning according to the cost
- extended resource planning possibility
- system unity of estimated pricing, budgeting, control, execution,
- reducing the number of contractors, information dispersion and subjectivity in decision-making,
- minimizing the human factor influence, reducing mistakes and errors.

Currently, it is quite difficult to fully predict the results of the information modeling usage in construction, considering different indirect and synergetic effects. The considered 5D-stratum of the investment and construction project information model together with the 4D-stratum allow solving the problems of supply, logistics, construction technology, business processes of investment and construction activities and, as a result, optimize the project indicators of the work content, cost, schedule, quality.

4 Conclusions

Currently, information modeling technologies are becoming the heart of the main business process of the investment and construction activities' subjects, forming information flows and supporting management decisions. Digitalization of a capital construction object and the creation of a digital double of an asset allow optimizing the business processes, increasing their efficiency and reducing overheads. The profit of the company begins to depend on the usage of modern information technologies of the fourth industrial revolution. Management is carried out using a virtual model of the control object – a digital double, which is based on its information model. In fact, the information model is the basis of the management system.

The usage of information technologies for the management of investment and construction projects will allow achieving the following practical results:

- to increase the efficiency of planning and implementation of investment and construction projects,
- to increase the speed and productivity of management decisions,
- to optimize the processes of construction control and architectural supervision,
- to automatize the generation of project reports,
- to start forming a database, a knowledge base according to the results of completed projects, etc.

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