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Rationale for selecting organizational and technological solutions

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Abstract: Two approaches to choosing the optimal solutions are considered – the mathematical approach and the applied approach. The mathematical approach is presented as determining the extremum of a function on the considered segment. The applied approach is presented in the form of existing various assessments of organizational and technological solutions. A list of the main, local and individual indicators used for this, along with their combinations, is given. The paper substantiates the fundamental differences in the processes of optimization of organizational and technological solutions in the mathematical and applied approaches with the conclusion that it is inappropriate to use the term "optimization of organizational and technological solutions" in applied research. Synonyms for this term are proposed and the concept of "optimization of organizational and technological solutions" is adjusted. The paper highlights the current practice of conducting a thorough evaluation of organizational and technological solutions, which has proven to be effective in coordinating the construction of specific entities and their interconnected systems. This approach aids in creating a unified project for managing tasks within a construction company's production program, as well as in crafting documentation for operational and production planning purposes.

Keywords: *Choice of solution, comprehensive assessment, COP (Construction organization project), Optimization, extremum, criteria, Organizational and technological solution, WPP (Work production project).*

1. Introduction

When conducting scientific research in the field of organizing construction production, the term 'Optimization' is used quite often, especially when substantiating the choice of organizational and technological solutions. Moreover, the use of this term has become so commonplace that it has lost its original meaning as a strictly mathematical term. In most cases, the use of this term leads to the substitution of the true meaning of the result, emasculating and distorting the supporting material, and is a screen that hides the superficial process of research. In the paper, the authors present their point of view on the use of the term and concept of 'optimization' and offer an alternative to it.

2. Materials and Methods

In mathematics, computer science and operations research, when designing modern high-performance control systems, the concept of the term 'optimization' implies the process of determining the maximum and minimum of the function under study on a certain segment with the values of the arguments contained within this segment, i.e., the function at point X has a maximum if the value of the function at point X is greater than its values at all points of a certain interval containing point X. But it should not be assumed that the maximum and minimum of the function are its largest and smallest values on the segment under consideration. Thus, at the maximum point, the function has the greatest value only in comparison with the values it has at all points located close to the maximum point. Similarly, at the minimum point, the smallest value of the function occurs in comparison with the values

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that the function takes at all points located close enough to the minimum point. A slightly different interpretation of the optimization process can be given: the function has a maximum at point X if it is possible to outline a neighborhood within which the value of the function at point X will be greater than any value in this neighborhood [1]. The maxima and minima are called extremes. Sometimes they are called the global maximum and minimum, and all other values of the function on the segment under consideration are called local extrema. It should be borne in mind that the function has an extremum (maximum or minimum) only at values whose derivatives vanish [1,2].

It is much more difficult to find the maximum and minimum of functions of several variables that are related to each other by some condition. In this case, an auxiliary function is composed and its partial derivatives are equated to zero. But even in this case, the definition of the conditional maximum and conditional minimum is decided on the basis of additional considerations. Due to the above, a valid inquiry emerges: how can the mathematical tools for finding extreme values be effectively utilized in justifying and selecting organizational and technological solutions? To find the necessary argumentation, let's take a short retrospective.

In the works [3,4], the concept of 'Optimization of organizational solutions' is recorded as follows – the process of finding the best organizational solutions that ensure the achievement of their extreme values according to a given criterion of optimality. The criterion of optimality can be the minimum duration and cost of construction, labor intensity of construction and installation works, obtaining maximum profit. Nowadays, as well as in the last century, both traditional basic indicators of the organization of construction production and a number of local and individual indicators are accepted as criteria for choosing organizational and technological solutions [5]. For example, when assessing COP and WPP solutions, as a rule, such indicators as duration and cost of construction and installation works are most often used, and when assessing labor productivity – labor intensity and output. However, the first two indicators are generalizing, since they include the influence of architectural planning, design, technological and organizational solutions. Therefore, they should be considered as final, i.e., not purely 'organizational and technological'. Labor productivity indicators are also influenced by external and internal factors, including changes in the country's economy, the state of the construction labor market, the use of new technologies and mechanization tools, the experience and qualifications of workers, management style, the degree of wear and tear of construction equipment, etc. [6,7]. In addition to general indicators, local indicators are also widely used in assessing organizational and technological solutions – the level of mechanization of construction and installation work, the degree of prefabrication of structures, the manufacturability of design solutions, etc.

For example, when assessing operation schedules, such indicators as the unevenness of the movement of workers, specific labor costs per unit of volume of construction products, etc. are used. A number of studies also use so-called individual indicators – the level of flow, downtime of the work front, calendar density of work, the degree of their parallelism, etc. One of the solution components can be characterized by both local and individual indicators. These indicators include the degree of work integration, the level of industrialization achieved in assembling elements, and more. They play a crucial role as valuable supplements to the overall indicators [8, 9, 10].

More and more often, the indicator (level) of organizational and technological reliability of the construction of an object or complex of objects is used in calculations as the ability of organizational and technological solutions to maintain their designed qualities within specified limits under the influence of disturbing factors inherent in construction as a complex probabilistic system. It is advisable to present organizational and technological reliability indicators in the form of the probability of performing work, and their use is certainly effective in the operational management of the construction of objects and their complexes.

From the above review it is quite obvious that choosing the best organizational and technological solution based on one criterion is not effective, since this solution will not be the best based on other criteria. A more or less comprehensive assessment of the solution is required, using both general and local and individual indicators. In this regard, the most modern system of indicators for the comprehensive assessment of the organization of construction production, characterizing its main components and having a direct functional connection with the final result of the construction organization's activities – the duration and cost of construction and labor productivity. These indicators of the organization of construction production are assessed in relative values from 0 to 1 and include indicators of intensity, uniformity, continuity, rhythm of work production and their combination in time. Thus, the indicator of work production intensity shows the volume of output per unit of time, and the uniformity indicator measures the consistency of output volume across identical time intervals, reflecting the stability of production levels over time. The rhythm indicator plays a crucial role in evaluating the consistency of a unit of output, while the continuity indicator considers the effects of downtime, both supporting the assessment of these two indicators. And finally, the most important combination indicator reveals the coordination of works and their technological sequence. Therefore, conducting a thorough evaluation of the organization of construction production ensures a comprehensive and objective assessment. At the same time, the process of thorough evaluation itself has nothing in common with the mathematical process of optimization [11,12]. As practice shows, the specified system of thorough evaluation is effective in choosing organizational and technological solutions for the construction of individual objects and complexes, forming a consolidated project for organizing work on the production program of a construction organization, and developing documentation on operational and production planning [13].

3. Results

In construction, due to its complexity and probabilistic nature, variant de-sign is widely used, including when choosing organizational and technological solutions [14]. The process of finding the best solution is carried out in the overwhelming majority of cases using complex assessments of various indicators depending on the degree of complexity of the process being studied, the impact of a set of influencing factors, the prevailing conditions and resource capabilities. A clear confirmation of this thesis is the process of developing operation sched-ules. When they are made, a number of restrictions are imposed on the combination of work in time and space, the structure and use of labor and technical re-sources, the duration of work, etc.

As a rule, operation schedules include options that comply with the standard (directive) duration of construction, but despite this, the selected version of the operation schedule is checked for compliance with the limit of labor force and main construction equipment, uniform and continuous movement of construction teams, specific labor costs per unit of volume of construction products, output of workers per day, the level of mechanization of construction and installation works. And it is no coincidence that the chosen version of the operational schedule serves as the foundation for developing various schedules, including the movement of labor force, main construction machines, as well as the receipt of materials, products, building structures, and equipment at the site.

When creating a unified project plan for managing the production program of a construction organization, it is essential to conduct a thorough evaluation of both organizational and technological solutions. This evaluation is crucial for not only determining the sequence and schedule of work across all sites but also for ensuring timely coordination to achieve optimal productivity and seamless operations among all production units within the construction organization during the planning phase. Following the approved work organization plan, it is imperative to develop a comprehensive schedule for the delivery of technological sets comprising building materials, components, structures, and engineering equipment to the project sites of the construction organization. This schedule should be closely aligned with the activities of production units and the construction timelines of specific buildings and structures, including their components, as well as the execution of various work tasks. Coordination among these elements is essential for the successful execution and timely completion of the construction projects with-in the production program.

In addition, the consolidated project for the organization of work includes:

- Annual schedule of the need and supply of materials, parts, structures and construction equipment;
- Annual schedule of delivery of the main technological equipment to the sites;
- Annual schedule of development and issuance of design and work-in-progress documentation, work production projects;
- Annual schedule of work of the main construction machines and mechanisms at the sites;
- Annual schedule of the need for labor resources.

When choosing organizational and technological solutions, the widespread use of mathematical methods and software packages has become almost the norm. The ability to construct mathematical dependencies and symbolic logical expressions allows for high quality and dynamism in the display of the research object [15,16]. As a result, the accuracy and effectiveness of selecting the most suitable organizational and technological solutions are significantly increased. Correlation and regression analysis theory is extensively utilized to determine the relationships between variables, identify correlation patterns, and ascertain the forms and parameters of regression lines while ensuring their reliability. At the same time, the use of the correlation and regression method is well supported by expert assessment methods. In many cases, for example, the multiple regression equation is used as an integral assessment of solutions.

It should be noted that such an applied mathematical discipline as mathematical programming becomes the main tool, for example, for determining the minimum costs when finding an effective plan for construction and installation work or finding the maximum effect when limiting various types of resources. Sometimes, when assessing organizational and technological solutions, their integral indicator is a combination of several indicators. The simplest and most well-known criterion is the additive criterion of optimality, which is used when all indicators are measured on the same scale. With equal significance of indicators, a multiplicative generalized criterion of optimality is used, which is formed by simply multiplying the indicators[17,18,19].

4. Discussion

Linear programming problems are characterized by having infinitely many solutions, making it impractical to determine the variable values through conventional methods. For this purpose, special methods are used that allow analyzing not the entire set of solutions, but only the most important of them. due to an emergency situation, a section of the road's embankment gets washed away. Re-storing the road requires a long time, so a decision is made to restore it in stages: Stage 1 — bypassing the destroyed section with backfilling the roadbed and laying precast concrete slabs; Stage 2 — restoring the road along the old axis. The most labor-intensive part is backfilling the roadbed on the bypass. A construction organization can deploy earthworks on a wide front using units of two types. The productivity of each unit is calculated on the basis of standards. It is required to determine how many units of the first and second types a road construction organization should form on the basis of its existing equipment so that their total productivity is maximum, and the completion time is the shortest. In this problem, the optimality criterion is productivity, and the goal of solving the problem is to reduce the time for completing earthworks due to the high productivity of the units' equipment. The objective function of the problem is:

$L = 600x_1 + 800x_2 \rightarrow \max.$

The task's constraints determine the availability of various types of equipment:

$2x_1 + 3x_2 \leq 12$ (constraint on bulldozers);

$x_1 + 2x_2 \leq 6$ (constraint on excavators);

$3x_2 \leq 6$ (constraint on dump trucks);

$x_1 \leq 3$ (constraint on motor graders).

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Table 1.
Reducing an unbalanced linear programming problem to a balanced one.

Bridges (i) \ Bases (j)	1	2	3	
1	5	10	10	1 200
2	4	11	8	1 500
3	12	15	3	1 000
	100	100	100	**1 000**
	2 000	1 500	1 200	4 700 / 4 700

Table 2.
Formation of specialized units.

Indicator	Composition of specialized units	
	1st type	**2nd type**
Types and quantity of equipment available in a road construction organization:		
Bulldozers – 12;	2	3
Excavators – 6;	1	2
Dump trucks – 6;	–	3
Motor graders – 3	1	–
Productivity of specialized units, m^3/shift	600	800
Number of divisions	x_1	x_2

In economic calculations for designing road construction projects, the graphical method holds significant importance. Let us consider its content in relation to the solution of the given example. Let us plot the values of $x_1$and x_2 on the abscissa and ordinate axes, respectively, and construct the constraint lines (Fig. 1). The line ab corresponds to the constraint on bulldozers. All values of $x_1$and x_2, enclosed within the triangle *Oab*, satisfy the inequality $2x_1 + 3x_2 \leq 12$. Having constructed constraints for the remaining types of equipment, we find the region of solutions that simultaneously satisfy all the given inequalities. It corresponds to the polygon *ABCDO*. This region has an infinite set of solutions, but there are only ten integer non-negative values of $x_1$and $x_2$that interest us. Let us analyze the vertices of the polygon. Point *B* does not satisfy the condition of integrality ($x_2 = 1.6$), so we exclude it from the analysis. Let us calculate the values of function *L* at points *A*, *B*, *D*:

$$L_A = 0 \cdot 600 + 2 \cdot 800 = 1\ 600 \text{ m}^3/\text{cm};$$
$$L_B = 2 \cdot 600 + 2 \cdot 800 = 2\ 800 \text{ m}^3/\text{cm};$$
$$L_D = 3 \cdot 600 + 0 \cdot 800 = 1\ 800 \text{ m}^3/\text{cm}.$$

Consequently, the equipment allocated for clearing the rubble can be used with maximum productivity if two type 1 units and two type 2 units are created on its basis. The example considered illustrates well the geometric meaning of linear programming problems, which boils down to finding the vertex of an *n*-dimensional polyhedron corresponding to the optimal solution. The graphical method is most convenient for problems in which the number of unknowns is two or three. If the problem considered allowed the creation of three types of units, then the solution would boil down to finding the vertex of a polyhedron constructed in *xyz* coordinates. If the number of unknowns is more than three, the problem becomes multidimensional, and its graphical solution becomes much more complicated [20,21,22].

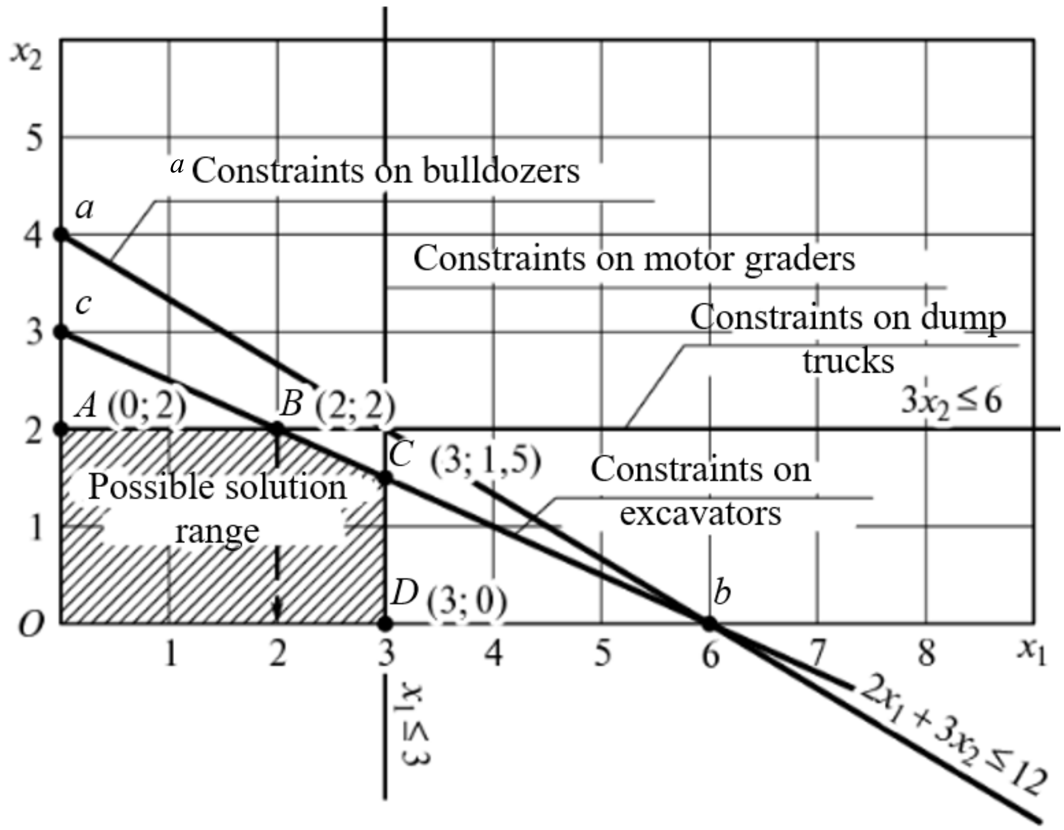

Figure 1.
Graph explaining the choice of the optimal set of machines.

Optimizing construction production involves a set of interconnected organizational and technological strategies, actions, and tasks aimed at ensuring the efficient execution of construction and installation activities for a project within the specified schedule and allocated time frames. Each organizational and technological solution in the system is selected based on the consideration, evaluation and comparison of several options.

5. Conclusion

Nowadays, there is no single comprehensive assessment of organizational and technological solutions. Therefore, as a rule, the assessment of solutions is carried out using general indicators in combination with local and individual indicators. A comprehensive assessment of the organization of construction production through indicators of intensity, uniformity, continuity, rhythm of work production and their combination in time has proven to be quite effective. It is recommended to evaluate specific organizational and technological solutions, such as selecting formwork systems and assembling sets of mechanization tools, by using comprehensive indicators derived from expert assessment methods, including the construction of simple and multiple regression equations. When solving transport, storage and resource problems, it is recommended to use mathematical programming methods in combination with graph theory methods for assessments. Furthermore, when conducting multi-criteria assessments of organizational and technological solutions, a variety of methods can be employed to combine criteria into a unified indicator. This can include approaches such as simple multiplication or calculating weighted average values following specific guidelines. Patterns in construction production significantly differ from those in natural sciences. In construction processes, causality is intricate and multifaceted, rather than simple and singular. In mathematics, the process of identifying an extremum (maximum or minimum) is established through theorems outlining the necessary condition for extremum existence (derivative equals zero) and the sufficient condition (derivative changes sign). Conversely, in construction production, the influence of diverse combinations of random factors can destabilize the system, leading to alterations in the intended technical and economic parameters [23,24,25,26].

Since the process of selecting the best organizational and technological solution is fundamentally different from the mathematical process of determining the extremum, it is not recommended to use the term 'Optimization', but to widely use its synonyms – improvement, development, enhancement, rational choice, structuring, etc. It is advisable to fix the following changes in the existing concept of 'optimization of organizational and technological solutions' – 'according to specified criteria' and 'effective value', and replace the term 'optimization of organizational and technological solutions' with 'selection of organizational and technological solution'. In this case, the following wording may be used: Selection of organizational and technological solution is the process of finding the best organizational and technological solution that ensures the achievement of an effective value according to specified criteria.

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