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# Optimization of Managerial, Organizational and Technological Solutions of Grain Storages Construction and Reconstruction

Aleksandr Menelylyuk, Aleksey Nikiforov\*

**Abstract:** The work is devoted to the important problem of optimization of managerial, organizational and technological solutions of construction and reconstruction of separate grain storages and the management of specialized building enterprise as a whole. Models of the company for the grain storages construction and renovation were designed, analyzed and described: multidimensional organizational structure, computer model of the enterprise. The results of a two-stage construction products cost optimization were presented. The recommendations for the adoption of optimal organizational and technological solutions were developed. The method for justification of financial income level for the grain storages construction and reconstruction using project management principles and provisions of the existing regulations was proposed.

**Keywords:** construction and reconstruction of the grain storages; business management techniques; multidimensional organizational structure; optimization; management; organizational and technological solutions

## 1 INTRODUCTION

The work is devoted to the important problem of optimizing the managerial, organizational and technological solutions of construction and reconstruction of separate grain storages and the management of specialized building enterprise in general.

Profitability is one of the key performance indicators in the management of individual objects in the grain storages construction or reconstruction, as well as managing the company's operational activity for the construction of such facilities. Modeling of resource assignments for construction and installation work performed during the grain storages construction or reconstruction, allows showing the full cost of production. Analysis of all construction projects, with a total budget conditionally equal to the average budget of the specialized enterprise, simulates the full structure of production costs and the profitability of such a construction organization.

It is obvious that the links are possible between different organizational and technological solutions for enterprise management in general and the construction of individual construction projects. This relationship may be modeled by multidimensional managerial structure. Its research will improve the quality of managerial decisions. Variation of organizational and technological solutions will change the structure and addends of the total production costs, the organizational structure of the enterprise. Construction of computer models of the totality of construction projects will allow tracking changes of the most important indicators of financial performance under the influence of different factors of organizational and technological nature.

The high relevance of the article is determined by large scale, special features of management of the grain storages construction and reconstruction, the absence of specific recommendations in the area under consideration and the availability of organizational and technological reserves of optimization.

## 2 AIM AND TASKS OF THE ARTICLE

This article aims to optimize the managerial, organizational and technological solutions for grain storages construction and renovation by organizational and economical mathematical modeling of operations of the specialized enterprises and the development of rational tools of their management.

Article tasks are the following:

1. Analyze information sources on the subject of research: the conditions of the grain storages construction and renovation, methods of organizational and numerical modeling.
2. Develop methodology for numerical simulation of the operating activity of the grain storages construction and renovation enterprise.
3. Develop models of the enterprise operating activity under consideration: a multi-dimensional organizational model, the computer model.
4. Get the numerical regularities of performance change in the enterprise operating activity and find the optimal organizational and technological solutions.
5. Suggest rational enterprise managerial tools for the construction and renovation of grain storages.

## 3 ANALYSIS OF INFORMATION SOURCES

Data on the segmentation of the grain storages construction market in the world [1-5] show that a significant proportion of the work is to upgrade existing storage facilities. Typically, this modernization involves the commissioning of new silos, the upgrading of technological equipment, productivity enhancement of transport lines and individual technological units of grain storage, associated with this dismantling work and the construction of small additional structures. As a rule, grain storage modernization is rarely of large scale. Grain storages reconstruction projects may have a budget up to 1 million UAH and labor input of construction and installation works up to 3 thousand hours

[5, 6]. Nevertheless, there are still tendencies to build new wide-scale grain storages and carry out large-scale renovation of existing ones. It can be concluded that the largest object for a typical grain storages construction and renovation enterprise has a budget of about 25-30 million UAH and the total labor intensity of construction and installation works for about 40 thousand hours [5, 6].

Analysis of types of enterprises organizational structures showed that the most common types are linear, linear-staff, project, matrix, multidimensional. The difference of these structures lies in different priorities of vertical and horizontal managerial relationships between their elements. Matrix and most multidimensional structures have the highest priority of horizontal relations among the considered structures. The development of such relations can be effective in the variable environment in which the company sells its activity [7].

It is advisable to use a simulation to improve construction activity. The most effective simulation of the operating activity of the enterprises is to build analytical, deterministic, optimizing, imitative, static, correlative-regressive, network models [8, 9].

The fundamental works on the organization of construction process proved that there was a correlation between the management processes of the organization and construction projects [10, 11]. It is proposed [12], that the operations of construction enterprises may be modeled using multidimensional organizational structures.

Analysis of works, devoted to the optimization of organizational and technological solutions for construction and reconstruction [13, 14], allows the conclusion that the application of experimental statistical modeling is an effective way of solving similar problems and can be used in modeling and optimizing the operating activity of enterprises for construction and renovation of dispersed different scale buildings.

The application of experimental statistical modeling for the methods of optimization are discussed in [15-17]. Also, the methods of optimization with the application of experimental statistical modeling are presented in [18-20]. It is advisable [21, 22] to use specialized programs for project management to create a model of the operating activity of the construction organization.

In the course of operational activity, important issues arise in the management of enterprise costs accounting. According to numerous works [23-24], it is advisable to divide cost by the accounting standard into direct costs and general production ones.

Regulatory methods for calculating costs and revenues are based on the use of a database of resource rates per unit of physical measurement of work, regulatory indicators of general production, administrative costs and profit on the consolidated labor input of construction [25, 26]. It is also allowed to use actual data for the calculation of general production and administrative costs indicators for construction enterprises [27, 28]. The usage of the internal database of resource rates per work unit is not prohibited for the construction company [26]. When managing projects [29], the special attention is recommended to pay to the formation of a full and detailed content and cost of the

project, as well as to integrate them with the goals of the project-oriented enterprise as a whole. That means to consider the cost of the project only in the context of the organization that implements it.

#### 4 OVERALL METHODOLOGY OF STUDY

Fig. 1 shows the block diagram of the experimental studies.

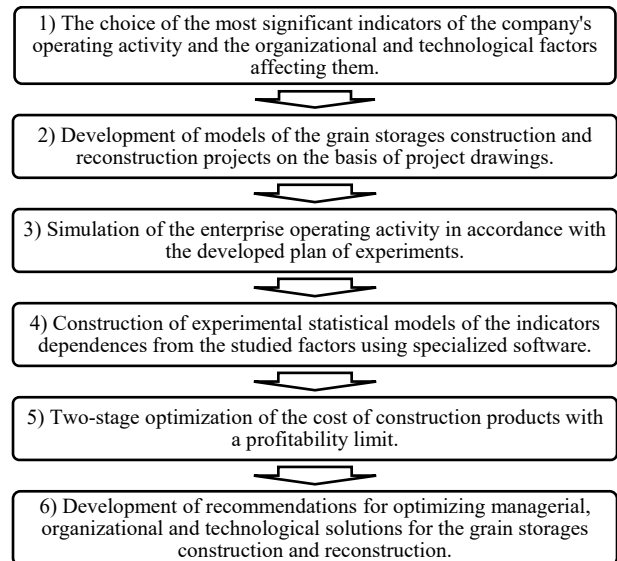


Figure 1 Block diagram of the experimental studies to optimize the organizational and technical solutions grain storages construction and reconstruction enterprise

The polynomial experimental statistical (ES) model was selected in this study in order to solve optimization problems. Eq. (1) presents it in a common form:

$$Y_n = b_0 + b_1X_1 + b_{11}X_{12} + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{14}X_1X_4 + b_2X_2 + b_{22}X_{22} + b_{23}X_2X_3 + B_{24}X_2X_4 + b_3X_3 + b_{22}X_{22} + b_{33}X_{32} + b_{34}X_3X_4 + B_4X_4 + b_{44}X_{42} \quad (1)$$

The transition to the coded variables was configured by the typical equation:

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

where:  $x_i$  – predetermined level of factor in a normalized form;  $X_i$  – predetermined factor level in natural form;  $X_{i \max}$  – the maximum level of the factor in its natural form;  $X_{i \min}$  – the minimum level of factor in its natural form.

Tab. 1 presents the plan used in numerical experiment.

The calculation of the regression coefficients was carried out according to standard equations using interactive COMPLEX system. The regression coefficients are statistical estimates of the true coefficients of the addendum of the polynomial model, therefore, require verification of the

difference between estimates of coefficients of ES-models and zero. This test was carried out at bilaterally specified risk equal to 10% ( $\alpha = 0.1$ , or  $\pm 5\%$ ), in accordance with Gaussian distribution law. After sieving coefficients, which were recognized indistinguishable from zero, ES-model with all significant coefficients was checked for adequacy by Fisher test. If the criterion was less critical for a given risk in view of the obtained degrees of freedom, i.e.  $F_a < F_{kr}(\alpha, f_{na}, f_e)$ , it was adequate.

**Table 1** Plan of numerical experiment in coded variables

#	Normalized factor values				#	Normalized factor values			
	$X_1$	$X_2$	$X_3$	$X_4$		$X_1$	$X_2$	$X_3$	$X_4$
1	2	3	4	5	1	2	3	4	5
1	1	1	1	1	13	-1	-1	1	1
2	1	1	1	-1	14	-1	-1	1	-1
3	1	1	-1	1	15	-1	-1	-1	1
4	1	1	-1	-1	16	-1	-1	-1	-1
5	1	-1	1	1	17	1	0	0	0
6	1	-1	1	-1	18	-1	0	0	0
7	1	-1	-1	1	19	0	1	0	0
8	1	-1	-1	-1	20	0	-1	0	0
9	-1	1	1	1	21	0	0	1	0
10	-1	1	1	-1	22	0	0	0	1
11	-1	1	-1	1	23	0	0	-1	0
12	-1	1	-1	-1	24	0	0	0	-1
					25	0	0	0	0

The computer model of the operating activity of the enterprise was considered as the system under investigation. This model was variable under the action of studied factors according to the experimental design.

Fig. 2 presents the method of modeling the total production cost and the cost of construction products for grain storages construction and renovation. Fig. 3 shows the method of modeling the profitability of the enterprise in question in accordance with the recommendations of normative documents of Ukraine [28].

### 5 MODELING OF OPERATING ACTIVITY OF GRAIN STORAGES CONSTRUCTION AND RECONSTRUCTION ENTERPRISE

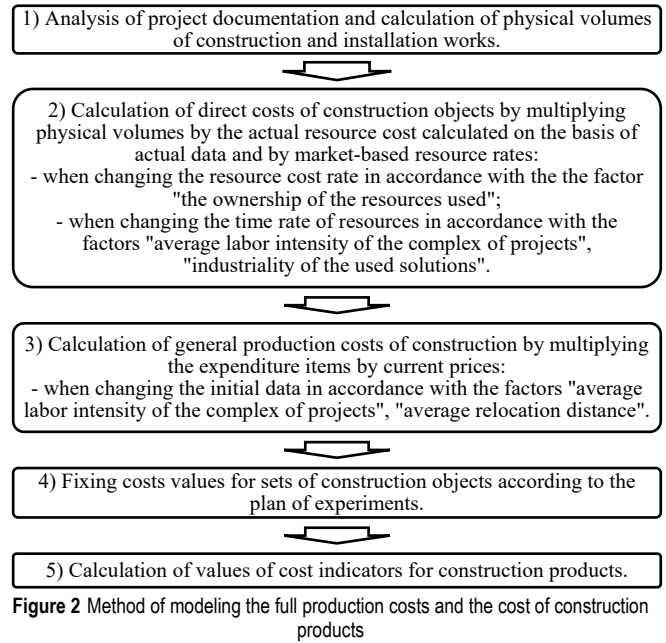
Tab. 2 presents description of the elements of the developed models.

Construction products can be described as a set of indicators, by which they are shown. It can be written that the construction products are characterized by the following performance indicators (Eq. (3)):

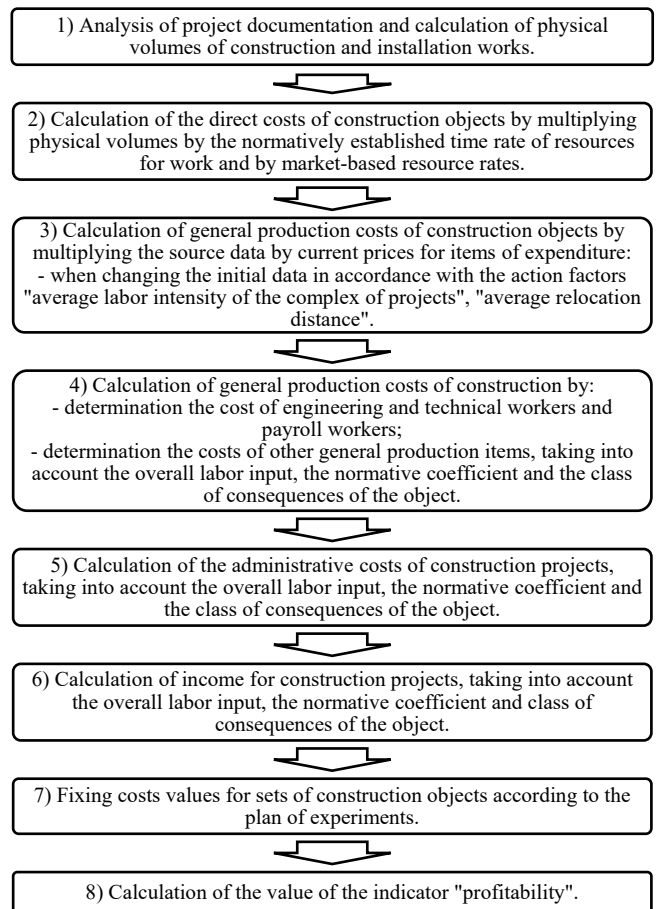
$$ICP \subseteq \{ \{Y_{tech.}\}, \{Y_{econ.}\}, \{Y_{env.}\}, \{Y_{soc.}\} \} \quad (3)$$

**Table 2** The determinants of the organizational structure of the enterprise business processes of the grain storages construction and renovation enterprise

Designation	Full title
ICP	– indicators of construction products
DCC	– departments of construction company
R	– resources for the building production
MCE	– management of construction enterprise
MCP	– management of construction project
S	– suppliers
WBS	– work breakdown structure



**Figure 2** Method of modeling the full production costs and the cost of construction products



**Figure 3** Method of modeling profitability of the enterprise in accordance with the recommendations of normative documents

where:  $\{Y_{tech.}\}$  – indicators of technical efficiency;  $\{Y_{econ.}\}$  – indicators of economic efficiency;  $\{Y_{env.}\}$  – indicators of environmental efficiency;  $\{Y_{soc.}\}$  – indicators of social efficiency.

In this study, the following indicators were suggested:

- $Y_1$  – profitability – the percentage ratio between the value of the total production costs, calculated on the basis of actual operating data of the enterprise, and the value of income, calculated in accordance with the regulatory procedure. Such revenues include compensation for direct costs of general production, administrative costs and profit.
- $Y_{2-6}$  – Cost of construction products – direct costs of the construction products. The cost prices were calculated for the following main units: the concrete structures arrangement ( $Y_2 - 1 \text{ m}^3$ ), installation of bearing steel structures ( $Y_3 - 1 \text{ t.}$ ), silo ( $Y_4 - 1 \text{ m}^3$ ), the transport equipment installation (noria ( $Y_5$ ), conveyor ( $Y_6 - 1 \text{ m}$ ). Thus, the construction products (ICP indicators) included for the present study: (Eq. (4))

$$ICP \subseteq \{Y_1, Y_2, Y_3, Y_4, Y_5, Y_6\} \quad (4)$$

Tab. 3 shows the variation matrix of factors taken in this study as the input parameters of the system under study.

**Table 3** Matrix variation factors

Factor name	Factor levels		
	-1	0	+1
$X_1$ - average labor input of the projects totality	2.2 thousands hours	19.6 thousands hours	37 thousands hours
$X_2$ - average relocation distance	100 km	550 km	1000 km
$X_3$ - membership of resources used	0%	50%	100%
$X_4$ - industriality of applied solutions	0%	50%	100%

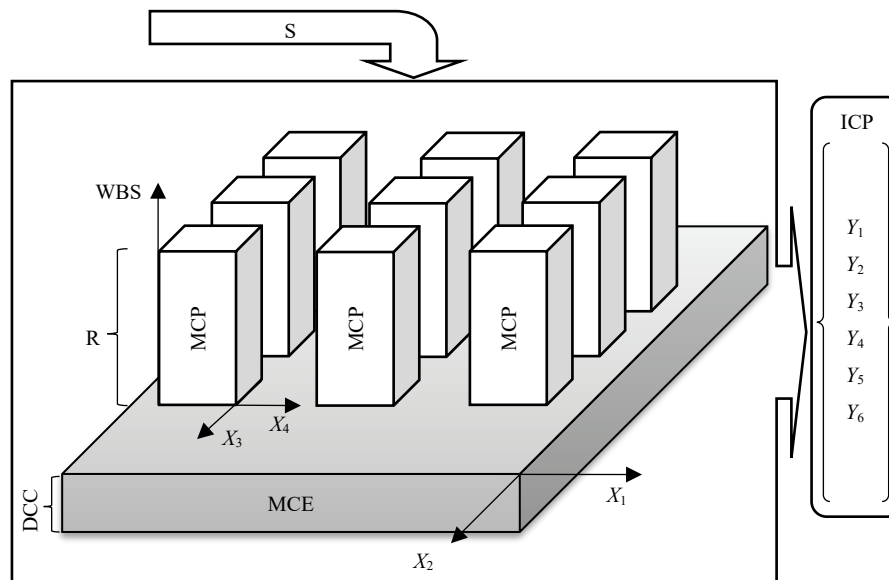
Considered indicators and factors, as well as internal determinants, can be presented as a multi-dimensional

organizational structure of the enterprise management for the grain storages construction and renovation (Fig. 4).

Multidimensional structure shown in Fig. 4 allows to group construction projects performed by the organization, depending on their scale ( $X_1$ ) and territorial dispersion ( $X_2$ ). This makes it possible to analyze the technological organizational relationship between such construction projects. Various organizational and technological solutions ( $X_3, X_4$ ) are possible while performing construction works on individual projects. The model shows that there is a relationship between the organizational structure (DCC) and its managerial methods (MCE), as well as between the structure (WBS) and control methods (MCP) of individual projects. It can be noted that the resources (R: labor, material, technical, intellectual, financial, and technology), used in the creation of construction products, can be put in order through the project work breakdown structure (WBS). As seen from the figure, the developed multidimensional managerial structure is a tool for transforming external resources provided by suppliers into construction products.

Developed multidimensional organizational structure (Fig. 4) allowed solving one of the problems of the rationalization of managerial, organizational and technological solutions of grain storages construction and reconstruction– improving organizational structures of considered enterprises. Namely, the rationalization was possible due to a new approach to:

- formalizing the management interactions between elements of the considered companies operating activity in vertical and horizontal directions;
- organization of operating activity of enterprises under consideration and construction projects logistics at various levels of variable factors.



**Figure 4** The multidimensional organizational structure of the grain storages construction and reconstruction enterprise

It is necessary for the success of the numerical experiment: to build a trustworthy computer model of the system under study; to choose the input and output

parameters – factors and indicators. Data of the construction projects was used to create a computer model of the optimization of the operating activity of the grain storages

construction and reconstruction enterprise. Its structure is presented in the graphical analytical form in Fig. 5.

The presented computer model (Fig. 5) was variable, as the levels of its input parameters (factors) vary in the numerical experiment. The variability of computer model was possible under the influence of each factor by:

- $X_1$  – the average labor input of the projects totality. The compliance of a considering set of projects with the desired value of the variation characteristic should be ensured – the arithmetic mean of labor input of construction and installation works on the projects of this totality.
- $X_2$  – the average relocation distance. The necessary value of the variation characteristic (the arithmetic mean of distances relocation of resources between any two objects of the chosen totality) was taken as an input when calculating the cost of relocation of industrial and household premises, vehicles, machinery and construction equipment as a part of general production costs.
- $X_3$  – membership of resources used. The difference of using the subcontract resources in comparison with the

own resources was characterized as follows: unit prices for the resource (labor, machinery or equipment) are higher by 18%, which is justified by the market situation in Ukraine. However, the cost of relocation of industrial and household premises, vehicles, machinery and construction equipment will be lower, since the involvement of subcontractors is desirable when their material and technical supply base is closer to the construction site. In this study, it is accepted that the use of subcontractor resources relocation costs is reduced by 2 times. This change is introduced together with the varying of the  $X_2$  factor.

- $X_4$  – industriality of applied solutions. This factor had a complex effect on the methods of work production of the grain storages construction and renovation. The use of industrial methods allowed achieving this: pre-prepared construction equipment, materials, products and structures; the streamflow organization of production operations; the mechanization rate of work. Simulation of this factor is done by resource assignments adjustment of corresponding works.

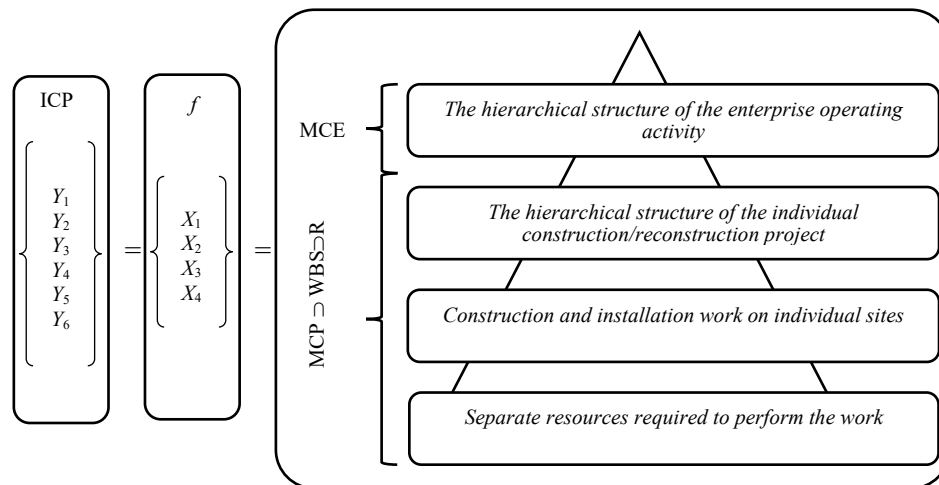


Figure 5 Graphical analytical form of a computer model of the operating activity of the grain storages construction and renovation enterprise

## 6 OPTIMIZATION OF ORGANIZATIONAL AND TECHNOLOGICAL SOLUTIONS OF GRAIN STORAGES CONSTRUCTION AND RECONSTRUCTION

Tab. 4 presents the results of the experimental statistical modeling.

The indicator changes of profitability are presented in Eq. (5). Factors, recognized by Student's test as indistinguishable from zero, are not shown here or below.

$$Y_1 = 11.5549 - 0.2591X_1 - 0.0178X_2 - 0.0761X_3 - 0.0467X_4 + 0.0024X_1X_2 + 0.0004(X_1X_2 + X_1X_4) \quad (5)$$

Analysis of addendum characters of the Eq. (5) showed that the influence of the factor  $X_1$  ("average labor input of projects totality") increments the profitability ( $Y_1$ ) both in its individual influence and when combined with other

influencing factors. However, the individual influence of factors  $X_2$  ("average relocation distance") and  $X_3$  ("membership of resources used") reduces the indicator value.

The most convenient graphical representation of the analytical dependence of the four factors is the chart "squares on the square". It reflects the change of the indicator from two factors within nine "small" squares, which are located on the "big" square, showing nine combinations of the values of the other two factors.

Fig. 6 shows the regularity of profitability change ( $Y_1$ ) from the membership of resources used ( $X_3$ ) and the industriality of applied solutions ( $X_4$ ) for nine combinations of values of the average labor input of the projects totality ( $X_1$ ) and the average relocation distance ( $X_2$ ).

Hereafter, the indicator extrema within two-factor diagrams are marked by bold; the extrema within the entire diagrams – underlined; factor levels values – italics.



The analysis of Fig. 6 allowed noting the following. The character of factor influence "industriality of applied solutions" ( $X_4$ ) does not change depending on the level of factor "average relocation distance" ( $X_2$ ), but is different at different levels of the factor "average labor input of the projects totality" ( $X_1$ ).

Magnification of factor  $X_4$  reduces the value of the indicator when  $X_1 = 2.2$  thous. hours; factor  $X_4$  does not affect indicator when  $X_1 = 19.6$  thous. hours; factor  $X_4$  increases the value of the indicator when  $X_1 = 37$  thous. hours. Character of influence of factor "membership of resources" ( $X_3$ )

changes depending on the area of factors' space: the parameter decreases with increasing of levels of this factor.

Thus, it was concluded that the application of subcontracting forces on the grain storages construction and reconstruction facilities reduces the profitability of 5-7% at all levels of strategic factors of organizational technological nature. Application of industrial construction methods can only be justified on large ( $X_1 = 37$  thous. hours) grain storages construction and reconstruction facilities, increasing the profitability from 3.24 to 5.1%. Such methods reduce profitability of 2.31-4.4% on small objects ( $X_1 = 2.2$  thous. hours).

Table 4 Results of the experimental statistical modeling

#	Indicators					
	Profitability, $Y_1$	Cost of reinforced concrete structures unit, $Y_2$ (thous. UAN/m <sup>3</sup> )	Cost of load-bearing metal structures unit, $Y_3$ (thous. UAN/ton)	Cost of grain silo storage installation, $Y_4$ , (UAN/m <sup>3</sup> storage)	Cost of noria section installation, $Y_5$ (thous. UAN/m)	Cost of conveyor section installation, $Y_6$ (UAN/m)
1	-2.24%	3,276.17	4,653.77	41.50	1,196.46	794.88
2	-7.69%	3,766.31	5,170.86	49.66	1,329.40	883.20
3	2.92%	3,162.74	4,046.76	36.13	1,040.40	709.00
4	-1.20%	3,627.29	4,496.40	43.24	1,156.00	787.77
5	0.11%	3,276.17	4,653.77	41.50	1,196.46	794.88
6	-4.41%	3,766.31	5,170.86	49.66	1,329.40	883.20
7	6.23%	3,162.74	4,046.76	36.13	1,040.40	709.00
8	2.08%	3,627.29	4,496.40	43.24	1,156.00	787.77
9	-17.65%	3,888.06	4,653.77	72.88	1,218.85	843.68
10	-13.65%	3,722.22	5,170.86	87.43	1,314.07	937.42
11	-9.83%	3,736.82	4,046.76	63.49	1,059.87	752.42
12	-6.32%	3,586.13	4,496.40	76.16	1,142.67	836.02
13	-1.81%	3,888.06	4,653.77	72.88	1,218.85	843.68
14	2.12%	3,722.22	5,170.86	87.43	1,314.07	937.42
15	6.00%	3,736.82	4,046.76	63.49	1,059.87	752.42
16	9.46%	3,586.13	4,496.40	76.16	1,142.67	836.02
17	-0.62%	3,452.90	4,591.95	42.55	1,180.56	793.71
18	-6.18%	3,733.31	4,591.95	74.84	1,183.86	842.39
19	-3.74%	3,448.75	4,591.95	43.04	1,188.16	818.38
20	0.36%	3,448.75	4,591.95	43.04	1,188.16	818.38
21	-4.87%	3,511.51	4,912.32	46.01	1,271.05	865.33
22	-2.82%	3,286.01	4,653.77	41.97	1,205.04	819.87
23	1.49%	3,385.98	4,271.58	40.06	1,105.26	771.43
24	-3.61%	3,678.66	4,833.63	46.98	1,249.87	861.37
25	-1.69%	3,448.75	4,591.95	43.04	1,188.16	818.38

In general, there was negative profitability in many areas of the investigated factor space when considering the income, calculated in accordance with the recommendations of existing regulations and the expenses calculated according to the analysis of the actual costs of the grain storages construction and reconstruction enterprise. This proved that the regulatory methods for calculating construction companies' income are imperfect.

Considered data showed that the method of calculating the general production and administrative costs, which is recommended in current regulations, is not effective enough to calculate the construction companies who build on sites with a small distance relocation (profitability is  $Y_1 = 1.78 \div 9.3\%$ ). In addition, it is ineffective for enterprises which build the objects with an average relocation distance more than  $X_2 = 625$  km (profitability decreases to  $Y_1 = -17.58\%$ ). Also, the operating activity of companies specializing in the construction on small-scale sites ( $X_1 = 2.2$  thous. hours)

becomes unprofitable at average relocation distance equal  $X_2 = 495$  km.

All of the above proves that the most effective approach is to use project-based methods to justify the income value, especially for the general production costs, administrative costs. Namely, to conduct detailed calculation of all items of expenditure according to § 4.3.8, 5.3.6 of the [9]. There cannot be is invited to apply the additional calculation of general production, administrative costs to the calculation of direct costs. 0.6-4.5% of profitability can be reached by taking into account the additional calculation of general production, administrative costs for enterprises operating activity. Such low profitability values require the use of a project approach to the justification of the estimated profit (§ 6.1.2 instructions [9]).

The profit value can be justified in the construction contract based on simulation and considering:

- the degree of uniqueness of erected structure;

- the need to form a temporary project management team for work in special conditions;
- one-night performance of the construction project, respectively, the unique nature of the distribution of profit over time.

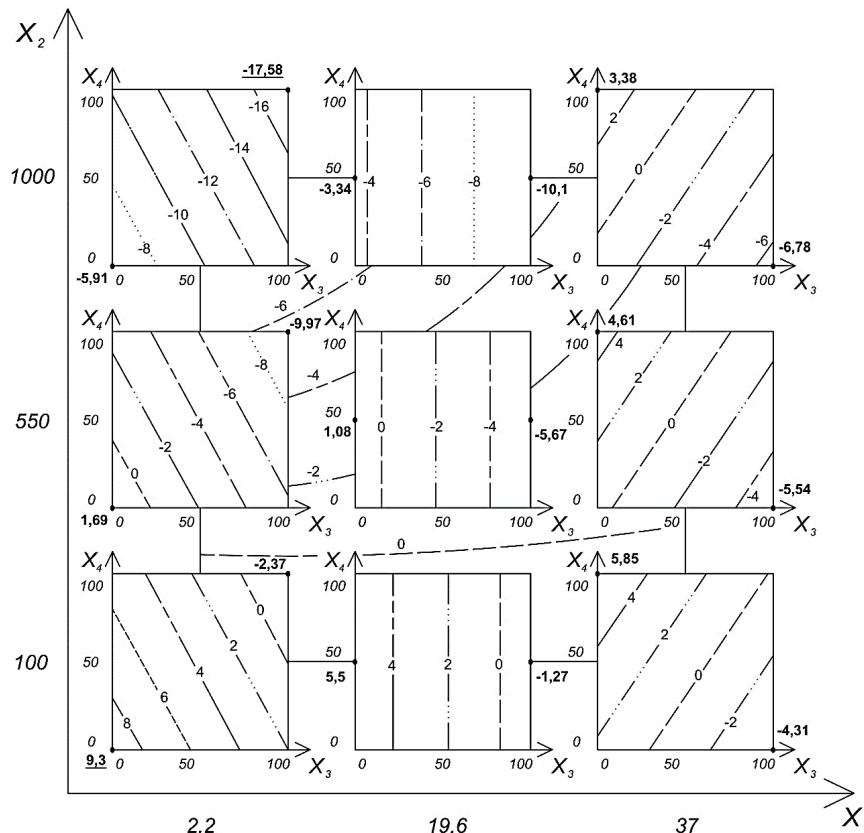


Figure 6 Change of profitability ( $Y_1$ , %) depending on membership of resources used ( $X_3$ , %) and industriality of applied solutions ( $X_4$ , %) at various strategic solutions of the enterprise management

The indicator changes of cost of reinforced concrete structures unit ( $Y_2$ ) are represented in analytical form in Eq. (6):

$$Y_2 = 3634.4 - 16.475X_1 + 0.453X_1^2 - 0.183X_1X_4 + 1.339X_3 - 1.801X_4 \quad (6)$$

The analysis of Eq. (6) showed that increasing of factors "average labor input of the projects totality" ( $X_1$ ) and "industriality of applied solutions" ( $X_4$ ) reduces the value of indicator  $Y_2$ , while the factor "membership of resources used" ( $X_3$ ) increases. This is indicated by addendum characters of the first degree corresponding variables. Large scale construction sites allow to use industrial methods of work, as well as to increase productivity through the use of in-line production of work. The savings due to the involvement of closely spaced resources without the need to spend money to reline are not taken into account, since the cost of construction products includes only the direct costs.

The optimization of cost of construction products was carried out according to the results of constructing regularities of these parameters change. The first step of optimization was to identify the areas of financially effective organizational and technological solutions for the enterprise

as a whole. The indicator "profitability" ( $Y_1$ ) was chosen as the first stage optimization criterion. Those areas were chosen as the effective in which profitability is equal to or more than zero. The second stage of the optimization was to determine the minimum values of the cost of construction products. The search was conducted only in the areas chosen by the first stage of optimization. Namely, in the areas of finance effective organizational and technological solutions.

Fig. 7 contains the results of optimization of the cost of reinforced concrete structures unit ( $Y_2$ ) influenced by membership of resources used ( $X_3$ ) and the degree of industriality of applied solutions ( $X_4$ ) at various values of strategic solutions factors in the management of construction organizations. The analysis of Fig. 7 shows that character of factor  $X_4$  influence differs depending on the level of factor  $X_1$ . The use of industrial organization and technological solutions on small sites is impractical, since it increases the cost of reinforced concrete structures arrangement. The minimum value of  $Y_2$  indicator is 3.6 thous. UAN/m<sup>3</sup> when  $X_1 = 2.2$  thous. hours; 3.29 thous. UAN/m<sup>3</sup> – when  $X_1 = 19.6$  thous. hours; 3.14 thous. UAN/m<sup>3</sup> – when  $X_1 = 37$  thous. hours.

The decrease in the optimized indicator is correlated with an increase of "profitability" ( $Y_1$ ) in all areas of the factor space. The closely placed sites show the highest efficiency of

cost of reinforced concrete structures unit in all operating activity of the considered enterprise. The minimum value of cost of reinforced concrete structures unit ( $Y_2$ ) is equal to:

$$Y_{2 \min} = 3.14 \text{ thous. UAN/m}^3 \text{ (} X_1 = 37 \text{ thous. hours; } X_3 = 0\%; X_4 = 0\%).$$

Eq. (7) represents the dependence of cost of load-bearing metal structures unit ( $Y_3$ ) from the studied organizational and technological factors:

$$Y_3 = 4576.419 + 8.664X_3 - 0.019X_3^2 - 0.007X_3X_4 - 8.308X_4 + 0.041X_4^2 \quad (7)$$

Let us consider Fig. 8. It graphically shows the optimization of the cost of load-bearing metal structures unit ( $Y_3$ ) influenced by membership of resources used ( $X_3$ ) and the industriality of applied solutions ( $X_4$ ). Analysis of Fig. 8 showed that increasing the level of factor  $X_3$  ("membership of resources used") enhances the average value of indicator  $Y_3$  by 1.14 times; increasing the level of factor  $X_4$  ("industriality of applied solutions") reduces it by 1.1 times. The action of factors meets their organizational and

technological sense: attraction of expensive resources increases the cost of installation of metal structures, the use of industrial methods of work reduces the cost of the production process.

The minimum indicator  $Y_5$  value is equal to the following under any strategic decisions of management of the grain storages construction and reconstruction enterprises except the ( $X_1 = 2.2$  thous. hours;  $X_2 = 550$  km):

$$Y_{3 \min} = 4.16 \text{ thous. UAN/ton (} X_3 = 0\%; X_4 = 100\%).$$

Eq. (8) represents the regularity of change of cost of grain silo storage installation ( $Y_4$ ) is in analytical form:

$$Y_4 = 82.312 - 2.932X_1 + 0.051X_1^2 - 0.001X_1X_3 + 0.002X_1X_4 + 0.112X_3 - 1.5 \times 10^{-4} X_3X_4 - 0.126X_4 \quad (8)$$

Eq. (8) showed that enhancing levels of factors  $X_1$  ("average labor input of the projects totality") and  $X_4$  ("industriality of applied solutions") reduces the value of the indicator  $Y_4$ ; increasing level of factor  $X_3$  ("membership of resources used") increases. Signs of the corresponding coefficients of the formula indicate this.

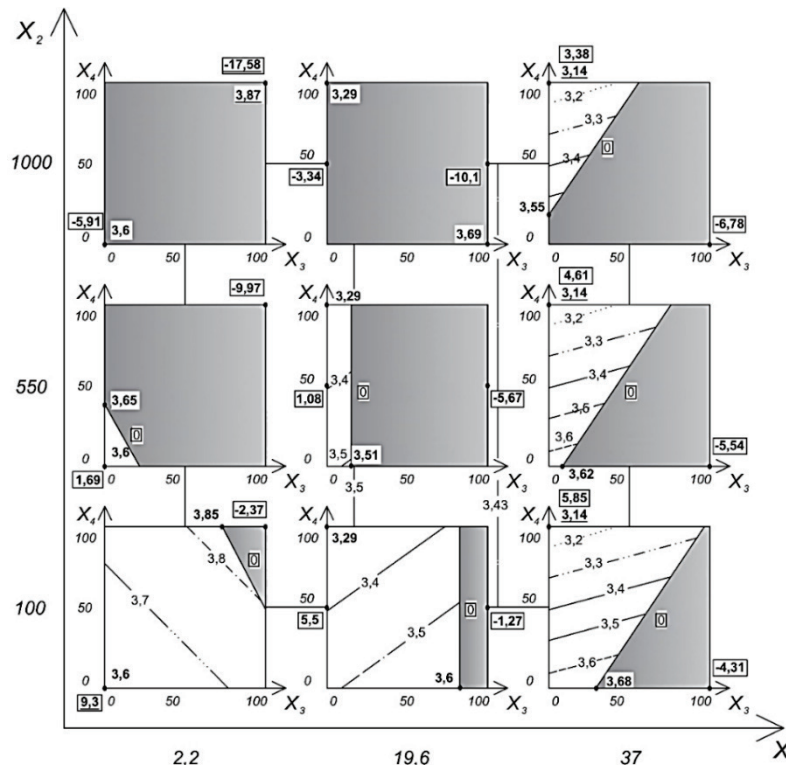


Figure 7 Optimization of cost of reinforced concrete structures unit ( $Y_2$ , thous. UAN/m<sup>3</sup>) influenced by membership of resources used ( $X_3$ , %) and industriality of applied solutions ( $X_4$ , %) at various strategic solutions of the enterprise management and under limitation of  $Y_1 \geq 0\%$

Fig. 9 contains the results of the optimization of cost of grain silo storage installation ( $Y_4$ ) under the influence of membership of resources used ( $X_3$ ) and the industriality of applied solutions ( $X_4$ ) at different levels of the strategic organizational and technological factors ( $X_1$  and  $X_2$ ).

The nature of the influence of factors  $X_3$  and  $X_4$  does not change at the different levels of the factor  $X_1$ , as Fig. 9 presents. In case of small amounts of work

( $X_1 = 2.2$  thous. hours) membership of resources used ( $X_3$ ) and industriality of applied solutions ( $X_4$ ) change indicator  $Y_4$  in the range of 63.8 to 86.88 UAN/m<sup>3</sup> storage; in case of medium amounts ( $X_1 = 19.6$  thous. hours) – from 36.66 to 52.75 UAN/m<sup>3</sup> storage; in case of large amounts ( $X_1 = 37$  thous. hours) – from 34.88 to 43.13-48.02 UAN/m<sup>3</sup> storage (dependent on the level  $X_2$ ).

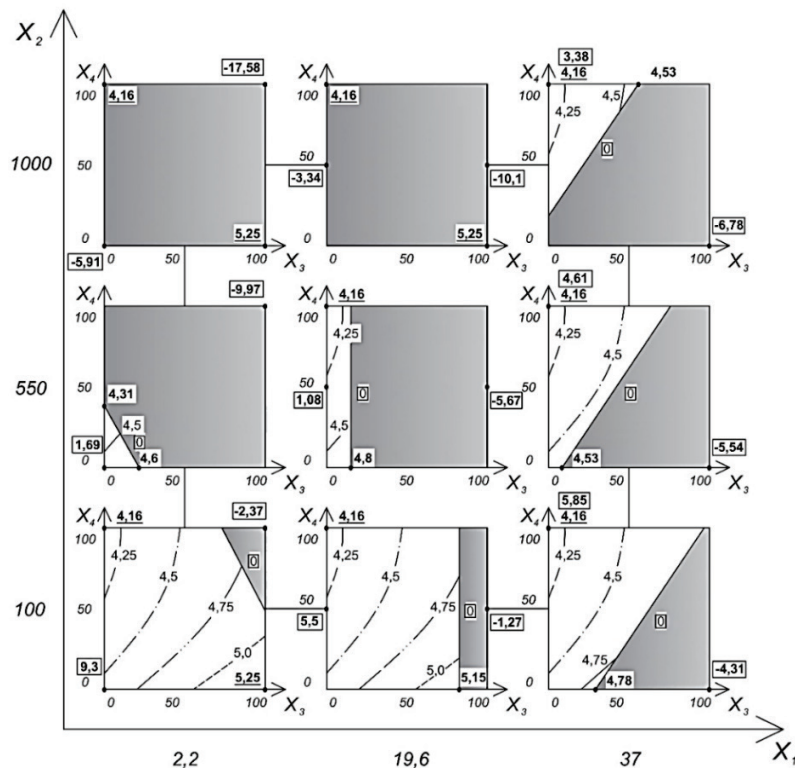


Figure 8 Optimization of cost of load-bearing metal structures unit,  $Y_3$  (thous. UAN/ton) influenced by membership of resources used ( $X_3$ , %) and industriality of applied solutions ( $X_4$ , %) at various strategic solutions of the enterprise management and under limitation of  $Y_1 \geq 0\%$

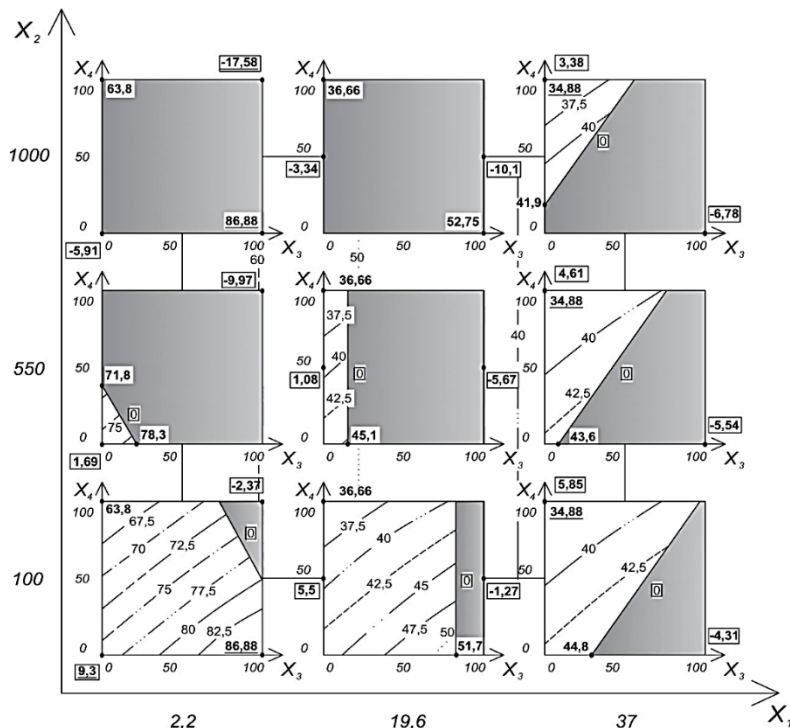


Figure 9 Optimization of cost of grain silo storage installation,  $Y_4$ , (UAN/m<sup>3</sup> storage) influenced by membership of resources used ( $X_3$ , %) and industriality of applied solutions ( $X_4$ , %) at various strategic solutions of the enterprise management and under limitation of  $Y_1 \geq 0\%$

Thus, the minimum value of the indicator was achieved at all levels of strategic organizational and technological solutions, except for ( $X_1 = 2.2$  thous. hours;  $X_2 = 550$  km), with the values of two other factors ( $X_3 = 0\%$ ;  $X_4 = 100\%$ ).

A large change of the indicator was observed for the following reasons:

- A significant share of the cost structure for silo storages assembling is occupied by manpower, machines and

mechanisms (in the considered model of the enterprise operating activity – 87%). Subcontractors’ resources significantly increase the cost of production of such works.

- Proposed industrial solution (usage of hydraulic jacks for wall mounting) greatly optimizes silo installation process by increasing the intensity and the degree of safety of works.

Cost of grain silo storage installation ( $Y_4$ ) has the minimum value at ( $X_1 = 0\%$ ;  $X_2 = 100\%$ ) in all areas of the space factor, where this restriction does not preclude  $Y_1 \geq 0\%$ . In this case, the minimum point is still close to these levels of factors.

Eq. (9) presents the change of cost of noria section installation ( $Y_5$ ) from the organizational and technological factors:

$$Y_5 = 1180.606 + 2.221X_3 - 0.005X_3^2 - 0.002X_3X_4 - 1.461X_4 + 0.011X_4^2 \quad (9)$$

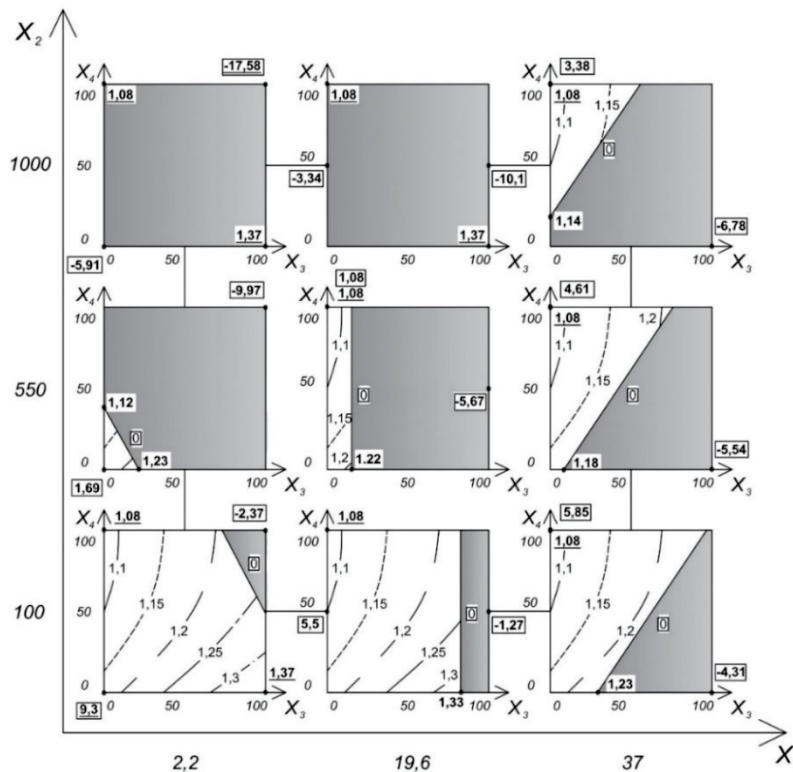
Let us consider Fig. 10. The results of cost optimizing of noria section installation ( $Y_5$ ) are shown in it graphically.

Analysis of Fig. 10 showed that enhancing the value of factor  $X_3$  increases the average value of indicator  $Y_5$  by 0.17 thous. UAN; increasing the value of factor  $X_4$  – decreases by 0.1 thous. UAN.

The minimum values of indicator levels for all combinations of factors  $X_1$  ("average labor input of the projects totality") and  $X_2$  ("average relocation distance") were observed at the point ( $X_3 = 0\%$ ;  $X_4 = 100\%$ ) and are equal to  $Y_{5 \min} = 1.08$  thous. UAN/m. Exception is the area at ( $X_1 = 2.2$  thous. hours;  $X_2 = 550$  km). It’s minimum value of indicator "cost of noria section installation" ( $Y_5$ ) is located at a point ( $X_3 = 0\%$ ;  $X_4 = 40\%$ ) and is equal to  $Y_{5 \min} = 1.12$  thous. UAN/m.

The regularity of cost changes of conveyor section installation ( $Y_6$ ) by factors studied is represented in Eq. (10):

$$Y_6 = 844.439 - 0.449X_1 - 0.024X_1^2 + 1.216X_3 - 2.8 \times 10^{-3}X_3^2 - 1.42X_4 + 6.08 \times 10^{-3}X_4^2 \quad (10)$$





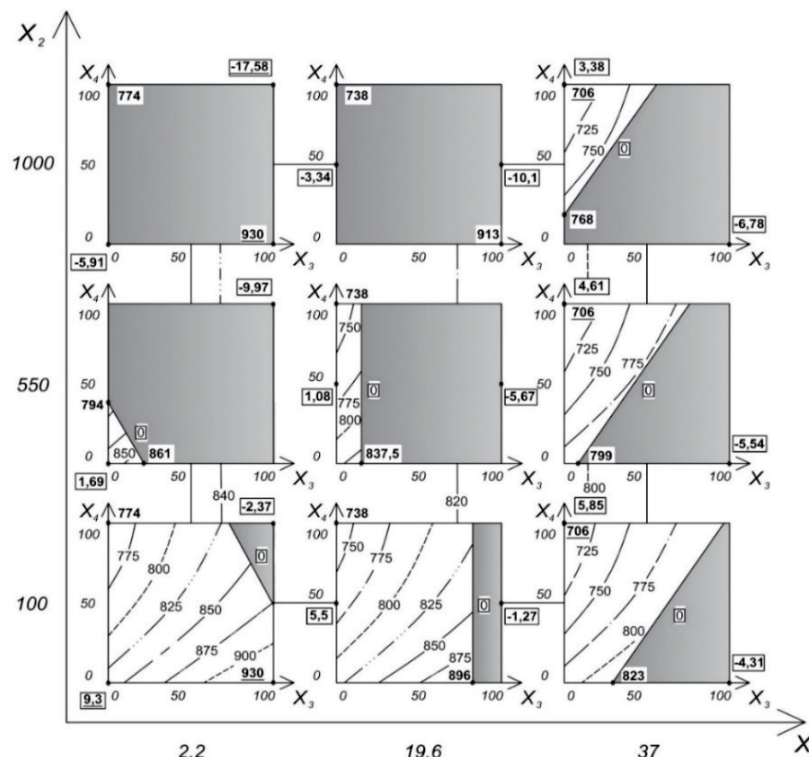


Figure 11 Optimization of cost of conveyor section installation,  $Y_6$  (UAN/m) influenced by membership of resources used ( $X_3$ , %) and industriality of applied solutions ( $X_4$ , %) at various strategic solutions of the enterprise management and under limitation of  $Y_1 \geq 0\%$

## 7 RATIONALIZATION OF MANAGERIAL DECISIONS OF GRAIN STORAGES CONSTRUCTION AND RECONSTRUCTION

Multidimensional structure, presented in Fig. 4, allows to group projects executed by the organization, depending on their scale ( $X_1$ ) and territorial diversity ( $X_2$ ). This makes it possible to analyze organizational and technological interrelationships between similar projects. In the framework of individual projects, different organizational and technological solutions are possible ( $X_3$ ,  $X_4$ ). The model shows that there is a connection between the structure of the construction enterprise (DCC) and the management of the construction enterprise (MCE), as well as between the structure (WBS) and the management methods (MCP) of individual projects.

Let us consider examples of companies that have chosen as a development four combinations of strategic organizational and technological decisions:

1. Focusing on objects of a large scale and labor intension, which are located at a considerable distance from each other: MCE  $\supset \{X_1 \rightarrow 37$  thousand hours;  $X_2 \rightarrow 1000$  km}.
2. Focusing on small objects located within a limited area: MCE  $\supset \{X_1 \rightarrow 2.2$  thousand hours;  $X_2 \rightarrow 100$  km}.
3. Focusing on large and small objects in the ratio of direct costs 75% to 25%: MCE  $\supset 0,75 \{X_1 \rightarrow 37$  thousand hours;  $X_2 \rightarrow 1000$  km}  $\cup 0,25 \{X_1 \rightarrow 2.2$  thousand hours;  $X_2 \rightarrow 1000$  km}.

4. Focusing on large and small objects in the ratio of direct costs 25% to 75%: MCE  $\supset 0,75 \{X_1 \rightarrow 2.2$  thousand hours;  $X_2 \rightarrow 1000$  km}  $\cup 0,25 \{X_1 \rightarrow 37$  thousand hours;  $X_2 \rightarrow 1000$  km}.

In the case of intermediate combinations, the proposed solutions require appropriate adaptation.

For combinations 1, 3, 4, there was selected the biggest value of the factor "average relocation distance" ( $X_2$ ) as it is the most likely to perform work on various distance in case of an objects totality.

Character of the interactions for each of the strategic combination of organizational and technological solutions contains in Tab. 5. Tab. 6 describes features of the management of enterprises, which construct dispersed different scale buildings, depending on their orientation on own ( $X_3 \rightarrow 0\%$ ) or contracted ( $X_3 \rightarrow 100\%$ ) resources, high ( $X_4 \rightarrow 100\%$ ) or low ( $X_4 \rightarrow 0\%$ ) degree of industrialization of used technological solutions.

The enterprise prepares so that project managers can be recruited from among the existing managers (heads of departments and heads of construction sites) in case of change the organizational and technological conditions, bring them in from outside as needed. In case of unfavorable changes in the organizational and technical conditions, project managers are transferred to the post of heads of departments or construction sites, or their number is reduced.

Analysis of Tab. 5 showed that the main priority for the optimization of the grain storages construction enterprise are: organization of the relevant management system, in-line long-term work performance and optimal scheme of supply.

**Table 5** Management interactions between the elements of the enterprise operating activity, which construct grain storages

Connections type	Structure level of the enterprise	Combinations of strategic organizational and technological solutions			
		1	2	3	4
Vertical	All levels	Senior management has control of project managers and makes strategic decisions. The main center of org. tech. solutions – project management office.	Senior management is involved in the management of all projects and executes them according to the department division of responsibilities.	Senior management has control of project managers and makes strategic decisions. One or more of project managers and their teams manage a portfolio of small projects.	Senior management is involved in the management of all projects and executes them according to the department division of responsibilities. Heads of departments are appointed responsible for major projects.
Horizontal	Group of projects / operating activity as a whole	The management team is formed for each project. The team performs all the functions of engineering, economic and material supplies for the project.	Management of all projects is carried out by departments that perform each of its production function.	Management of portfolio of small projects (multi-project) is assigned to the separate team. Management of large projects is performed according to combination 1.	The workers within the functional departments of the organization are assigned for a large project. The rest of the staff is involved in the projects' management according to combination 2.
	Projects	Participation / non-participation in the project and its linkage with other projects of the organization is measured by the presence of a sufficient number of project management personnel. With a lack of resources, they are involved from outside.	Participation / non-participation in the project and its linkage with other projects of the organization is measured by the presence of labor and / or equipment. Management personnel can be engaged from outside.	The decision on participation / non-participation in the project is carried out according to combination 1. Multi-project in this case is treated as a separate project.	The decision on participation / non-participation in the project is carried out according to combination 2.
	Construction and installation work	It is vital to organize rationally planned engineering workflows within individual projects with their subsequent linkage between projects.	Work is intensified, and slowed down according to the workspace at other sites, in order to develop the company overall continuity of the process flow.	The portfolio of small projects considered as a multi-project with appropriate org. tech. linking work within it. Active flows link large projects and multi-project.	Repeats approach for combination 2. Major project receives priority in the overall enterprise for organizational and technological linking of works.
	Resources	Resources for projects are provided by the project management team. Sharing resources between projects impossible or severely restricted. Sharing human resources and technology available only at the end of their work on the technological flow.	Projects are centrally provided with resources by the department of logistics. Intensive sharing of resources between projects is encouraged. Necessary for specialized work human resources and equipment are transported.	Supply of resources is performed in two ways: individually for each major project and centrally for small projects portfolio. Approaches are combined according to combinations 1 and 2.	Supply of resources is centralized with the priority of major projects.

**Table 6** Peculiarities of operating businesses in grain storages construction in the orientation on the different ownership of resources used and industrialization of solutions used

		Attribution of resources ( $X_3$ )	
		( $X_3 \rightarrow 0\%$ )	( $X_3 \rightarrow 100\%$ )
Industrialization of applied solutions ( $X_4$ )	( $X_4 \rightarrow 0\%$ )	It is appropriate to be involved in small-scale projects, located a short distance from each other. It is required to set qualified contractors, workers and to establish effective systems of operational management. The optimization of logistics methods is critically important. Production functions are distributed between specialized enterprise departments. It is irrational to invest in high-performance engineering and construction machines, because it can be more profitable to draw them from outside.	It is appropriate to be involved in large and medium scale projects at different distances from each other. Management of the work and workers, as well as entire construction projects, should be organized on the principles of engineering. It is of critical importance to create the system of periodic accounting and control the construction works course. Logistical supply may be a duty of the enterprise or responsibility of involved organizations and structures. It is rational to invest in high technology and construction machines.
	( $X_4 \rightarrow 100\%$ )	It is appropriate to be involved in projects of large and medium scale, at different distances from each other. Qualification of technical staff in the use of effective organizational and technological solutions should be the best. Job function can be organized either by their distribution between the profile departments, and by forming project teams. Using high technology and construction machines requires the creation of depreciation funds.	It is appropriate to be involved in projects of large and medium scale at different distances from each other. Average production functions are efficiently implemented by forming project teams. It is advisable to impose logistical supply on subcontractors. Engineering and technical personnel involved from outside has to be certified in order to perform effective organizational and technological solutions. It may be rational to rent construction equipment and tooling by lease or short lease. It is critically important to create the office of accounting and control the course of construction works and the system of economic accounting and control of operating machinery and equipment. It is mandatory to create depreciation funds.

The algorithm for calculating the income of grain storages construction and reconstruction enterprises is shown in Fig. 12. According to this figure, the general production cost should be calculated in detail, since the cost of these items is different for each individual project. In addition, enterprises shall determine the amount of monthly administrative costs and desired profit level, based on the timing and composition of already implemented construction projects. As a general rule, the longer the lifetime of the project is and the smaller implemented projects are, the greater the level of administrative costs is put in bids on the project. The amount of profit is determined from the same parameters.

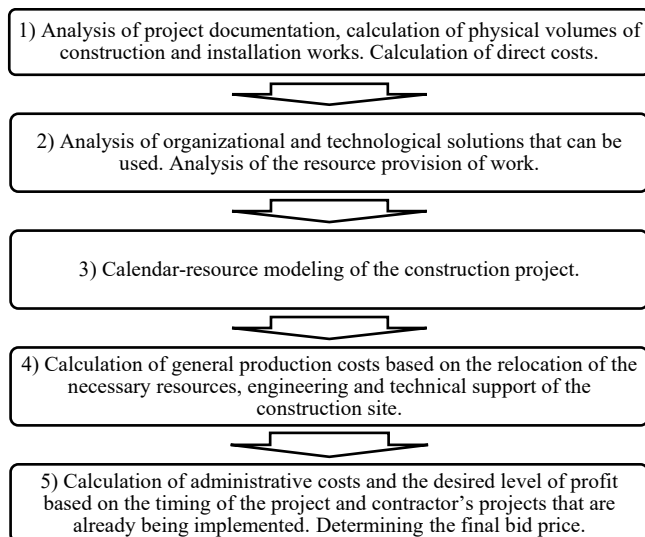


Figure 12 The algorithm for income calculating of grain storages construction and reconstruction enterprises

## 8 CONCLUSIONS

- Analysis of information sources on the study allowed confirming the high relevance of the present study and justifying the a priori positions.
- The developed method of experimental statistical simulation allowed numerical optimizing of the operating activity of grain storages construction and reconstruction enterprise.
- The proposed model of the operating activity of the grain storages construction and reconstruction enterprise made it possible to theoretically substantiate the link between organizational and technological decisions for the management of individual construction projects and operating activity of the enterprise as a whole.
- The minimum cost of construction products was observed at:  $X_1 = 37$  thous. hours ("average labor input of the projects totality");  $X_2 = 100$  km ("average relocation distance");  $X_3 = 0\%$  ("membership of resources used");  $X_4 = 100\%$  ("industriality of applied solutions"). It is as follows:
  - for reinforced concrete structures unit ( $Y_2$ ) – 3.14 thous. UAN/m<sup>3</sup>;

- for load-bearing metal structures unit ( $Y_3$ ) – 4.16 thous. UAN/ton;
- for grain silo storage installation ( $Y_4$ ) – 34.88 UAN/m<sup>3</sup> storage;
- for noria section installation ( $Y_5$ ) – 1.08 thous. UAN/m.;
- for conveyor section installation ( $Y_6$ ) – 706 UAN/m.
- Designed recommendations are ready for use in order to rationalize the management of companies under consideration.
- The developed method allowed justification of raising of the standard level of income of companies which construct grain storages. The estimated amount of income should be separately justified and fixed in the contract on the basis of the principles of the project management approach.

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