Economic-mathematical model for calculating the labor cost as a part of the investment construction project’s cost on the estimated standardization and market pricing methods’ basis

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Abstract. Effective management of investment and construction projects is associated with the problem of cost estimation. The guidelines for the construction products’ determining prices disclosing methods have been developed. However, in practice, the investor estimates, which is an important condition, but not sufficient are used as basic. The need for an accurate calculation of the investment construction project cost for both the investor and the contractor dictates the new requirements for finding approaches to the materials’ systematization, as well as streamlining the procedure for calculating the construction products’ price. At the pre-investment stage of design, cost optimization should be carried out by calculating the capital investments using the aggregated indicators. In this situation, priority attention should be directed to rationing and labor costs. The calculation of probable labor costs for a certain period will make it possible to increase the validity of the decisions taken at the initial stage of the investment construction project’s development. Today it is necessary to develop a new approach to the issue of calculating labor costs in construction, which, on the one hand, will determine the amount of labor costs and production efficiency, and on the other hand, make an investment and construction project attractive in modern market conditions.

Introduction
An important component of production costs is wages, therefore the employer seeks to reduce them, while the employee seeks to increase wages, which represents the bulk of his income. The level and change in labor costs are due to the diverse interests of workers and employers. This divergence of interests contributes to the effective use of the organization’s resources. The economic-mathematical model of calculating the labor cost resolves this contradiction between the employee and the employer, guaranteeing a fair income distribution.

The relevance of research in this area is confirmed by the fact that the construction industry development level determines the social and economic potential of the country, which, in turn, is determined by the population income level. The construction industry is among the leaders of the Russian economy in terms of technologies used, equipment of enterprises, quality of materials, while there is no effective wage system that takes into account labor efficiency and the contribution of each employee to the final result.
The specifics of construction project management are presented in foreign publications by authors such as J.E. Schaufelberger and L. Holm [1], C. Preece, K. Moodley, P. Smith, P. Collar [2], management and resource allocation strategies are considered by L. Trigeorgis [3], Ronald Oaxaca and Michael Ransom [4] dealt with the formation of econometric models for adjusting wages. In domestic works, N. Bereza, A. Bereza, M. Lyashov, L. Blanco [5], L. Zelentsov and L. Mailyan [6], A. N. Sekisov, O. G. Degtyareva, N. V. Samsonova, M. N. Grigoryan [7] disclosed the problems of generating production costs, including wages in construction.

The problems of control modeling are studied by by O.I. Ohrimenko, I. M. Maltsev [8] V.P. Iosifov, V.A. Kamaev, A.V. Melikov, D.M. Korobkin [9], V.I. Rodionova, L.A. Shvachkina, K.V. Vodenko, P.A. Ponomaryov [10], control modeling in construction - by V. Kostuchenko, A. Zdanov, A. Rodionov [11], T. Rogovenko, M. Zaitseva [12] and others.

Despite the fact that the diverse scientific papers are regularly published on the issues of assessing the labor productivity factors, managing the construction project’s costs, the development criteria for budget valuation and market pricing methods [13, 14, 15], the area of economic and mathematical modeling of labor value of an investment construction project on the basis of estimated standardization and market pricing methods remains undetected.

Materials and methods
Wages in construction, as in other industries, consist of a constant and variable part. The permanent part is basic and mandatory, the variable depends on different conditions are set by the employer. The constant part of wages is under the scrutiny of both employees, employers and owners.

Today, the construction uses tariff, non-tariff and mixed wage systems. They are based on the qualification division of personnel and the link to the position, the result of which is the presence of the tariff grid and categories. Elements of the tariff-qualification system are linked as follows: the tariff category takes into account the construction production peculiarities; qualification level depends on the level of professional training of the employee; tariff coefficients are formed taking into account the qualification categories and reflect the ratio of tariff rates of various categories with the category I tariff rate; the tariff grid is a combination of tariff categories of work and is formed depending on the work complexity and qualification characteristics of workers, and also takes into account tariff factors.

The constant part of wages does not reflect labor efficiency and the contribution of each employee to the final result, which is its main drawback. We propose the use of the ball-factor method, which involves the consolidation of individual production tasks for the individual employees.

Discussions and Results
We also propose to let management determine the possibility of redistributing these tasks in the process of implementing the production process. The formation of the fixed part of wages is shown in Figure 1.
Figure 1. Algorithm for the labor costs’ constant part formation as a part of the construction project value

Within the framework of this algorithm, six stages can be distinguished; each of which consists in performing certain actions. In the above-shown diagram, we have provided both the action itself at each stage and the proposed list of operations provided in each of these actions. As a result of the phased proposed activities, we will receive a reasonable fixed part of the salary, which depends not only and not so much on the position, but on the tasks that should be solved within the framework of this position.

At the first stage, the position is described in accordance with the duties (Procedure A), after which a detailed list of job tasks is formed, which are a part of the general tasks list in the company (Concretization A).

At the second stage, the evaluation method (Procedure B) is selected, such methods as: rating scales, ranking, situational assessment method, point-factor method, non-traditional assessment methods, etc. can be used. In this model, according to the authors, the use of the point-factor method (Concretization B) is justified.

The third stage, the algorithm for the labor cost constant part formation as a part of the construction project cost, provides the preparation for the assessment of the previously selected point-factor method (Procedure C), in which it is primarily intended to select the factors that will be used in the assessment, then they need to be described in detail and the level should be defined, as well as set the weight of each factor depending on the degree of importance, as a result of which a usable point-factor scale is developed (Concretization C).

The fourth stage provides the direct assessment (Procedure D), which without fail involves the creation of a matrix of job tasks with an indication of their weight categories determined by the expert group conducting the assessment (Concretization D).

At the fifth stage, grading is carried out, or in other words, a grouping of a structural unit’s posts (team or unit) by the selected attribute, determination of the value or weight of each post in order to form a motivation system (Procedure E). Grading is carried out on the basis of the stepwise range coefficients or on the basis of the professions’ clusters (Concretization E).

The final sixth stage ensures the compilation of a position ranking (Procedure F), on the basis of which the constant part of the salary is adjusted, the grade value is calculated and fixed, the so-called
rank forks are developed for each group of posts and the base salaries are compared to the actual salaries (Concretization F).

In order to more convenient practical application, we introduce the following conventions:

- $S$ is the total number of tasks in the construction organization;
- $N$ is the number of experts evaluating;
- $M$ is the matrix of tasks provided for by a particular position taking into account the value;
- $M_j$ is the task weight;
- $n_i$ is the ranking number of the ranked position;
- $z_{n_i}$ is the cost of one grade in the position $n$, taking into account the average level of remuneration for this position and employee qualifications;
- $z_{n_i+b}$ is an excess of the cost of one grade for combining job responsibilities;
- $\Sigma z_i$ is the final grade evaluation in grades.

We give the formula for calculating the constant part of the labor cost in the construction project cost (formula 1):

$$ W_{G_{\text{constant} i}} = \sum_{j=1}^{S_{g}} M_j \times \sum_{i=1}^{N} z_i x z_{n_i} + \sum_{j=1}^{S_{g}} M_j \times \sum_{i=1}^{N} z_i x z_{n_i+b}. $$ (1)

The developed formula includes:
1) the constant part of remuneration for the main position (formula 2):

$$ W_{G_{\text{main} i}} = \sum_{j=1}^{S_{g}} M_j \times \sum_{i=1}^{N} z_i x z_{n_i}. $$ (2)

2) The constant part of remuneration for a combined position (formula 3):

$$ W_{G_{\text{comb} i}} = \sum_{j=1}^{S_{g}} M_j \times \sum_{i=1}^{N} z_i x z_{n_i+b}. $$ (3)

As a result, we get (formula 2) the basic salary level, tied to the level of the employee’s core competencies in the respective position, and the increment of the salary (formula 3) in case of combining other duties of a different level. Such an approach to the formation of a salary will allow taking into account the employee’s value for the company and his personal contribution to the final product, ensure the transparency of professional and career growth, link the job evaluation system with the pay system, and determine the main criteria for the staff selection.

We will determine the procedure for the labor cost variable part formation as a part of the construction project cost, based on progressive approaches to assessing the staff labor effectiveness. Today, a widespread reception aimed at the direct dependence of the employee’s value within the company and his remuneration. The fairest is the piecework wage system that supports this approach.

The variable part of remuneration in the market should certainly take into account the participation of the employee and the effectiveness of his work. The participation of the employee in the final result occurs with the help of the corresponding coefficient - the labor efficiency coefficient $LEC$. It takes into account both the main part of labor remuneration through the base salary coefficient $C_{wg}$, and the variable part reflecting the employee’s contribution to the final result, by means of the employee’s labor participation coefficient $C_{lp}$.

The construction industry is very specific and too many resources are involved in the construction industry, so it is very difficult to determine the participation degree in the final result of each specific worker.

It is proposed to correct the considered methods by questioning the employees and sharing the goals and objectives of the construction organization between the employees, taking into account the reproductive-significant part of their labor potential. To determine the workers’ labor potential reproducibly significant part level, it is necessary to create a statistical base using the company tasks’
distribution system developed by the authors. This system, in fact, is a matrix that takes into account the weight of goals and objectives in the framework of the evaluated posts and the potential of each employee.

The system is based on a cross-evaluation of the work results of each team member by management and peers equal in rank. After the period agreed in advance, we get the data that allows us to assess the level of each member of the team in dynamics. This can be realized with the help of developed questionnaires, which indicate the production task of the corresponding specialist, and an assessment is made on this task’s implementation not only by the head of the relevant structural unit, but also by the closest colleagues in this unit.

Such an approach will not only provide the organization’s leadership with the initial information for the implementation of the developed model, but will also contribute to a more rational labor resources’ use, which in turn will lead to an increase in labor productivity without any additional costs.

With a sufficient amount of data and after appropriate processing, the results of observations actually play the construction enterprise activity model role. In our opinion, information processing can be performed using the standard office information technologies, and the additional software products will not be needed.

In dynamics, this information will allow managers of different levels to evaluate the labor activity of personnel, track changes, and timely adjust it using operational management decisions. This model allows you to determine the degree of participation of each member of the team in the final result and reflect this in the variable part of wages.

The generated statistical base, taking into account the personnel labor activity degree, allows us to introduce the corresponding coefficient $\text{C}_{\text{lp}}$, reflecting the productivity contribution of each employee to the overall activity of the structural unit and the participation degree in the final goal of the entire construction enterprise (formula 4).

$$
\text{C}_{\text{lp}} = \sum_{i=1}^{C} \left[ \text{It}_{i} \times \text{Io}_{i} \times \text{Is}_{j} \times \sum_{i=1}^{N} \frac{\text{As}_{i}}{N} \right]
$$

(4)

where $\text{Io}_{i}$ – is the weight of the $i$-th organization goals in the overall strategy;

$\text{It}_{i}$ – is the weight of $i$-th company objectives in its goals;

$\text{Is}_{j}$ – defines the employee’s task weight for organization;

$\text{As}_{i}$ – shows the performance assessment of the $i$-th expert;

$N$ – is the number of experts;

$C$ – is the number of tasks for each employee.

The variable wages’ share, in our opinion, should be tied to the planned profit that the organization will receive from the implementation of a specific investment and construction project, and in this case, it is proposed to use formula 5 to determine the variable part of the wages:

$$
\text{WG}_{\text{variable}} = \text{L}_{cr} \times (\Delta \text{EP} - \Delta \text{EP} \times \alpha).
$$

(5)

where $\text{L}_{cr}$ – is the labor contribution ratio;

$\Delta \text{EP}$ – is the increase in the estimated profit of a construction company from the implementation of a specific investment and construction project;

$\alpha$ – is the percentage of the organization’s reserve funds.

Thus, within the framework of the proposed model, the employees’ participation in the profits of the organization intended for the material incentives for employees is provided. Moreover, this participation in profit, in our opinion, will be clearly justified by the participation of each employee in the labor process and will increase the interest of ordinary employees in the final result of the enterprise, that is, in profit.
The proposed algorithm for the variable part formation of the labor in the construction object cost is shown in Figure 2.

Figure 2. Algorithm for the variable part formation of the labor cost of in the construction object cost

The algorithm for the variable part formation of the labor cost of in the construction object cost formation involves the sequential implementation of the following actions:

1. The 1st action is the construction of a closed graph: the top of the graph is the organization goal; the edges of the graph are the tasks of each employee;
2. The 2nd action - the calculation of the weighting coefficients of each goal and the task using the expert estimates (Io, It, Is);
3. The 3rd action - the formation of a matrix of employee’s labor behavior (As);
4. The 4th action is the calculation of the labor contribution coefficient based on the graph;
5. The 5th action - strict inequality is checked \( L_{cr} > 1 \), and if the equality is true, then step 6 is performed, if false - step 7 is performed;
6. The 6th action or sixth action - strict inequality is verified \( \Delta EP - \Delta EPx > 0 \), and if the inequality is true, then step 8 is performed, if it is false, then step 7 is performed;
7. The 7th action - the amount of the variable part of the salary is assumed to be zero due to the insufficient level of the employee’s participation in the implementation of official tasks (5th action) or the lack of sufficient profit from the implementation of the investment construction project (6th action), in connection with which the total salary remains at the level its constant part;
8. The 8th action – the calculation of the salary’s variable part for each employee;
9. The 9th action – the calculation of the total amount of the wages’ variable part of the labor collective to be included in the construction project’s costs.

When studying the modern generally accepted approaches to the formation of wages in construction, the authors revealed not only a certain subjectivity of this procedure, but also the fact of using rather
complex, cumbersome mathematical schemes, for example, the use of data on costs in the implementation of similar investment and construction projects. This situation causes certain inconvenience not only within the organization, but also provokes many negative aspects at the stage of approval and signing of the planned estimates with the customer or investor. Unfinished moments in the construction pricing entail a distortion of the construction project’s real value, and as a result, longevity, unfinished and mothballed construction projects, and litigation.

We propose to revise the approach to the labor costs’ formation in the cost of a construction project, we propose to use the developed model not only at the investment and construction project’s implementation stage, but also at the planning stage. The proposed model will also allow to manage the costs associated with the use of labor resources at a construction site.

In the implementation of the investment construction project, the importance of the human factor is difficult to overestimate. The developed model makes it possible to take into account the contribution of each member of the labor collective to the final result. The model has the following form (formulas of the system of equations 6):

\[
\begin{align*}
WG_{gen} &= \sum_{i=1}^{M} (WG_{constant_i} + WG_{variable_i}) \\
WG_{constant_i} &= \sum_{j=1}^{S} M_j \times \sum_{i=1}^{N} z_i x z_i n_i + \sum_{j=1}^{S} M_j \times \sum_{i=1}^{N} z_i x z_i n_i + b, \\
WG_{variable_i} &= L_{cri} \times (\Delta EP - \Delta EP \times \alpha)
\end{align*}
\]

where \( M \) – is the total staff.

The resulting system of equations, according to our assumption, should be a part of the methodology for calculating the building products’ costs aimed at optimizing its structural elements.

**Summary**

As a result, the formed economic and mathematical model (system of equations), which describes the functional relationship between the organization’s goals, its profit and the tasks faced by every employee, as well as the planned construction costs, will allow for constant monitoring of the construction site, which will help to timely solve the problems of optimizing the investment construction project’s costs.

That is, the created model allows the head of the organization to assess the needs for personnel, and more precisely, for the human resources with certain labor characteristics, to predict the possible downtime and risks due to non-compliance with the characteristics of the employee’s labor behavior and the production tasks faced by him at the design and construction stage, and not commissioning when human costs turn into losses.

In addition, the resulting working model for calculating the construction cost can be used not only at the construction planning stage, but also at any other stage, allowing the manager to track the changes in cost and, if necessary, modify the production process.

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