Optimal order of construction of facilities in complex development with minimal additional costs

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Abstract. Stream methods of work during the construction of a group of construction projects provide the selection of priorities in the optimization of calendar plans. This can be a reduction in the duration of construction or resource provision in time. Due to the change in the arrangement of objects in the stream, the total duration of the work on the entire object complex can be changed. By the methods of organizational and technological modeling, a rational sequence of work is selected taking into account the optimization of resource costs. When constructing a complex of objects, a comparative analysis of various combinations of grouping objects, using the methods of decomposition and aggregation, allows you to carry out a numerical rating of various parameters of the work, such as duration, labor, providing material and technical resources, etc. This ensures the optimal ratio between the duration of the construction of the object complex and additional costs that arise during the parallel construction of several objects. A graphical interpretation of the choice of the optimal organizational and technological solution is work schedules at the facilities, allowing differentially and integrally to evaluate the development of material and technical resources.

1. Introduction
As a rule, in the process of organizing work during the construction of a complex of construction facilities, it is necessary to solve problems associated with determining the optimal order of inclusion of facilities in the stream, subject to the minimum additional costs arising from the violation of the existing recommended dependencies between works that ensure the minimum construction time [1-3].

If the construction organization does not have the necessary capacities to ensure simultaneous operation at several facilities, then it is forced to either attract additional resources associating with additional costs or to perform work sequentially by increasing the total duration of the entire complex of works [4,5].

The costs of material and technical resources in construction have different units of measure. Therefore, they must be systematized and reduced to a universal estimated indicator in the form of financial costs.

2. Methods
The network diagram is the arrangement of objects in the stream, as shown in figure 1. Jobs are the tops of the network. The total duration of the work of the whole complex of objects may change in case of a
change in the arrangement of objects in the stream. The values indicated in the arcs are relevant to the work and connect the vertices of the network graph. The number of the object is indicated at the top of the peak, and the duration of the work at the bottom.

Let us evaluate the costs of the enterprise for the organization of parallel execution of works at facilities 2, 4, 6 (figure 1) [6-7]. In the case when the work is performed sequentially (figure 2), the total execution time is 74 without any additional costs.

![Figure 1. The parallel execution of works at facilities 2, 4 and 6.](image-url)
Figure 2. The sequential execution of works at facilities 2, 4 and 6.

In the other case when the dependence (2.4) is taken into account, but the dependence (4.6) is not (figure 3), the total duration changes to 56 at an additional cost of 24.

Figure 3. The sequential execution of works at facilities 2 and 4.

In another option, when dependence (4.6) is taken into account, but dependence (2.4) is not, which corresponds to the simultaneous execution of works at 2 and 4 facilities (figure 4), the total duration changes to 47 at an additional cost of 20 per account of the fact that the dependence was not taken into account.
When constructing a complex of objects, the flow method is usually chosen. This method involves the construction and installation work consistently for individual stages, such as the construction of underground and aboveground parts of buildings, roofing and finishing works, and in parallel for different stages at various objects.

This work procedure provides the optimal use of resources in the construction of a construction project complex. At the same time, ensuring rhythmic consumption of resources is complicated by the fact that the individual buildings and structures included in its composition have different construction and technological parameters, such as building volume, square, number of storeys, space-planning and design solutions, etc.

To determine the optimal sequence of work in the construction process of a facility complex at minimal additional cost, providing a reduction of construction time of a building complex, organizational and technological modeling is used as a toolkit [7-9].

The studies were conducted on the example of the construction of a 7 object complex, the duration of the construction of which was 11, 19, 13, 12, 15, 19 and 17 months using network models.

3. Results and Discussion
We construct a table based on the calculation results (table 1).

|   | 30 | 47 | 74 |
|---|----|----|----|
| 30 | 0  | 20 | 0  |
| 18 | 24 | 44 | 56 |
| t6 | 12 | 20 | 39 |
| t4 | 20 | 0  | 0  |
It turns out that the total duration of the work will be 74, provided that work at facilities 2, 4 and 6 are performed sequentially and there are no additional costs. And if the work at facilities 2, 4 and 6 will be carried out in parallel the total duration will be equal to 44 but at the same time there will be additional costs, which will be 44. The most optimal option is that the work at facilities 2 and 4 will be carried out in parallel, then the duration is 47 and the additional cost is 20.

Thanks to the results obtained, we can conclude that not always obvious solutions are economically feasible. Obviously, the organization requires parallel execution of work at facilities 2, 4 and 6. This corresponds not only to the maximum cost but also to the minimum duration. However, it turns out that the organization of the parallel execution of work at the 6th facility reduces the construction period by only 3 but at the same time increases the costs by 24, which cannot be called economically feasible [10-13].

Let’s draw up a schedule of work for the objects, based on the solution that is presented in figure 5 and the investment development schedules — differential (figure 6) and integral (figure 7).

![Figure 5. The schedule of work for the facilities.](image)

![Figure 6. Differential capital investment development schedule.](image)
4. Conclusions

When erecting a complex of construction objects, each of which has individual constructional and technological parameters, scheduling of individual objects does not allow us to identify the optimal resource support for the construction of the entire complex. For this, they are integrated into a complex model.

Using the methods of organizational and technological modeling allows us to predict the necessary costs and evaluate the balance between the ability to significantly reduce the duration of construction or optimize the cost of additional costs. In the construction of a facility complex, multivariate solutions of organizational and technological problems allow the selection of their optimal grouping and construction sequence [14-21].

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Figure 7. Integral capital investment development schedule.
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