Особливі умови реалізації проектів з будівництва транспортних споруд показують, що управління собівартістю робіт вимагає відповідної оптимізації організаційних та технологічних рішень. Розроблено комп'ютерну модель та методику вибору оптимального управління для мінімізації собівартості будівельних робіт. Модель показує організаційну та технологічну змінність підприємства, характерну для транспортного будівництва. Методика дозволяє проводити варіантне моделювання, за яким складаються закономірності зміни собівартості будівельних робіт, співвідношення прямих і загальновиробничих витратпід впливом наступних факторів: середня трудомісткість сукупності проектів, середня відстань перебазування, належність ресурсів, індустріалізація використаних рішень.

Проведені чисельні експериментальні дослідження кількісно довели, що організаційні та технологічні рішення, характерні в цілому для підприємства, впливають на рішення окремих проектів будівництва транспортних споруд. А саме, виявлено, що при зменшенні середньої трудомісткості сукупності проектів вплив індустріалізації використаних рішень змінюється на протилежний та починає підвищувати собівартість робіт.

Знайдене найменше значення зміни собівартості (–13,6 %), що відповідає найбільш ефективними організаційними та технологічними рішеннями: середня трудомісткість сукупності проектів X_1=2,2 тис. люд.-год., середня відстань перебазування X_2=100 км., використання тільки власних техніки та трудових ресурсів (X_3=0 %), мінімальна індустріалізація використаних рішень (X_4=0 %).

Виявлено, що підрядні організації, що зводять відносно малі транспортні споруди, мають використовувати традиційні методи виробництва робіт. Також встановлено економічну ефективність рішень, згідно з якими підприємства з будівництва територіально розосереджених споруд мають використовувати підрядні ресурси із місцевою матеріально-технічною базою

Ключові слова: будівництво транспортних об'єктів, організаційні та технологічні рішення, чисельна оптимізація, моделювання витрат

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TRANSPORT CONSTRUCTION COST MANAGEMENT BY RATIONAL ORGANIZATIONAL AND TECHNOLOGICAL SOLUTIONS

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1. Introduction

The relevance of management of construction costs by optimizing organizational and technological solutions of transport construction is due to the main three reasons. Namely:

1) large volumes of transport construction;

2) organizational and technological features of construction of such facilities;

3) available reserves for reducing the cost of construction of transport infrastructure.

First, the ever-increasing volume of transport construction indicates the importance of research in this industry. The importance of transport infrastructure construction is evidenced by the fact that in different countries the share of the transport sector varies by 8–10 % of gross domestic product. In some of these countries, up to 7 % of the total employed population works in this area. Many elements of transport infrastructure (roads, bridges, piers, etc.) need repair or reconstruction. In Ukraine, for example, this category includes state importance roads with a length of 49,117.4 km. These roads are to become highways, but the construction is being postponed for various reasons.

Secondly, the peculiarity of the organization of transport construction is the production scale and geographical dispersion of facilities under construction. Technological features: availability of different methods of certain construction works (different degrees of mechanization of works, structures consolidation, etc.).

Third, one of the available reserves of management efficiency is the adoption of rational organizational and technological solutions based on the criteria of construction cost. An unused reserve for efficiency improvement is the optimization of organizational and technological solutions of individual construction projects in the context of the organization as a whole.

The need to implement various transport construction projects encourages cost management by searching for the most effective organizational and technological solutions for such construction. Therefore, research on this topic should be considered relevant for the modern development of the science of management processes, in particular, methods of management of the enterprises of the construction industry and its material and technical base.

2. Literature review and problem statement

Construction of transport facilities has a number of features that significantly distinguish it from other branches of construction. Naturally, the development of numerical methods of cost estimation for the construction of transport infrastructure is still relevant. All these methods include estimation of construction cost [1, 2]. The studied works [1, 2] do not contain the results of research on the impact of organizational and technological solutions of transport construction on cost indicators. The available research does not take into account the specifics of organizational and technological features of transport construction. Most of the analyzed works [1–6] contain studies of the efficiency of transport construction by the impact on the development of industry and tourism (Ukraine, Poland, Belgium, the United States), but are not aimed at managing the construction cost. The literature review proves that transport infrastructure facilities can be extended in length and located in different places [7]. This shows that the construction of such facilities requires organizational and technological solutions that meet these specifics. The size of the country plays an important role in the functionality and types of infrastructure facilities to be [3, 4]. Thus, the development of transport infrastructure requires the construction of specialized transport facilities, which can mainly be characterized by different geographical dispersion and volumes of work necessary for their construction. The main works on the organization of the construction process prove that there is a correlation between the development of organizational and technological solutions related to the whole organization and those related to individual construction projects [8, 9]. At the same time, no special methods have been developed to study numerical relationships between organizational and technological construction solutions related to the enterprise constructing transport facilities in general, and solutions related only to such construction projects.

When modeling [10–12], it is advisable to divide the cost into direct and general production costs according to accounting standards. It is desirable to use modeling to improve the operational activity of construction [13]. However, the search did not reveal the methods of variant optimization modeling of construction solutions adapted to transport construction. Although some optimization studies provide rational solutions for enterprises when using network model analysis [14], their use is too time-consuming. Alternative methods (including Petri nets, fuzzy data optimization methods) cannot be used for a low number of experimental points [15, 16]. The analysis of the works on the optimization of organizational and technological solutions for construction and reconstruction [5, 6, 17] suggests that the use of experimental statistical modeling is an effective way to solve such problems. Such modeling can be used for modeling and managing the cost of enterprises constructing transport facilities. Numerical modeling and optimization of organizational and technological solutions of construction and reconstruction are discussed in [5, 6, 17]. These works prove that the key to effective optimization is the reliability of computer models of the facility under consideration. Optimization methods using experimental statistical modeling are considered in [18–21]. These works allow adapting the methods of experimental statistical modeling to the specifics of transport construction. The application of experimental statistical modeling for optimization is discussed in [22]. In order to create a model of the operational activity of a construction organization, it is recommended [5, 6, 17] to use specialized project management software.

The analysis of the given information shows that transport construction is implemented in special organizational and technological conditions that require numerical research and development of rational management tools. To do this, it is advisable to use cost indicators of construction works in the construction of transport facilities and methods of variant modeling, in particular experimental statistical modeling.

3. The aim and objectives of the study

The aim of the study is to determine the patterns of construction cost management by selecting rational organizational and technological solutions for the construction of transport facilities. This will reduce the cost of construction of transport facilities and streamline the ratio of direct and general production costs.

To achieve this aim, the following objectives were set:

– to select and justify organizational and technological, mathematical methods of modeling;

– to obtain the results of experimental statistical modeling of organizational and technological solutions for the construction of transport facilities;

– to analyze alternatives when selecting a rational management option for different organizational and technological conditions.

4. Materials and methods of cost management when selecting organizational and technological solutions of the enterprise constructing transport facilities

It is proposed to use the theory of experimental statistical modeling for efficiency evaluation and selection of optimal organizational and technological solutions in the management of the enterprise constructing transport facilities. The essence of this modeling is to observe the investigated system by recording the values of the initial indicators when determining the levels of input factors. At the same time, the system is presented in this study as a computer model of organizational and technological solutions of the enterprise. The method for identifying cost management patterns when selecting organizational and technological solutions of the enterprise under consideration is shown in Fig. 1.

The polynomial experimental statistical model (ES model) was chosen in this study to solve optimization problems. Equation (1) represents it in the general form:

$$\begin{aligned} Y = b_0 + b_1X_1 + b_{11}X_1^2 + b_{12}X_1X_2 + b_{13}X_1X_3 + \\ + b_{14}X_1X_4 + b_2X_2 + b_{22}X_2^2 + b_{23}X_2X_3 + b_{24}X_2X_4 + \\ + b_3X_3 + b_{33}X_3^2 + b_{34}X_3X_4 + b_4X_4 + b_{44}X_4^2. \end{aligned} \quad (1)$$

A numerical experiment was conducted to observe changes in the indicators of the enterprise under study by changing the selected factors, for which a plan of experiments was specially selected. The selection was carried out in the following sequence:

1) determination of characteristics of variable factors: independent, quantitative, varying at three levels, total number – 4;

2) selection of characteristics of the ES model: a free-term quadratic model, including direct and quadratic influences and their interaction;

3) selection of an experimental plan that corresponds to the characteristics of the variable factors and the selected ES model in accordance with [22]. Table 1 contains the main characteristics of the considered plans (where e_D, e_A, e_E, e_Q – values of the corresponding optimality criteria; d_{max} – normalized estimate of the model, i. e. a maximum in the planning area; $|p_{max}|$ – maximum modulus of correlation of coefficients of indicator estimates);

Table 1

Characteristics of the considered experimental plans

No.	Number of points	e_d	e_a	e_e	e_Q	d_{max}	$\|p_{max}\|$	Note	Plan number according to [22]
1	24	0.966	0.872	0.647	0.913	18.5	0.26	Composite, symmetrical, three-level	60
2	25	0.627	0643	0.49	0.737	66.5	0.47	Composite, symmetrical, orthogonal	61
3	27	0.979	0.862	0575	0826	–	0.33	Three-level	63
4	42	0.979	0.9	0475	0.82	18.2	0.51	Composite, symmetrical, three-level	65

4) selection of an experimental plan based on the analysis of the characteristics and values of optimality criteria.

Plan 4 is immediately rejected by comparing the characteristics of the plans listed in Table 1, even though the values of the optimality criteria are very high. This was due to the large number of observations in the plan (42). Plans 1–3 remain. None are optimal, despite the fact that the values of the optimality criteria of plans 1 and 3 are quite high. Plan 1 has the largest values of the optimality criteria. It was decided to adopt it as an experimental plan and add the $X_1=X_2=X_3=X_4=0$ point, taking into account the experimental conditions.

Regression coefficients were calculated according to standard formulas using the COMPEX dialog system. Regression coefficients are statistical estimates of the true coefficients of a polynomial model, so the coefficients must be tested for significance. That is, whether the estimates of the experimental coefficients of the statistical model are nonzero. This test was performed at a bilateral risk of 10 % (α=0.1), according to the Student's criterion with normal distribution law. After removing the considered coefficients that do not differ from zero according to the test results, the experimental statistical model with all significant estimates of the coefficients was tested for adequacy by Fisher's test. If this criterion was less critical for the risk, given the number of degrees of freedom obtained, $F_a<F_{cr}(\alpha, f_{na}, f_e)$, the model was considered adequate for engineering analysis.

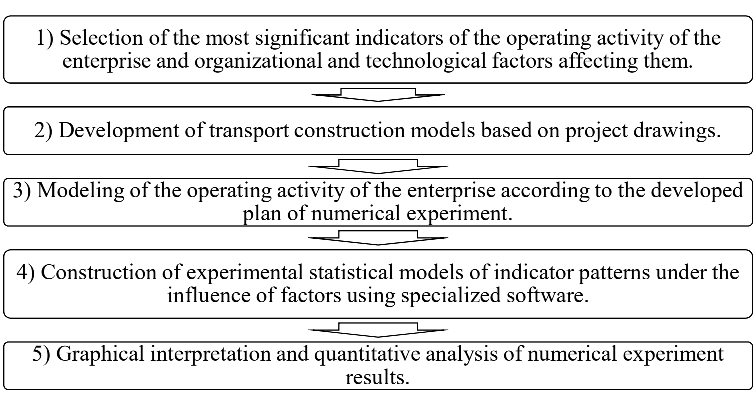

Fig. 1. Method of identifying cost management patterns when selecting rational organizational and technological solutions for the construction of transport facilities

The transition to the coded levels of factors was carried out according to the standard formula (2):

$$x_i = \frac{X_i - \dfrac{X_{i\,max} + X_{i\,min}}{2}}{\dfrac{X_{i\,max} - X_{i\,min}}{2}}, \qquad (2)$$

where x_i is a given level of the factor in normalized form, X_i is a given level of the factor in normal form, $X_{i\,max}$ is the maximum level of the factor in normal form, $X_{i\,min}$ is the minimum level of the factor in normal form.

5. Selection and substantiation of organizational and technological, mathematical methods of modeling

According to item 1 of the method in Fig. 2, the most significant indicators were considered:

– cost change (Y_1) – percentage change in the cost of construction works depending on management actions through the influence of organizational and technological factors. As a basic model, the cost change of which is zero, a model was adopted that reflects the most typical organizational and technological solutions of the enterprise constructing transport facilities. In this study, such a model is observed at the average levels of the considered factors. The cost of construction works is the sum of direct and general production costs. General production costs include: costs for maintenance of engineering and technical staff, relocation of construction equipment, construction of temporary buildings, utilities, warehouses, etc. Direct costs include: wages and business trips; cost of consumables; equipment operation; operation of construction machines and mechanisms; basic materials; subcontracted services;

– the ratio of direct and general production costs (Y_2) – percentage ratio of general production costs to the amount of direct costs for the project totality.

Variable organizational and technological factors and their numerical characteristics are presented in Table 2. The computer model of organizational and technological solutions for the construction of transport facilities was chosen as the system under study. The graph-analytical form of the model is shown in Fig. 2. Fig. 3 presents a method of modeling the cost change and the ratio of direct and general production costs for the construction of transport facilities.

Table 2

Variable factors

Factor	Variable characteristic
X_1 – average complexity of the project totality	Arithmetic mean of the complexity of construction works of the project totality, thousand hours
X_2 – average relocaa tion distance	Arithmetic mean of resource relocation distances between any two projects of the whole totality, km
X_3 – attribution of resources	Percentage of own resources in the total resource use
X_4 – industrialization of applied solutions	Percentage of using industrial methods in the total volume of works

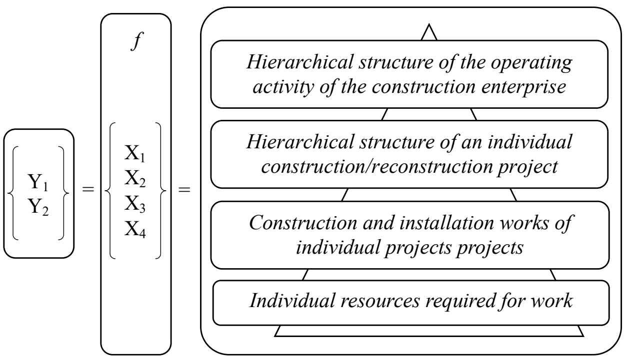

Fig. 2. Graph-analytical form of the computer model of organizational and technological solutions for the construction of transport facilities

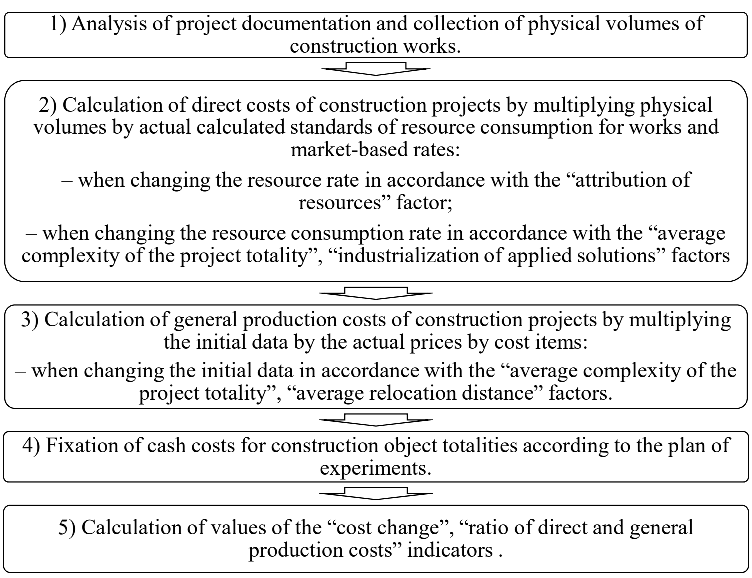

Fig. 3. Methods of modeling the cost change and the ratio of direct and general production costs for the construction of transport facilities

The presented computer model (Fig. 2) was variable, as the levels of its input parameters (factors) varied in the numerical experiment. The variability of the computer model was possible under the influence of each factor:

– X_1 – average complexity of the project totality (organizational factor). The project totality should be consistent with the required variation characteristic – the arithmetic mean of the complexity of construction work on the facilities of the totality;

– X_2 – average relocation distance (organizational factor). The variation characteristic of this factor is the arithmetic mean of resource relocation distances between any two facilities of the selected totality. It was used as input data in calculating the cost of relocation of household premises, vehicles, machinery and construction equipment as part of general production costs. The initial data for calculating general production costs are given in Table 3, their composition – in Table 4;

– X_3 – attribution of resources (organizational factor). The difference in the use of subcontracted resources compared to own was calculated as follows: the unit cost of contracted resources (labor, machinery or equipment) is 18 % higher, which is justified by the market situation. However, the cost of relocation of industrial and domestic premises, vehicles, machinery and construction equipment will be lower, as the involvement of subcontractors is desirable when their material and technical base is closer to the construction site. The study assumes that the subcontractor’s expenditures for resource relocation are 2 times less. This change is introduced together with the variation of the X_2 factor;

– X_4 – industrialization of applied solutions (technological factor). This factor had a complex impact on the methods of construction of transport facilities. The use of the following industrial methods was modeled: high-performance construction equipment, consolidated products and structures; mainstreaming of production operations; mechanization. Modeling of this factor was carried out by adjusting the resource assignments of the respective works.

Table 3

Initial data for calculating general production costs

Cost item	Unit
Number of teams (10 people)	teams
Distance to construction site	km
Planned completion period	months
Number of relocated pieces of equipment	pieces
Number of relocated sets of construction equipment	set
Number of foremen	people
Number of geodesists	people
Number of storekeepers	people

The developed auxiliary components of modeling methods (Fig. 2, 3, Tables 3, 4) allow to conduct a numerical study of the cost of construction of transport facilities, and the selected factors (Table 1) characterize the features of organizational and technological solutions under consideration.

Table 4

Composition of general production costs in the construction of transport facilities

No.	Item	Unit
1	ETS wages (including taxes)	
1.1	foreman	people
1.2	geodesist	people
1.3	storekeeper	people
2	ETS travel costs	
2.1	foreman	people
2.2	geodesist	people
2.3	storekeeper	people
3	Communication	
3.1	Internet	people
3.2	mobile	people
4	Personal protective equipment, medicines, office supplies	supply
5	Protection of construction site	service
6	Certification of labor protection	people
7	Repair	service
8	Relocation of construction equipment	cu/km
9	Transportation of technical and household premises	cu/km
10	Transportation of construction equipment	cu/km
11	Arrangement of temporary water supply	service
12	Arrangement of temporary power supply	service
13	Temporary fencing	service
14	Temporary warehouse	service

6. Results of experimental statistical modeling of organizational and technological solutions for the construction of transport facilities

According to item 2 of the method in Fig. 1, a set of transport construction models was developed, which are different in complexity and location. The models are not included in the paper, as their development is a technical rather than a scientific task. Then, in accordance with item 3 of the algorithm in Fig. 1 and the method in Fig. 3, of all models those were selected corresponding to the levels of the variable factors X_1 ("average complexity of the project totality") and X_2 ("average relocation distance") according to the plan of experiments (Table 5, columns 2–3). After that, the set of models was transformed according to the action of the X_3 ("attribution of resources") and X_4 ("industrialization of applied solutions") factors according to the method in Fig. 3 and the experimental plan (Table 5, columns 4–5).

The results of the numerical experiment are presented in Table 5. This table summarizes the results of calculations (columns 6–7) according to the method shown in Fig. 3. They cannot be more fully disclosed due to the limited volume of the paper.

As a result of experimental statistical modeling using the COMPEX program (item 4 of the method in Fig. 1), the following equations (3), (4) of changes in the studied indicators under the influence of variable factors were obtained.

Hereinafter, the coefficients that are considered close to zero according to the assessment of their significance by the Student's criterion are not shown. For the convenience of engineering calculations, the dependences were transformed using formula (1), which allowed the use of full-scale values of factor levels in the calculation of indicators Y_1 ("cost change" – formula 3), Y_2 ("ratio of direct and general production costs" – formula 4).

$$Y_1 = -13.083 + 0.557X_1 - 0.006X_1^2 - 2\times10^{-4}X_1X_2 + 8\times10^{-4}X_1X_3 - 0.002X_1X_4 + 0.018X_2 - 4\times10^{-6}X_2^2 - 5\times10^{-5}X_2X_3 + 0.06X_3 + 0.037X_4, \quad (3)$$

$$Y_2 = 9.281 - 3.746X_1 + 2.469X_1^2 - 2.839X_1X_2 + 1.3X_1X_3 + 3.745X_2 - 1.466X_2X_3 - 1.99X_3. \quad (4)$$

The most convenient graphical representation of the change in the indicator from four factors is the "squares on a square" scheme. This scheme reflects the pattern of changes in the indicator from two factors within the nine "small" squares, which are located on the "large" square, reflecting nine combinations of the values of the other two factors. When constructing diagrams of this type, it is advisable to divide the factors into two pairs, each of which has its own meaning in terms of studying a given system.

Table 5

Results of experimental statistical modeling

No.	X_1, thousand hours	X_2, km	X_3, %	X_4, %	Cost change, Y_1	Ratio of direct and general production costs, Y_2
1	37	1,000	100	100	–0.222 %	8.20 %
2	37	1,000	100	0	5.223 %	7.75 %
3	37	1,000	0	100	–4.647 %	10.68 %
4	37	1,000	0	0	0.373 %	10.09 %
5	37	100	100	100	–1.691 %	6.61 %
6	37	100	100	0	3.753 %	6.24 %
7	37	100	0	100	–7.587 %	7.27 %
8	37	100	0	0	–2.566 %	7.27 %
9	2.2	1,000	100	100	2.301 %	16.13 %
10	2.2	1,000	100	0	–1.015 %	16.76 %
11	2.2	1,000	0	100	3.225 %	27.84 %
12	2.2	1,000	0	0	0.333 %	28.87 %
13	2.2	100	100	100	–5.141 %	7.69 %
14	2.2	100	100	0	–8.457 %	7.99 %
15	2.2	100	0	100	–11.658 %	9.41 %
16	2.2	100	0	0	–14.550 %	9.76 %
17	37	550	50	50	–0.967 %	7.93 %
18	2.2	550	50	50	–2.274 %	15.02 %
19	19.6	1,000	50	50	0.895 %	10.98 %
20	19.6	100	50	50	–2.125 %	7.65 %
21	19.6	550	100	50	1.896 %	8.35 %
22	19.6	550	50	100	0.063 %	9.25 %
23	19.6	550	0	50	–3.127 %	10.35 %
24	19.6	550	50	0	1.742 %	9.08 %
25	19.6	550	50	50	–0.615 %	9.31 %

Table 5 allows constructing experimental statistical dependences of the studied indicators on variable factors by processing the presented data with the help of modern software.

7. Analysis of alternatives in the management of cost indicators by selecting organizational and technological solutions

In this study, the factors X_1 and X_2 reflect the organizational solutions that characterize the operating activity of the construction enterprise as a whole; the factors X_3 and X_4 – organizational and technological solutions within a separate construction project. Further in this section, the graphical interpretation and quantitative analysis of patterns 3 and 4 according to item 5 of the algorithm in Fig. 1 are presented.

Consider Fig. 4. The figure shows graphically the pattern of cost change (Y_1) from the attribution of resources (X_3) and industrialization of applied solutions (X_4) with nine combinations of levels of average complexity of the project totality (X_1) and average relocation distance (X_2).

Hereinafter, the extremes of the indicators within the two-factor diagrams are highlighted in bold, and within the entire four-factor diagram – underlined.

The "cost change" indicator (Y_1) reflects the relative financial efficiency of management under various organizational and technological solutions. As can be seen in Fig. 3, such efficiency differs in certain organizational and technological solutions at facilities for different levels of organizational and technological factors that generally characterize the operating activity of the enterprise under consideration. In addition, the influence of such solutions (i. e., the influence of the X_3 and X_4 factors) differs depending on the levels of the X_1 and X_2 factors.

Table 6 reflects the relative efficiency of management through organizational and technological solutions that generally relate to the activities of the construction enterprise under consideration. The estimates presented in Table 6 were calculated by finding the difference between the maximum and minimum cost change (Y_1) for each of the nine "small" squares in Fig. 4.

It can be noted that the efficiency of the necessary organizational and technological solutions for a particular object increases with increasing average complexity of the project totality ($X_1 \to max$) and decreases with increasing average relocation distance ($X_2 \to max$).

The level of the X_1 and X_2 factors also affects how the X_3 and X_4 factors affect the value of Y_1. At low values of the Y_1 factor, the increase of industrialization of applied solutions (X_4) increases construction costs (at X_2=100 km – by 2.1 %, at X_2=550 km – by 3.05 %, at X_2=1,000 km – from 3.1 %). At high – decreases (at X_2=100 km – by 5.4 %, at X_2=550 km – by 5.07 %, at X_2=1,000 km – by 4.9 %). In other words, the use of highly efficient construction and installation methods is desirable at large facilities. Analyzing the angle of inclination of the isolines to the axis of the "attribution of resources" factor (X_3), we can come to the following conclusion. An increase in the level of the X_2 factor reduces the effect of the X_3 factor on the indicator. In other words, the use of subcontracted resources is more appropriate when facilities are far apart. However, the use of own labor resources, machines and mechanisms for the construction of transport facilities is more profitable than attracting them from the outside in any case.

The minimum value of the "cost change" indicator (Y_1), equal to 13.6 %, is observed at the average complexity of the project totality X_1=2.2 thousand hours, the average relocation distance X_2=100 km, X_3=0 %, industrialization of applied solutions X_4=0 %.

Fig. 5 contains a graphical representation of the impact of attribution of resources (X_3) and industrialization of applied solutions (X_4) on the ratio of direct and general production costs (Y_2) with nine options of the average complexity of the project totality (X_1) and average relocation distance (X_2).

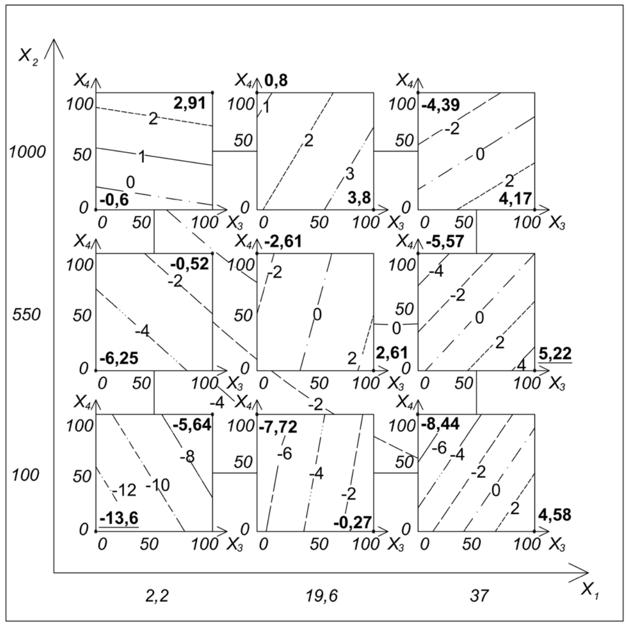

Fig. 4. Cost management (Y_1) by selecting attribution of resources (X_3) and industrialization of applied solutions (X_4) for different levels of the "average complexity of the project totality" (X_1) and "average relocation distance" (X_2) factors

Table 6

Relative management efficiency (%) when selecting organizational and technological solutions for different levels of the "average complexity of the project totality" (X_1) and "average relocation" (X_2) factors

Level of X_2 factor, km	Level of X_1 factor, thousand hours		
	2.2	19.6	37
1,000	3.51	3	8.56
550	5.73	5.22	10.79
100	7.96	7.45	13.02

The influence of attribution of resources (X_3) on the ratio of direct and general production costs (Y_2) remains unchanged at all points of the factor space. Increasing the use of subcontracted resources reduces general production costs and increases the share of direct costs. In the general case, this leads to a decrease in Y_2.

The influence of the X_1 and X_2 factors depending on the degree of influence of the X_3 factor on the indicator should be noted. Table 7 estimates the impact of attribution of resources (X_3) on the ratio of direct and general production costs (Y_2). The estimates presented in the table are calculated by finding the difference between the maximum and minimum ratio of direct and general production costs (Y_2) for each of the nine "small" squares in Fig. 5. The influence of the X_3 factor on Y_2 decreases with increasing average complexity of the project totality ($X_1 \to max$) and increases with increasing average relocation distance ($X_2 \to max$).

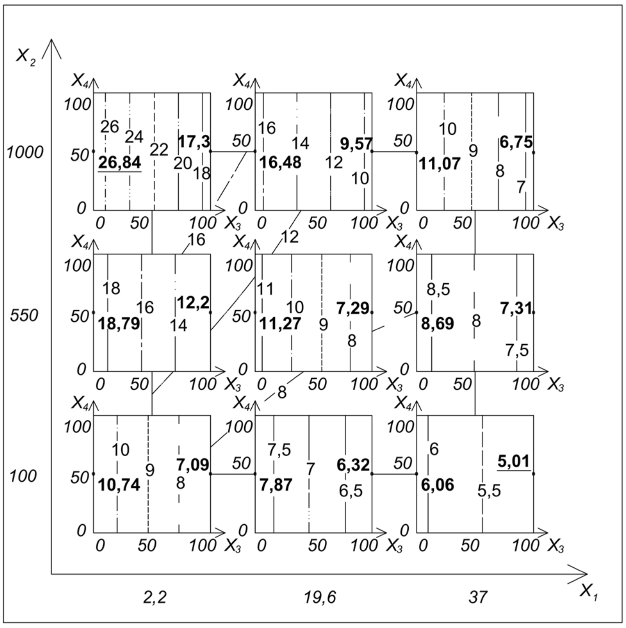

Fig. 5. Management of the ratio of direct and general production costs (Y_2) by selecting the attribution of resources (X_3) and industrialization of applied solutions (X_4) for different levels of the "average complexity of the project totality" (X_1) and "average relocation distance" (X_2) factors

Table 7

Changes in the ratio of direct and general production costs (%) for various organizational and technological solutions of transport construction

Level of X_2 factor, km	Level of X_1 factor, thousand hours		
	2.2	19.6	37
1,000	3.51	3	8.56
550	5.73	5.22	10.79
100	7.96	7.45	13.02

The study shows that effective organizational and technological solutions for the construction of transport facilities can reduce the cost of works and streamline the cost structure. In addition, the connection between organizational and technological solutions in the management of the transport construction enterprise as a whole and in the management of the construction of individual transport facilities is proved.

8. Discussion of the results of modeling organizational and technological solutions for cost management of transport construction

Summing up the study, we can emphasize the following. The problem of optimal cost management of transport construction can be solved by selecting rational organizational and technological solutions for transport construction. This is confirmed by the definition of patterns for cost management (Fig. 1) and the computer model of organizational and technological solutions for the construction of transport facilities (Fig. 2). The computer model demonstrates organizational and technological variability of transport construction, which is modeled by a set of auxiliary components of the modeling method (Fig. 3, Tables 3, 4) and experimental statistical modeling. The resulting pattern of changes in the cost – formula (3) – and the ratio of direct and general production costs – formula (4) – are explained by the high share of general production costs in the cost of transport construction and special organizational and technological conditions (different scales and dispersion of facilities).

Analytical (3), (4) and graphical (Fig. 4, 5) representation of the found patterns allows to offer optimal organizational and technological solutions according to the cost criteria. Thus, any transport construction enterprise can reduce the cost of work by selecting and implementing the necessary solutions depending on the conditions of operating activities.

The main innovations resulting from the study are:

– method of developing patterns of cost management of transport construction by selecting rational organizational and technological solutions (Fig. 1);

– experimental statistical patterns of changes in the cost and ratio of direct and general production costs of transport construction under the influence of organizational and technological factors – formulas (3) and (4).

In addition, for transport construction, the analysis of patterns showed that for facilities of different scales and dispersion (located at different distances from each other), different solutions on the attribution of resources and industrialization of applied solutions may be rational. For example, for large facilities it is more efficient to use powerful mechanical means, consolidated structures, etc., and for small – less efficient. Similarly, for dispersed facilities it is more effective to use the involved equipment, for closely located – own. Due to obtaining numerical patterns, this result is qualitatively new compared to previous studies [8, 9]. Thus, the knowledge about the correlation between organizational and technological solutions that apply to the entire organization and those related to individual construction projects was further developed.

The obtained experimental statistical dependences allow managing organizational and technological solutions of transport construction by selecting rational values of average complexity of the project totality, average relocation distance of equipment and temporary premises, equipment ownership (own or involved) and industrialization of applied solutions (use of powerful mechanical means, structures consolidation, etc.). In comparison with [1–6], these results allow to reduce the cost of construction works and to rationalize the ratio of direct and general production costs.

The reliability of the presented results is substantiated by the following:

– using the theory of experimental planning;

– developing numerical models of organizational and technological solutions of transport construction using real construction projects;

– using the methods of mathematical statistics in the processing of experimental results.

The obtained patterns of changes in the cost of work and the ratio of direct and general production costs, as well as the results of their analysis, can be used only for transport construction enterprises, as the basis for a numerical experiment are models of transport construction processes. In addition, the nature of changes in the studied indicators may differ beyond the variation of the "average complexity of the project totality" (X_1=[2.2; 37] thousand hours) and "average relocation distance" (X_2=[100; 1,000] km) factors. The consistency of the simulation results is ensured by the statistical compliance of labor cost standards and resource prices relative to those used in the development of models of transport construction processes.

These limitations determine the two directions of further research on the topic. First, it is the development of a mathematical apparatus of cost management when selecting organizational and technological solutions for other types of construction: industrial, civil, and so on. Secondly, it is the development of a mathematical apparatus for managing other indicators of the enterprise (profit, income, etc.) when selecting the current factors of economic, organizational and technological nature. Both directions can be implemented using an approach similar to the method of developing patterns (Fig. 1).

9. Conclusions

1. The use of experimental statistical modeling and methods of developing patterns allows with a given error (5 %) to manage the cost of transport construction by selecting rational organizational and technological solutions.

2. The most effective cost values are:

– "cost change" Y_1=–13.6 %, observed at the average complexity of the project totality X_1=2.2 thousand hours, average relocation distance X_2=100 km, using only own equipment and labor resources (X_3=0 %), minimal industrialization of applied solutions (X_4=0 %).

– "ratio of direct and general production costs" Y_2= =4.99 %, observed at the average complexity of the project totality X_1=37 thousand hours, average relocation distance X_2=100 km, only attracted equipment and labor resources (X_3=100 %), and any degree of industrialization of applied solutions (X_4).

3. For transport construction, it is proved that:

– for large facilities, the use of powerful mechanical means, consolidated structures, etc. is less costly (cost reduction by 5.39–5.58 %) and for small – more costly (cost increase by 2.91–3.36 %);

– for dispersed facilities, the use of attracted equipment is less costly (cost reduction by 0.6–3.17 %), for closely located – own (cost reduction by 4.6–7.58 %).

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CHOOSING THE RATIONAL MANAGEMENT OF HIGH-RISE BUILDING CONSTRUCTION PROJECTS

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Розроблено підхід до вибору раціонального управління проектами спорудження висотних будівель, який забезпечує ефективне використання ресурсів. Такий підхід спрямований на забезпечення економічності, енергоощадності, якості, безпечності та екологічності висотних будівель.

Запропоновано вирішувати такі завдання на основі пошуку раціональних рішень, що найбільше відповідають бажаним (заданим) техніко-економічним характеристикам (показникам), на основі застосування статистичного моделювання проектів як керованих процесів. Разом із цим доцільно враховувати вплив визначальних організаційно-технологічних, технічних та управлінських факторів. Для оцінювання рішень відносно цих факторів необхідно відшукати раціональне значення критерію ефективності управління. З позиції замовника (інвестора) в якості одного з таких критеріїв доцільно розглядати мінімум вартості спорудження висотних будівель.

Запропоновано враховувати вплив факторів якості, безпечності, енергоефективності, екологічності, оптимальної експлуатації висотної будівлі. Достатність і суттєвість впливу цих факторів на прийняття раціональних рішень при управлінні проектами висотного будівництва обґрунтовано результатами експертного опитування.

Отримано математичні моделі, які засновані на врахуванні системного впливу визначальних факторів. Ці моделі надають можливість кількісного оцінювання рівня досягнення заданого результату, зокрема за критерієм вартості спорудження висотних будівель, на різних етапах управління проектом.

Одержані результати є актуальними, оскільки дозволяють досягати раціональних значень бажаних показників у конкретних умовах виконання будівельно-монтажних робіт та в межах заданих ресурсних обмежень. Оперуючи прогнозованими оцінками очікуваних результатів, інвестори мають можливість відкоригувати свої цілі та обрати найбільш раціональний варіант реалізації інвестиційно-будівельного проекту

Ключові слова: проект, раціональне управління проектом, критерій ефективності управління, висотне будівництво, ефективне використання ресурсів, організаційно-технологічні, технічні та управлінські фактори

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1. Introduction

The development of modern cities is characterized by high population density, a shortage of land plots for the construction of the sites for different functional purposes, which, in turn, raises the cost of vacant sites in cities. It causes an increase in the number of stories in buildings and density of the city development, and in combination with measures of the economy, caused by the increasing scale of construction of buildings, makes high-rise buildings a viable