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RATIONAL ORGANIZATIONAL AND TECHNOLOGICAL DECISIONS ON THE GRAIN STORAGES CONSTRUCTION OR RENOVATION SITES

The article presents a method for choosing rational organizational and technological decisions at the grain storages construction or reconstruction sites using the results of the author's experimental and theoretical studies. It is given conditions analysis for the investigated enterprises operational activity. The obtained experimental statistical dependencies of the indicators change of such operational activity from the varied organizational and technological factors and the developed algorithms allow choosing rational organizational and technological decisions for the elevators construction and reconstruction based on the construction site conditions analysis and on the effective planning.

Keywords: *organizational and technological solutions, grain storages construction and renovation, experimental and statistical modeling, algorithm.*

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ВИБІР РАЦІОНАЛЬНИХ ОРГАНІЗАЦІЙНО-ТЕХНОЛОГІЧНИХ РІШЕНЬ НА ОБ'ЄКТАХ З БУДІВНИЦТВА АБО РЕКОНСТРУКЦІЇ ЕЛЕВАТОРІВ

У статті представлена методика вибору раціональних організаційно-технологічних рішень на об'єктах з будівництва або реконструкції елеваторів з використанням результатів експериментально-теоретичних досліджень автора. Наведено аналіз умов, в яких здійснюється операційна діяльність розглянутих підприємств. Отримані експериментально-статистичні залежності зміни показників такої операційної діяльності від організаційно-технологічних факторів і розроблені алгоритми дозволяють вибрати раціональні організаційно-технологічні рішення при будівництві та реконструкції елеваторів на підставі аналізу умов будівництва об'єкта і ефективного планування.

Ключові слова: організаційно-технологічні рішення, будівництво і реконструкція елеваторів, експериментально-статистичне моделювання, алгоритм.

Introduction. Experts estimate the volume of certified facilities for the grains and oilseeds storage in Ukraine at 31-33 mln. tons. Silo capacity deficit is about 15-20 mln. tons, considering the annual carryover grain stocks in Ukraine (about 10 mln. tons) and the expected crop volume at 40 mln. tons. Special conditions of grain storages construction and reconstruction projects realization require systematic studies on the optimization of organizational and technological enterprises solutions in focus. Such research will improve the organizational, technological and economic efficiency of the grain storages construction and renovation companies management.

Analysis of the latest sources of research and publications. Data on the segmentation of the grain storages construction market in the world [1, 2] 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 has rarely 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 [3]. 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 typical grain storages construction and renovation enterprise will have budget for about 25-30 million UAH and the total labor intensity of construction and installation works for about 40 thousand hours [3].

Statistical methods for solving optimization problems applying are widely used [9, 10]. Analysis of works, devoted to the optimization of organizational and technological solutions for construction and reconstruction [5, 6], allows to conclude 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 grain storages construction and renovation enterprises.

The application of experimental statistical modeling for the methods of optimization is discussed in [4, 7, 8]. It is advisable [5, 6] to use specialized programs for project management to create operating activity model of the construction organization.

Allocation of unresolved parts of the general problem. According to the results of the information sources analysis, it was established that a number of outstanding scientists were engaged in the development of methods for choice of rational organizational and technological decisions. Dikman L., Chernenko V., Kirnos V., Zalunin V., Dadiverina L., Ushackiy S., Berezyuk A. are among them. However, algorithmized solutions for solving this problem have not been developed when managing works on individual construction projects and the enterprise as a whole, which is done in special conditions of grain storages construction and renovation: territorial fragmentation of construction or reconstruction sites; differences in their scales; specificity of construction and installation works.

Formulation of the problem. The purpose of the article is to develop algorithms for choosing rational organizational and technological solutions at individual grain storages construction and renovation sites.

The essence of the method of choosing rational organizational and technological method solutions is the consistent decision of the following tasks:

– Identify the specificity of the conditions of grain storages construction and renovation.

– Construct experimental statistical dependencies of the studied indicators from the varying organizational and technological factors.

– Develop an algorithm for calendar and network planning of the grain storages construction and renovation, taking into account the analysis and improvement of organizational and technological solutions.

– Create an algorithm for choosing organizational and technological solutions at the grain storages construction or reconstruction sites.

Main part and results. To evaluate the efficiency and to select optimal organizational and technological solutions for the management of the grain storages construction and renovation enterprise, it is proposed to use the experimental statistical modeling theory. The essence of this theory is in observing the system by fixing the values of the outgoing parameters when specifying input parameters. The system under investigation in this study is presented in the form of a computer model of the company's operating activity. As the investigated indicators, the following factors were considered:

– Total production cost change (Y_1) – percentage of total production cost change, depending on the impact of organizational and technological factors. The cost change is zero in a basic model, which reflects the most typical operating activity conditions of the grain storages construction and renovation enterprise. In the present study, such model is observed at the middle levels of the considered factors. Total production costs are the sum of direct and general production costs.

– Ratio of direct and general production costs (Y_2) – the percentage of total production to the amount of direct costs for a totality of projects.

– Cost of construction product unit – direct costs, which are necessary for the production of a construction product unit of the enterprise: reinforced concrete structures (Y_3 – 1 m^3); load-bearing metal structures (Y_4 – 1 ton); cubic meter of grain silo storage (Y_5 – 1 m^3 of storage); section of transport equipment (noria (Y_6), conveyor (Y_7) – 1 m.).

Varying organizational and technological factors and their numerical characteristics are presented below:

– X_1 – average complexity of projects totality (average arithmetic complexity of construction and installation works of the projects under consideration, mln. UAH).

– X_2 – average relocation distance (average arithmetic distance of the relocation of resources between any two projects from the totality under consideration, km.).

– X_3 – ownership of the used resources (the percentage of own resources use to the total volume of used resources).

– X_4 – industrialization of applied solutions (percentage ratio of industrial methods use in the total amount of work).

The results of the numerical experiment are shown in the Table 1.

As a result of the experimental statistical modeling, change dependencies of studied parameters (1 – 7) from the variable factors were obtained.

The algorithm of calendar and network planning for the grain storages construction and renovation is shown below (Fig. 1), considering the analysis and improvement of organizational and technological solutions. It can be used for the implementation of grain storages construction and reconstruction projects of any scale or remoteness.

The general organization of technological flows during the grain storages construction and renovation is desirable to implement using the following principles:

– Planning of technological flows is rationally to implement with the help of project management software. The automation of planning is possible by the preparation of templates, containing a particular set of work, technological flow, the construction of typical objects.

Table 1 – Results of experimental statistical modeling

№	Actual values of the factors				Indicators						
	X_1, thousand hours.	X_2, km.	X_3, %	X_4, %	Total production cost change, Y_1, %	Ratio of direct and general production costs, Y_2, %	Cost of reinforced concrete structures unit, Y_3	Cost of load-bearing metal structures unit, Y_4	Cost of cubic meter of grain silo storage, Y_5	Cost of noria section, Y_6	Cost of conveyor section, Y_7
1	6	7	8	9	10	11	12	13	14	15	16
1	37	1000	100	100	-0,222	8,20	3 276,17	4 653,77	41,50	1 196,46	794,88
2	37	1000	100	0	5,223	7,75	3 766,31	5 170,86	49,66	1 329,40	883,20
3	37	1000	0	100	-4,647	10,68	3 162,74	4 046,76	36,13	1 040,40	709,00
4	37	1000	0	0	0,373	10,09	3 627,29	4 496,40	43,24	1 156,00	787,77
5	37	100	100	100	-1,691	6,61	3 276,17	4 653,77	41,50	1 196,46	794,88
6	37	100	100	0	3,753	6,24	3 766,31	5 170,86	49,66	1 329,40	883,20
7	37	100	0	100	-7,587	7,27	3 162,74	4 046,76	36,13	1 040,40	709,00
8	37	100	0	0	-2,566	7,27	3 627,29	4 496,40	43,24	1 156,00	787,77
9	2,2	1000	100	100	2,301	16,13	3 888,06	4 653,77	72,88	1 218,85	843,68
10	2,2	1000	100	0	-1,015	16,76	3 722,22	5 170,86	87,43	1 314,07	937,42
11	2,2	1000	0	100	3,225	27,84	3 736,82	4 046,76	63,49	1 059,87	752,42
12	2,2	1000	0	0	0,333	28,87	3 586,13	4 496,40	76,16	1 142,67	836,02
13	2,2	100	100	100	-5,141	7,69	3 888,06	4 653,77	72,88	1 218,85	843,68
14	2,2	100	100	0	-8,457	7,99	3 722,22	5 170,86	87,43	1 314,07	937,42
15	2,2	100	0	100	-11,658	9,41	3 736,82	4 046,76	63,49	1 059,87	752,42
16	2,2	100	0	0	-14,550	9,76	3 586,13	4 496,40	76,16	1 142,67	836,02
17	37	550	50	50	-0,967	7,93	3 452,90	4 591,95	42,55	1 180,56	793,71
18	2,2	550	50	50	-2,274	15,02	3 733,31	4 591,95	74,84	1 183,86	842,39
19	19,6	1000	50	50	0,895	10,98	3 448,75	4 591,95	43,04	1 188,16	818,38
20	19,6	100	50	50	-2,125	7,65	3 448,75	4 591,95	43,04	1 188,16	818,38
21	19,6	550	100	50	1,896	8,35	3 511,51	4 912,32	46,01	1 271,05	865,33
22	19,6	550	50	100	0,063	9,25	3 286,01	4 653,77	41,97	1 205,04	819,87
23	19,6	550	0	50	-3,127	10,35	3 385,98	4 271,58	40,06	1 105,26	771,43
24	19,6	550	50	0	1,742	9,08	3 678,66	4 833,63	46,98	1 249,87	861,37
25	19,6	550	50	50	-0,615	9,31	3 448,75	4 591,95	43,04	1 188,16	818,38

$$Y_1 = 0{,}557\,X_1 - 13{,}083 - 0{,}006\,X_1^2 - 2\times10^{-4}\,X_1X_2 + 8\times10^{-4}\,X_1X_3 - 0{,}002\,X_1X_4 + 0{,}018\,X_2 - 4\times10^{-6}\,X_2^2 - 5\times10^{-5}\,X_2X_3 + 0{,}06\,X_3 + 0{,}037\,X_4. \quad (1)$$

$$Y_2 = 9{,}281 - 3{,}746\,X_1 + 2{,}469\,X_{12} - 2{,}839\,X_1X_2 + 1{,}3\,X_1X_3 + 3{,}745\,X_2 - 1{,}466\,X_2X_3 - 1{,}99\,X_3. \quad (2)$$

$$Y_3 = 3634{,}4 - 16{,}475\,X_1 + 0{,}453\,X_1^2 - 0{,}183\,X_1X_4 + 1{,}339\,X_3 - 1{,}801\,X_4. \quad (3)$$

$$Y_4 = 4576{,}419 + 8{,}664\,X_3 - 0{,}019\,X_{32} - 0{,}007\,X_3X_4 - 8{,}308\,X_4 + 0{,}041\,X_{42}. \quad (4)$$

$$Y_5 = 82{,}312 - 2{,}932\,X_1 + 0{,}051\,X_{12} - 0{,}001\,X_1X_3 + 0{,}002\,X_1X_4 + 0{,}112\,X_3 - 1{,}5\times10^{-4}\,X_3X_4 - 0{,}126\,X_4. \quad (5)$$

$$Y_6 = 1180{,}606 + 2{,}221\,X_3 - 0{,}005\,X_{32} - 0{,}002\,X_3X_4 - 1{,}461\,X_4 + 0{,}011\,X_{42}. \quad (6)$$

$$Y_7 = 844{,}439 - 0{,}449\,X_1 - 0{,}024\,X_{12} + 1{,}216\,X_3 - 2{,}8\times10^{-3}\,X_{32} - 1{,}42\,X_4 + 6{,}08\times10^{-3}\,X_{42}. \quad (7)$$

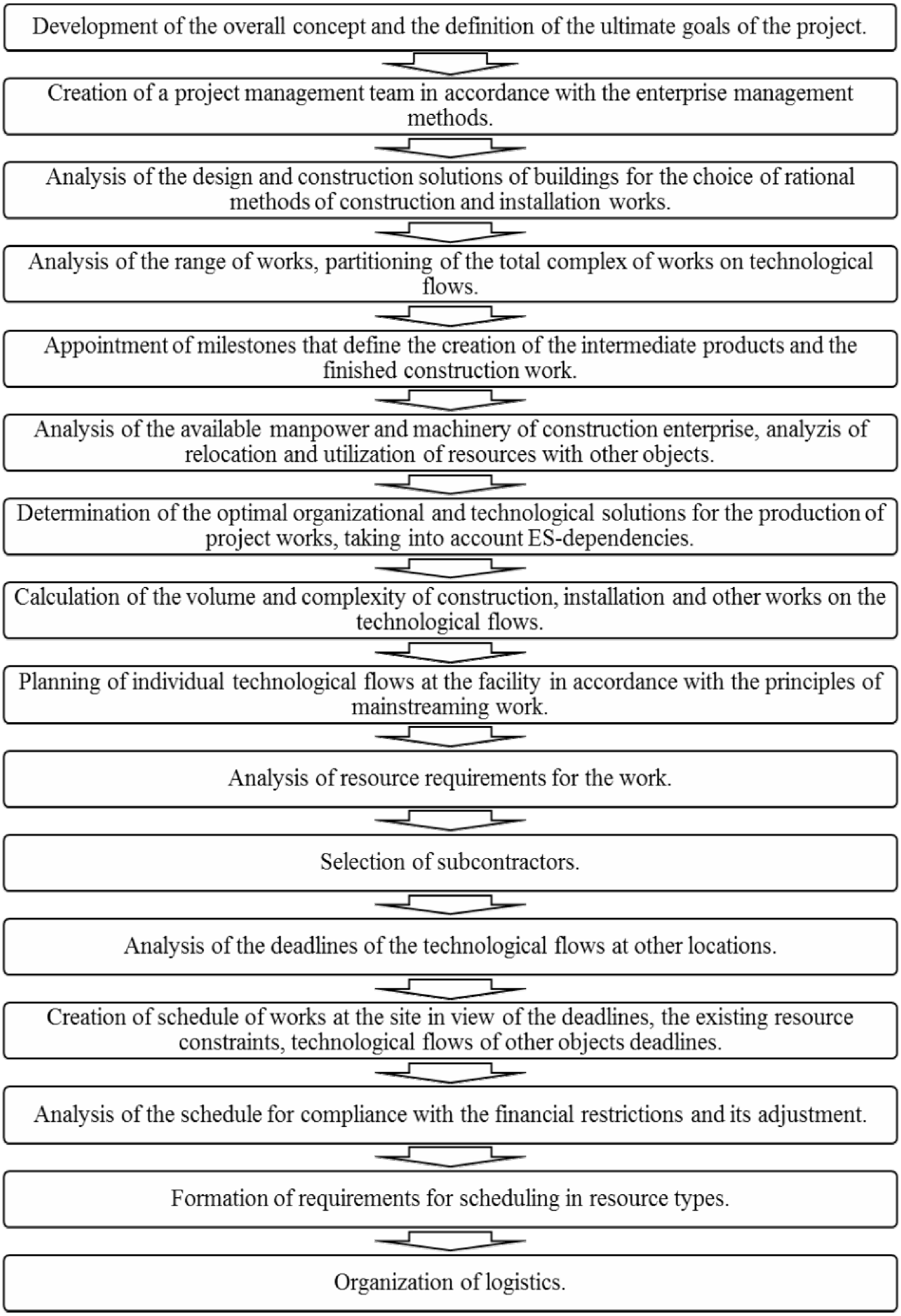

Figure 1 – Algorithm of calendar and network planning of grain storages construction and renovation sites

– The linking of technological flows to each other can be carried out sequentially, in parallel, in combination. Linkage is regulated by technological and organizational links. Technological links ensure compliance with the technology of works production. Organizational links regulate the supply of labor resources and equipment and can be placed either between the flows of one project, or between different projects.
– The the assessing criterion of the correctness of the calendar plan development is a schedule of labor resources consumption of each qualification and in general. Correctly designed plan will ensure smooth increase and decrease in the consumption of labor resources in time.
– The division of the site is different for small and large projects. The work is often done at one or two places of the grain storage plan in case of small construction or renovation projects. In such a case, it is advisable to divide the site according to the technological nodes of the grain storage, to the individual places of construction work production. For large projects, it is rational to tie more closely to the places of the grain storage plan or to combine several small places into one capture. Such capture will correspond from the work complexity viewpoint to one large place of the grain storage plan.

The experimental statistical dependencies can be used for the adoption of optimal organizational and technological solutions at the grain storages construction and renovation sites. The algorithm for making such decisions is shown in Fig. 2.

The algorithm, shown in Fig. 2, assumes acceptance of the compromise administrative decision for each kind of the construction or installation works executed on object. It is necessary to choose the optimal organizational and technological decisions for performing a particular type of work, considering the rational level of reduction of total production costs (Y_1) by solving a system of inequalities (8):

$$\begin{cases} Y_1 \geq f(X_3; X_4) \\ Y_n = f(X_3; X_4), n \in (3,...7) \end{cases}. \tag{8}$$

The upper inequality of system 8 allows to set rational level for total production costs reduction, the lower equation is to choose the optimal pair of factors X_3 (ownership of the used resources) and X_4 (industrialization of applied solutions). Different combinations of levels of X_3 and X_4 factors are possible when solving such a system. The final choice depends on the availability of the company's own resources for the performance of a particular type of work, the availability of high-performance equipment or mechanisms, the possibility and feasibility of using industrial methods of production.

For convenience of utilization, the experimental statistical dependences were calculated on the basis of formulas 1-7 in a separate approach for each combination of strategic organizational and technological solutions (levels of factors X_1 and X_2). Calculation of economic benefit can be made by finding the difference between the maximum value of construction products and unit production cost, obtained on selected levels of factors X_3 and X_4, and multiplying this difference by the physical volume of the respective work type. If necessary, steps 3 and 4 of the algorithm can be repeated several times.

Conclusions:

1. Analysis of grain storages construction and renovation industry, and the use of experimental and statistical modeling allowed building change dependences of the most important indicators on the organizational and technological factors.
2. The developed algorithm of calendar and network planning allowed optimizing the process of grain storages construction and renovation.
3. The built experimental statistical dependencies made it possible to optimize the organizational and technological solutions of the certain area of building production using a specially developed algorithm.

1) Calculate the volume of the project construction work.

2) Select the volume of construction and installation work for the following construction unit:
Y_3 – reinforced concrete structures;
Y_4 – load-bearing metal structures;
Y_5 – cubic meter of silo storage;
Y_6, Y_7 – section of noria, and plain conveyor.

3) Using the ES-dependencies, listed below, determine the optimal levels of factors, X_3 and X_4 for each type of work in the following way:
- Select suitable ES-dependence and set the optimum level of total operating costs reduction in accordance with the strategic enterprise solutions (levels of factors X_1 and X_2).
- Solve the system of inequalities for the construction work types, select the optimal levels of factors X_3 and X_4.

X_1	X_2 = 100 km.	X_2 = 550 km.	X_2 = 1100 km.
37 thousand hours.	$Y_1 \le 3{,}51\%$ $Y_1 = 0{,}332 + 0{,}085\ X_3 –$	$Y_1 \le 3\%$ $Y_1 = 3{,}932 + 0{,}062\ X_3 – 0{,}037\ X_4$	$Y_1 \le 8{,}56\%$ $Y_1 = 6{,}077 + 0{,}09\ X_3 – 0{,}037\ X_4$
	$Y_3 = 3644{,}982 + 1{,}339\ X_3 – 8{,}572\ X_4$ $Y_4 = 4576{,}419 + 8{,}664\ X_3 – 0{,}019\ X_3^2 – 0{,}007\ X_3X_4 – 8{,}308\ X_4 + 0{,}041\ X_4^2$ $Y_5 = 43{,}647 + 0{,}075\ X_3 – 1{,}5{\times}10^{-4}\ X_3X_4 – 0{,}052\ X_4$ $Y_6 = 1180{,}606 + 2{,}221\ X_3 – 0{,}005\ X_3^2 – 0{,}002\ X_3X_4 – 1{,}461\ X_4 + 0{,}011\ X_4^2$ $Y_7 = 704{,}07 + 1{,}216\ X_3 – 2{,}8{\times}10^{-3}\ X_3^2 – 1{,}42\ X_4 + 6{,}08{\times}10^{-3}\ X_4^2$		
19.6 thousand hours.	$Y_1 \le 5{,}73\%$ $Y_1 = – 3.103 + 0.071\ X_3 –$	$Y_1 \le 5{,}22\%$ $Y_1 = 2.063 + 0.048\ X_3 –$	$Y_1 \le 10{,}79\%$ $Y_1 = 6.122 + 0.076\ X_3 –$
	$Y_3 = 3485{,}51 + 1{,}339\ X_3 – 5{,}388\ X_4$ $Y_4 = 4576{,}419 + 8{,}664\ X_3 – 0{,}019\ X_3^2 – 0{,}007\ X_3X_4 – 8{,}308\ X_4 + 0{,}041\ X_4^2$ $Y_5 = 44{,}437 + 0{,}092\ X_3 – 1{,}5{\times}10^{-4}\ X_3X_4 – 0{,}087\ X_4$ $Y_6 = 1180{,}606 + 2{,}221\ X_3 – 0{,}005\ X_3^2 – 0{,}002\ X_3X_4 – 1{,}461\ X_4 + 0{,}011\ X_4^2$ $Y_7 = 826{,}419 + 1{,}216\ X_3 – 2{,}8{\times}10^{-3}\ X_3^2 – 1{,}42\ X_4 + 6{,}08{\times}10^{-3}\ X_4^2$		
2.2 thousand hours.	$Y_1 \le 7{,}96\%$ $Y_1 = – 10.432 + 0.057\ X_3 +$	$Y_1 \le 7{,}45\%$ $Y_1 = – 3{,}444 + 0{,}034\ X_3 – 0{,}007\ X_4$	$Y_1 \le 13{,}02\%$ $Y_1 = 2.584 + 0.007\ X_3 –$
	$Y_3 = 3600{,}35 + 1{,}339\ X_3 – 2{,}204\ X_4$ $Y_4 = 4576{,}419 + 8{,}664\ X_3 – 0{,}019\ X_3^2 – 0{,}007\ X_3X_4 – 8{,}308\ X_4 + 0{,}041\ X_4^2$ $Y_5 = 76{,}109 + 0{,}11\ X_3 – 1{,}5{\times}10^{-4}\ X_3X_4 – 0{,}122\ X_4$ $Y_6 = 1180{,}606 + 2{,}221\ X_3 – 0{,}005\ X_3^2 – 0{,}002\ X_3X_4 – 1{,}461\ X_4 + 0{,}011\ X_4^2$ $Y_7 = 843{,}335 + 1{,}216\ X_3 – 2{,}8{\times}10^{-3}\ X_3^2 – 1{,}42\ X_4 + 6{,}08{\times}10^{-3}\ X_4^2$		

4) Determine the economic impact of the application of organizational and technological decisions for each type of work.

5) Make a conclusion about the use of various organizational and technological decisions for each type of work, based on the work load of the enterprise resources.

Figure 2 – Algorithm of choosing rational organizational and technological decisions on the grain storages construction or renovation sites

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