Досліджено процеси управління вартістю будівельно-енергетичних проектів. Виявлено недостовірність результатів застосування класичних методів для планування їх вартості. Обґрунтовано необхідність створення таких методів планування вартості, які будуть враховувати специфіку даних проектів. Сформовано метод планування вартості будівельно-енергетичних проектів, який враховує зміну вартості ресурсів з часом, інвестиційні та часові обмеження проекту

Ключові слова: метод, планування, вартість, будівельно-енергетичний проект, довгостроковість, ресурсомісткість

Исследованы процессы управления стоимостью строительно-энергетических проектов. Выявлена недостоверность результатов применения классических методов для планирования их стоимости. Обоснована необходимость создания таких методов планирования стоимости, которые будут учитывать специфику данных проектов. Сформирован метод планирования стоимости строительно-энергетических проектов, который учитывает изменение стоимости ресурсов во времени, инвестиционные и временные ограничения проекта

Ключевые слова: метод, планирование, стоимость, строительно-энергетический проект, долгосрочность, ресурсоемкость

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IMPROVING THE PROCESSES OF COST MANAGEMENT IN THE CONSTRUCTION AND ENERGY PROJECTS

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1. Introduction

The process of aging of energy equipment in Ukraine is growing, its efficiency decreases, as well as reliability and security, and, at the same time, the volume of financing of investment programs is lower every year. Under such conditions, the use of traditional approaches to strategic management is almost impossible. Today Ukraine begins to feel the need to implement a huge number of projects aimed at improving the reliability and efficiency of the energy sector of the state by renovation of the existing and construction of new energy facilities under conditions of scarcity of investment funds. Unfortunately, such a situation in the energy sector is observed not only in Ukraine, but also in many countries that are historically and geographically close to Ukraine.

As these projects are complex, intersectoral, characterized by large resource intensity and a long period of its implementation, when planning a budget for the construction and energy projects (CEP) it is necessary to take into account the factor of change in the cost of certain resources over time. It is also necessary to take into account the fact that CEP are implemented within the constraints, classic for projects, that is, they have definite investment and time parameters.

Some issues of project management, as well as the use of methodology of project management in the construction processes in the energy sector, are the subject of studies by many scientists. But at the same time, today the basic positions of the cost management of CEP as the most critical indicator for these projects remain insufficiently explored.

In the works [1–4], the processes of planning the projects costs are formalized, but the question of lowering the valuation entropy at the first stages of the life cycle of such high technological projects as CEP and formation of realistic estimates are studied insufficiently by them. All this makes the implementation of CEP at the planned level impossible due to inaccuracy of CEP estimates, received by application of classical methods to plan the costs, which deliberately reduce required amount of investments that is needed for their implementation. This leads to overspending of project funds, to the change in the timing of their implementation, or to cancelling of the project at all. That, taking into account the importance of the implementation of CEP for the country and the well- being of the population, is extremely undesirable.

All this actualizes the necessity of creation of new methods of CEP cost management, which will take their specific features into account, namely: complexity, resource intensity and availability of a large amount of resources. And they will be based on the theory of change of the cost of money over time and take into account the investment and time limitations that are inherent to the projects of this kind.

2. Literature review and problem statement

Modern theory of project management, presented in [5], identifies ten classical methods and tools that can be applied to estimate the cost of projects. However, not all of them are relevant to CEP, because these projects have a number of specific characteristics, defined in [6], namely:

– content complexity (availability of the features of construction, innovation, technological, organizational and system character);

– presence of a large number of various resources;

– long-term projects, and, consequently, variability in the cost of resources over time;

– a large number of stakeholders, and, therefore, a variety of requirements.

Thus, for example, such methods, proposed in [5], as expert evaluation, evaluation by three points and assessment by analogues provide subjective results, that is, they depend to a great extent on the person who makes decisions about the cost of the project. However, these methods can be applied for the evaluation of individual components of a project. As a drawback, it is advisable to mention a high cost of the method of expert evaluations and evaluation by three points. In its turn, assessment by analogues gives only approximate cost of a project.

Such tools of project cost estimation, proposed in [5], as "analysis of the reserves", and the "cost of quality" can be applied to predict the costs necessary to provide certain components of CEP. However, for the formation of a realistic estimate of CEP, the application of these methods only is insufficient.

Group decision-making methods, proposed in [5], are cumbersome and, therefore, have high cost. But under the condition of a correct set of specialists, they can provide an exact result, making these methods attractive for project managers. In case of application of group decision making methods for CEP, it is expedient to form several groups of specialists who will take part in the evaluation of the cost of the project.

In addition, there is a method of evaluation of the cost of a project, which is based on the use of a software product [5]. This method is efficient and widespread as the calculations are performed automatically, based on initial data. But it has high cost due to the price of the software and of training a specialist skilled in using the program. In addition, the result of this method depends in many aspects on the quality of the initial data that were used.

Analysis of offers from the suppliers is the most accurate method but it is difficult to estimate the cost of the entire project with its help because not all the operations are fulfilled with the participation of suppliers, contractors, etc.

Parametric evaluation is a complex method that is best applied to the projects of minor scale and when all the volumes of the project and their normative costs are known. However, CEP are the projects, characterized by high content complexity, so using this method is only possible to estimate the cost of some of its components.

And the last method, presented in [5], is a method of "bottom-up" evaluation, it is based on the work breakdown structure (WBS) of the project, implies in the beginning an evaluation of the smallest works, then their step by step summing, to the highest level – that is, to estimate the cost of the project as a whole. This method can be used for all projects, but it in many respects depends on a correctly formed structural decomposition of the project's work, which is for large projects, such as CEP, is difficult, and sometimes is not necessary, to work out in detail.

With regard to the characteristic features of CEP, presented earlier, it is expedient to note that the use of only one of the mentioned methods to form a realistic assessment of the cost of the project is impossible. The reason for this is the fact that some of the methods are inter-connected (i. e., some methods form a part of the source data for others), and neither assesses the impact of the external environment on the cost of the project.

Analysis of periodical literature [7–12], which examined the questions of the cost management of construction projects, revealed that traditional assessments should be combined, worked out further and developed.

Thus, for example, in [7] the authors offer to base the assessment of the project on the competences of assigned personnel, which is actual but may not act as a key parameter for estimation of CEP due to their considerable resource intensity.

The authors of [8] base the assessment of the project on its WBS, which, as already noted earlier, is an efficient and credible approach, but depends a lot on the quality of the WBS. In addition, for CEP, WBS is expedient to build in a software product, as CEP have considerable scale and hence the WBS is bulky and difficult to work with.

Availability of a large number of stakeholders is one of the key aspects for the formation of cost in the opinion of the authors [9]. However, CEP are projects, which have high technological complexity that does not always allow meeting all the requirements of the engaged parties, that is why using this method for the given projects in its basic form is not quite correct.

In [10] the authors' attention focuses on the analysis of causal relationships of the project that influence the duration and productivity of construction projects, as well as their cost. But this paper analyses internal variables of the project factors and relations between them but the impact of close and distant environment of the project is not considered, which for CEP, taking into account their importance and the presence of a wide range of stakeholders, is unacceptable.

In [11] they offered, for optimal estimates of the project, using the software package Last Planner System, which allows making adjustments to the original project plan and assessing alternative estimates. However, this approach to forecasting the cost of the project is based on traditional methods of assessment, which, as noted earlier, cannot form a realistic estimate of CEP. In addition, CEP have high level of uniqueness and manufacturability, which excludes the possibility of formation of alternative estimates. Therefore, the application of the Last Planner System for planning the cost of CEP is impractical.

In [12] the authors point out that construction projects are risky. In particular, they underline the risk of lack of funds as the cause of shortage in resources. The authors use the Monte Carlo method to analyze the risks of the project, in particular their cost estimate, based on which the estimate of the project is built. This method can be applied to CEP; however its use is appropriate at the stage of risk analysis while all other cost parameters of the project are proposed to calculate by using traditional methods. This leads to complicated and cumbersome methods of calculating the cost of CEP, which are not supported fully by one software product and therefore have high cost and are difficult to use. This, in turn, is undesirable for forecasting the cost CEP.

However, none of the presented methods, either in the PMBOK Guide or in the examined papers, takes into account the fact that the resources of the project change their cost over time. And given the fact that CEP are resource intensive and long lasting, this factor must be considered when forecasting the cost of CEP.

That is, there is an unsolved problem, which is in the absence of methods of cost management of CEP, which would take into account specific features of such projects, their limitations, and would be based on the theory of change in resource costs over time.

3. The purpose and objectives of the study

The aim of the work is to develop models and methods of planning the cost of construction and energy projects taking into account the fact that some resources change their cost over time, have investment limitations and defined terms of implementation.

To achieve the set goal, the following tasks were formulated:

– to improve the processes of cost management of CEP by way of developing a method of cost planning for construction and energy projects;

– to formalize mathematically the process of planning cost of CEP by constructing its forecasting assessment model;

– to conduct verification of the method of planning the cost of construction and energy projects.

4. Development of the method of planning the cost of CEP given the changeability in the cost of resources over time and their constraints

The main purpose of planning the cost of CEP is to create a budget, which is the main document for the formation of a schedule of financial activity of the project in its investment phase. An estimate of a project implies allocating the funds by a time parameter, with their subsequent summing, which in the theory and practice of project management is realized by aggregating and cumulation [13].

Taking into account the specificity of CEP, the method of planning its cost is advisable to develop based on the following points:

– CEP are complex and large- scale projects that require involvement of managers with high qualification, who have the knowledge of the subject area of the project. In addition, it is necessary to take into account the fact that not all of these resources can be engaged at any point in time and in full, that is, there are a number of specific limitations. Therefore it is advisable to define in the CEP cost planning a separate tool for evaluation of the cost required for provision of CEP management, i. e., organizational component of the project;

– owing to the fact that CEP is intersectoral and characterized by a large volume of resources, complex technological process and the presence of innovative and system components, it is expedient to define in the method of CEP cost planning the calculation of their costs a separate tool;

– given the CEP resource intensity and specificity of some resources, which is in their individuality for each project, the duration of the period of production and high cost, it is appropriate, when planning CEP cost, to consider a factor of change in the cost of resources over time, i.e., to include in the method of planning CEP cost the process of bringing to one point in time;

– in addition to the aforementioned, CEP has certain limitations of investment and time nature, which also needs to be considered when developing the method of planning CEP cost.

Thus, it was decided to divide the method of planning CEP cost into three stages:

1) calculation of the cost of the organizational component of the project;

2) calculation of the cost of construction, technological, system, innovation components of the project;

3) determining the total cost of CEP.

Moreover, it should be noted that the first two steps can be executed in parallel, and the third stage is implemented upon their completion.

Stage 1. Calculation of the cost of organizational component of a construction and energy project

The management costs include those that are meant to reduce non– productive costs and bring the project to the ideal technological level, i. e., ideal technological project implementation without any control and non–production costs. In this sense, all the processes of project management (PM), described in the PMBOK Guide, are non–production and the costs of their application are related to the cost of management. The set of processes of PMBOK and assignment of each process to one of the areas of expertise or a group of processes of PM is the basis for classification of the components of the cost management of the project.

According to the PMBOK Guide, the costs of PM are the expenses incurred in the fulfillment of any of the processes described in the standard and applied in the project. These costs can be further grouped and summed by groups of processes: “Initiation”, “Planning”, “Performance”, “Control”, “End” or by fields of PM knowledge: “Integration management”, “Content, timing and cost management”, “Quality management”, “Human resources management”, “Communications management”, “Risk management”, “Contract management”.

Let us assume that for the management of CEP it is necessary to fulfill M of management functions (i=1,...,M), each of which is characterized by the presence of the interval of performance t_i, and by the set of skills and abilities h_i y of resources necessary for its implementation.

Let there exists a set of resources R, in which each resource r_k (k=1,...,R) has its availability interval t_k, and its own set of skills and abilities h_k, by which s/he can perform in full or partially one or another management function m_i.

In addition, each resource has its cost C_k. The cost of resource can be adjusted by using the coefficient a_{ki}. With full use of all the skills of a resource to perform the management function m_i, a_{ki} will equal one. And when the resource is not using all his/her skills, the coefficient a_{ki} will take the form of fraction of one. That is, the coefficient a_{ki} can take any value in the range [0–1].

For efficient implementation of the project, the fulfillment of the following condition is necessary:

$$\sum_{i=1}^{M} h_i = \sum_{k=1}^{R} h_k, \qquad (1)$$

where M is the number of managerial functions, pcs.; h_i is the set of skills and abilities, necessary to perform the managerial functions m_i (i=1,...,M); R is the number of resources required for the implementation of the project, pcs.; h_k is the set of skills and abilities of each resource r_k (к=1,...,R).

Let us assume that all resources, necessary for implementation of managerial functions, are available, in the appropriate time an interval, i. e., the condition is satisfied:

$$t_i = t_k, \qquad (2)$$

where t_i is the time interval, in which the managerial function m_i (i=1, ...,M) is fulfilled, hours; t_k is the interval of time, during which the resource r_k (k=1, ...,R), h, is available.

To determine the cost of the resources required to perform all administrative functions of the project, let us apply the matrix of assignments. This matrix is a graphic model of resource allocation in their cost expression by managerial functions in each time interval t_i. The columns of the matrix are the intervals of time t_i of realization of managerial functions, and the lines of the matrix are the resources, necessary for their execution. In the cells of the matrix we indicate the cost of the skills and abilities of the resource, adjusted by the factor a_{ki}. This ratio shows the weight of competences of the resource, which is used for execution of this or that managerial function of the project. The sum of all the coefficients a_{ki} by an individual resource must be one. If, in some interval t_i, none of managerial functions, represented by resource in the line, is fulfilled, then the cell remains empty and equals zero at calculations. Example of the matrix of assignments for the project is presented in Fig. 1.

Thus, the cost of performing managerial functions of the project C_O is calculated by summing all the values in the matrix.

Resource \ Time interval	t_1	t_2	t_3	t_4	t_5	t_6	t_7	…	t_M
r_1		Managerial function, m_1: $a_{12}C_1$	$a_{13}C_1$	$a_{14}C_1$	$a_{15}C_1$			…	
r_2					Managerial function, m_2: $a_{25}C_2$	$a_{26}C_2$	$a_{27}C_2$	…	
r_3	Managerial function, m_3: $a_{31}C_3$	$a_{32}C_3$	$a_{33}C_3$					…	
r_4	$a_{41}C_4$	$a_{42}C_4$	$a_{43}C_4$			Managerial function, m_4: $a_{46}C_4$	$a_{47}C_4$	…	$a_{4M}C_4$
…	…	…	…	…	…	…	…	…	…
r_k						$a_{k6}C_k$	$a_{k7}C_k$	…	$a_{kM}C_k$

Fig. 1. Example of the matrix of assignments

In addition to the costs of assignment, the costs of CEP management include the costs of the tools C_I, which provides fulfillment of project management functions, namely: to use PM information system, to provide managers with office equipment and stationery, to pay for telecommunications, business trips, etc.

Thus, the total cost of managing CEP C_{PM} is defined as

$$C_{PM}=C_O+C_I, \qquad (3)$$

where C_O is the cost of fulfillment of managerial functions of the project, UAH.; C_I are the costs of the tools needed to perform the managerial functionsof the project, UAH.

Stage 2. Calculation of the cost of construction, technological, system, innovation components of CEP

Construction and energy projects are intersectoral, large-scale, long-lasting and consist of the work of different nature, namely, construction, innovation, system and technological.

Given the fact that CEP have a large number of operations, which considerably complicates the process of working with them, it is appropriate to reduce their number by grouping into functional elements. By a functional element in this article we will understand the operation or a set of operations that are combined by a technological feature, so that to simplify the processes of managing these operations, activities of forecasting their costs, implementation control, etc.

Based on the fact that the functional elements of innovation, system, and technological nature are aimed at creating energy object (technological equipment and systems) and their cost consists of the cost of resources, then the formula for calculating the cost of the technological component of CEP $C_{CEP\ Tech}$ will take the form

$$C_{CEP\ Tech}=C_B+C_{Tech}=R, \qquad (4)$$

where S_B is the cost of construction and installation operations, UAH.; C_{Tech} is the cost of creating an energy facility, UAH.; R is the total volume of resources for the implementation of CEP, UAH.

In this case, when planning the cost of a technological component of CEP, it is necessary to take into account such characteristics of the project as a long period of implementation and availability of the resources that are actively variable by cost.

The solution to this task involves the following steps:

– determining technologically necessary volume of resources for the implementation of CEP with regard to selection of less expensive (from resource perspective) technologies;

– formation of resource profiles of functional elements with regard to potential changes in the cost of resources over time;

– formation of resource profiles for artels;

– building a predictive resource model of the project taking into account the fact that the cost of money changes over time.

Step 1. Determining less costly (in terms of resources) technologies.

Construction and energy projects are related to high-technological projects, i.e., require significant capital investments in the creation of specific energy objects. With the purpose to comply with resource constraints of the project in assessing the cost, it is necessary to perform a procedure of comparing several variants of technology, equal in results. Choosing a variant is expedient at the stage of determining the cost of the work by the minimum of capital investment indicator (K).

This indicator can be calculated by different methods, for example:

1. Calculation of capital investment in block condensing power plants:

$$K_{KEC} = \left[K_1 + K_2(n_{bl} - 1)\right]C_p C_m, \quad (5)$$

where K_{KEC} is the capital investment in block condensing power plants, UAH; K_1, K_2 are the capital investments in the first and subsequent units, UAH; n_{bl} is the number of blocks, pcs.; C_p, C_m are the coefficients, which take into account the region of the facility and fuel type.

2. Calculation of capital investment in a thermal power plant with cross links:

$$K_{TEK} = K_{K1} + K_{T1} + K_{Kn}(n_b - 1) + K_{Tn}(n_T)C_p C_m, \quad (6)$$

where K_{TEK} is the capital investment in thermal power plant with cross links, UAH; K_{K1}, K_{T1} are the capital expenditures for the first boiler and the first turbine unit, UAH; K_{Kn}, K_{Tn} are the capital expenditures for each subsequent boiler and turbine unit, UAH; n_b, n_T are the numbers of similar boilers and turbine units, pcs.

3. Calculation of capital investments in industrial boiler plants:

a) with the same type of units:

$$K_{CI_{st}} = [K_{2b} + K_{sb}(n_b - 2)]C_p C_m, \quad (7)$$

where K_{CIst} are the capital investments in industrial boiler plants with the same type of units, UAH; K_{2b} are the capital investments in the first two boilers (two main ones as one boiler is not installed because of the condition of ensuring work of a boiler plant in the case of emergency), UAH; K_{sb} are the capital investments in each subsequent boiler, UAH; n_b is the number of boilers, pcs.

b) with different type of units:

$$K_{IBr} = [K_{2bi} + K_{sbi}(n_{bi} - 2) + \sum_{i=1}^{m}(K_{sbj} n_{pbj})]C_p C_m, \quad (8)$$

where K_{IBr} are the capital investments in industrial boiler plants with different type of units, UAH; K_{2bi}, K_{sbi}, n_{bi} are the same as before for the i-th type of boiler; K_{sbj} are the capital investments in each subsequent boiler of the type j, UAH; n_{pbj} is the number of subsequent boilers of the type j, pcs.; j is the number of groups of boilers of different types, with the exception of one type of unit, pcs.

4. Capital investments in heating networks:

$$K_{HN} = K_{sci} LDC_p, \quad (9)$$

where K_{sci} are the specific capital investments in heating networks, UAH thousand/km; L is the length of a heating network, km; D is the diameter of the pipeline, m; C_p is the coefficient, taking into account the region of the facility.

Based on the calculated data, the selection is conducted of the alternative of CEP, for which the indicator of capital investment K is the lowest.

Step 2. Formation of resource profiles of functional elements with regard to potential change in the cost of resources over time.

As a part of this step, those resources are first of all determined that are related to the category of "actively variable in cost over time".

Based on the obtained information, the resource profiles of functional elements are built, including taking into account the present value, which characterize the dynamics of consumption of resources of various types during their execution.

$$R_j = \sum_{n_j=1}^{l} R_{nj} + \sum_{n_j=1}^{l}\left(R^*_{nj}(1+r)^V\right), \quad (10)$$

where R_j is the resource profile of the j-th functional element, UAH; j=1,...,m; R_{nj} is the volume of resources, fixed by the cost over time, necessary for fulfilling the n-th work of the j-th functional element, UAH; n_j=1,...,l; l is the set of operations of the j-th functional element, pcs.; R^*_{nj} is the volume of resources, actively variable in cost over time, required for the execution of the n-th work of the j-th functional element, UAH; V is the number of time periods in the investment phase of CEP, pcs.; r is the coefficient of reduction.

Underlying this calculation is the fact that the cost of money decreases over time, objectively or subjectively [14]. Objectively is due to inflation and other external factors, subjective is owing to the fact that there is an opportunity to invest in alternative projects, less risky and with larger profitability [15]. In this regard, the operation of reduction is applied. In the given case, the magnitude of the coefficient of reduction r is constant for the entire interval of CEP life cycle.

It should be noted that if financing of CEP is provided by multiple sources, it is expedient to use a weighted average value of the coefficient of reduction in the calculations:

$$r_{wa} = \sum_{i=1}^{f}\left(r_i \alpha_i\right), \quad (11)$$

where r_{wa} is the weighted average value of the coefficient of reduction; r_i is the magnitude of the coefficient of reduction for the i-th capital; α_i is the share of this capital in the total amount of investment, i=1,...,f; f is the number of sources of funding, pcs.

After obtaining resource profiles of functional elements of CEP, one can proceed to the formation of resource profiles of artels of the project.

Step 3. Formation of resource profiles for artels.

This stage is carried out by the operation of cumulation of appropriate resource profiles of functional elements that are included in a particular artel.

In turn, artels of operations of the project are formed by aggregation, i.e., reducing the number of functional elements by replacement of several operations by one operation.

Within CEP, the aggregation of functional elements should be carried out taking into account the following:

– functional elements of CEP are technologically connected, indicating the appropriateness of their grouping them in a certain artel, which has its own resources, implementation time, limitations, etc.;

– due to the presence of a technological dependence, some functional elements must be carried out in parallel, which can affect the process of formation of артілей of the project;

– not all of the functional elements should be included in artel, i.e., there may be free functional elements of CEP;

– it is necessary to take into account that in every single point of time of the implementation of CEP there are certain investment, technological, resource, technical, etc. limitations.

The operation of cumulation CUM (Agr_i) means determining overall resource profile, built by summing the resource profiles of functional elements that are included in a particular artel of CEP. The number of resources, required for realization of the *i*-th artel, is calculated based on the assumption that the parameters of functional elements changed only in discrete points of time:

$$R_i = CUM(Agr_i) = \sum_{j_i=1}^{n_i} R_{j_i}, \quad (12)$$

where R_i is the volume of required resources for realization of the i-th artel, UAH, i=1,...,N; N is the number of artels in the project, pcs.; R_{ji} is the volume of resources, required for the implementation of the j–th functional element in the i-th artel, UAH, i_j = 1,...,n_i; n_i is the number of functional elements in the i-th artel;

After processing the artels of CEP and formation resource profiles for them, one can proceed to the calculation of cost of the technological component of the project.

Step 4. Building a forecasting resource model of CEP that is performed by the operation of cumulation of all resource profiles (El_m) of CEP:

$$R = CUM(El_m) = \sum_{i=1}^{N} R_i + \sum_{j^*=1}^{n^*} R_{j^*}, \quad (13)$$

where R is the total volume of resources for the implementation of CEP, UAH;

$$\sum_{i=1}^{N} R_i$$

is the number of resources needed for the implementation N of CEP artel, UAH, i=1,...,N;

$$\sum_{j^*=1}^{n^*} R_{j^*}$$

is the total volume of resources for the implementation of free (which are not included in any artel) functional elements of CEP, UAH, j*=1,..., n*; n* is the number of free functional elements of CEP.

After calculating the total volume of resources, required for the implementation of CEP, one can proceed to determining a predictive cost of CEP.

Stage 3. Determining of predictive cost model of CEP

Predictive cost model of CEP is formed through summing of its two components: organizational and technological (14).

$$CM_{BEP} = CUM(C_{PM}, R, T_{ex}) = C_{PM} + R. \quad (14)$$

Constraints:

$$CM_{BEP} \le S + D, \quad (15)$$

$$T_{ex} \le T_{dir}, \quad (16)$$

where S is the limited amount of funds that are planned to be spent on the implementation of CEP, UAH; D is the maximum permissible level of attracting extra funds, which includes provisions for risks and other unpredictable events, UAH; T_{dir} is the actual period of implementation of the project, hours; T_{ex} is the set timeframe of implementation of the project, hours.

Thus we obtained a predictive cost model of CEP, which is based on the selection in the given projects of organizational and technological components and takes into account changeability in the cost of certain resources over time.

5. Results of application of the method of planning the cost of construction and energy projects

Given that the method, proposed in this paper, of planning the cost of CEP takes into account changeability in the cost of some resources over time, which lays the foundation for formation of the assertion of a higher accuracy of forecasting data derived by application of the method, it is appropriate to carry out verification of this method. Verification of the method of planning the cost of CEP is planned to carry out through the analysis of the planned and actual indicators of the projects, already implemented, with magnitudes that are calculated by using the proposed method.

During the verification of the method, we analyzed nine construction and energy projects that have been implemented at the enterprises: PAT "Pivdenspecbud" (Kharkiv, Ukraine) and AK "Kharkivoblenergo" (Kharkiv, Ukraine). The information about the progress of these projects is a commercial secret, so the article presents only summary indicators of the cost of the project without going into detail and identification data.

As the criterion, by which we will make a conclusion about the accuracy of the method of planning the cost of construction and energy project, we propose to use the ratio of the actual indicator of the cost of the project to its planned indicator. Since this indicator is relative, then it is possible to compare different projects with its help. For CEP this is important because they are different both in scale and in terms of implementation.

In ideal case, when the planned cost of the project is accurately calculated, the ratio of the actual indicator of the cost of the project to its planned indicator will equal one. In the case when the resulting indicator is larger than or less than one, one may point out the inaccuracy of the results of the applied method of planning the cost of the project. More to the point, the larger a deviation from one, the lower is the accuracy of method of planning the cost of the project.

Thus, we will present the corresponding calculations and compile the obtained data in Table 1.

Presented Table 1 vividly shows that the planned indicators of the project that were calculated using traditional methods of forecasting the cost of the project, have larger deviation from one (Table 1, column 5) than those that were calculated using the method of planning the cost of CEP, presented in the article (Table 1, column 7).

In order to justify a possibility of application of this method for the entire general totality of construction and energy projects, it is necessary to calculate the coefficient of variation, which characterizes the degree of homogeneity of the data in the sample and the objectivity of the received data. The coefficient of variation for the number of events less than thirty is calculated by the formula:

$$V = \frac{\sigma}{\bar{x}}, \quad (17)$$

where V is the coefficient of variation, σ is the mean-quadratic deviation; $\bar{x}$ is the arithmetic mean of the elements of the sample.

Table 1

Results of application of the method of planning the cost of construction and energy projects

#	Project	Planned cost, UAH ths.	Actual cost, UAH ths.	Ratio of actual cost of the project to planned cost	Estimated planned cost, UAH ths.	Ratio of actual cost of the project to estimated cost
1	Project 1	125684,32	153216,14	1,22	143157,31	1,07
2	Project 2	134262,45	163689,14	1,22	153127,36	1,07
3	Project 3	253619,2	313647,89	1,24	301723,17	1,04
4	Project 4	133652,3	163175,31	1,22	159872,68	1,02
5	Project 5	146583,32	194623,14	1,33	189426,14	1,03
6	Project 6	333482,9	356127,3	1,07	352487,12	1,01
7	Project 7	269513,7	334872,5	1,24	323964,12	1,03
8	Project 8	283792,93	326589,1	1,15	302862,6	1,08
9	Project 9	326842,3	394856,14	1,21	379510,12	1,04

In its turn, the mean-quadratic deviation from the number of events less than thirty is calculated by the formula:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}\left(\bar{x} - x_i\right)^2}{n-1}}, \tag{18}$$

where n is the number of events (projects), pcs.; x_i is the characteristic of the i-th element of the sample.

For the given sample of projects, the mean-quadratic deviation is calculated for the indicator "ratio of actual cost of the project to the estimated cost" and equals 0.024. Thus, the variation of the given sample of the projects is 0.023.

The value of variation of the sample up to 10 % indicates its weak diversity and high typicality of the respective mean magnitude. This confirms expediency of application of the proposed method of planning the cost of the project to ensure forecasting consumption flows of construction and energy projects.

Thus, it is proved that the sample of the projects is representative and the given method can be applied to the general totality of construction and energy projects.

6. Discussion of the results of improvement of the processes of CEP cost management

The processes of CEP cost management have been improved by addition to the existing methodology of project management of the method of planning the cost of CEP. The proposed method is based on the theory of changeability in the cost of money over time. This direction of expanding the set of tools of planning the cost of CEP was chosen due to the fact that these projects are long-term and resource intensive, requiring the use of a specific approach to forecasting their cost.

The main advantage of the method of planning the cost of CEP is that it allows obtaining more accurate predictive data regarding the cost of a construction and energy project as early as at the stage of investment. This is achieved by analyzing the resource component of the project and the use of the procedure of reducing the cost of resources to a single point in time.

The drawbacks of this method are its bulkiness, which is caused by the scale of CEP. In addition, as a drawback, one may point out the need for accurate initial data concerning the technology of creation of CEP and which are not always easy to get, since these projects have high level of uniqueness. The difficulties may also arise in determining the dimension of the coefficient of reduction, which is also a drawback of the method.

The main area of application of the method of planning the cost of construction and energy projects is the energy sector in Ukraine and other countries. This method can be applied for other projects, too, that have a long-lasting period of implementation and a large volume of resources. These projects should also have a formalized technological component, since it is the largest cost driver of the project and is subject to detailed study when forecasting its cost.

This research is the foundation for further improvement in the following areas:

– designing a mechanism of determining the magnitude of the coefficient of reduction;

– unification of the method of planning the cost of CEP for the projects that have a significant period of implementation and large resource intensity;

– development or adaptation of existing software product to the cost planning method of construction and energy projects in order to simplify its application;

– addition of procedures to forecast change in the cost of resources to the method of planning the cost of construction and energy projects, as a reaction to external stimuli, in order to improve the accuracy of forecasting the cost of CEP.

7. Conclusions

1. The process of cost management of projects is improved, by addition to the totality of the tools of forecasting the parameters of the budget of a project of the method of planning the cost of CEP. Unlike the existing ones, it is based on the theory of changeability in the cost of some resources over time, takes into account availability of organizational and technological components of the project, investment and time limitations, and is oriented towards the projects that have long-term implementation and considerable resource component.

2. A mathematical interpretation of the project budget planning process was developed, which is presented in the form of predictive cost model of CEP. It, unlike the existing ones, is based on the cost approach and the cumulation of such parts of CEP as the cost of an organizational component and the cost of a technical component. In addition, this model has limitation by investment characteristic and time frame of CEP.

3. Approbation of the method of planning the cost of CEP was carried out, the coefficient of variation and the mean–quadratic deviation of the sample of projects were calculated, on the basis of which we conducted approbation. Conclusions about the adequacy of this method were drawn, indicating the expediency of its application in forecasting the cost of construction and energy projects.

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