Construction schedule planning for railway station facilities

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Abstract. The article discusses the improvement of the network modeling technique for solving problems in the design of the organization of work for the construction of station buildings and structures necessary for servicing passengers intended for operation on railway transport in the presence of various technological processes. The network model in the design of the organization of work on the construction of rather complex structures and in the presence of various technological processes becomes very cumbersome and poorly visible in terms of taking into account the interconnection of processes and the coordination of their movement along the work fronts. In addition, on such a network model it is rather difficult to consider the options for applying various methods and technologies of work organization. An example of the formation and calculation of a matrix-network model for the construction of a station complex is given, including 14 technological processes, showing the relevance of the chosen method.

1. Introduction

When designing the organization of work on the construction of rather complex structures and in the presence of various technological processes, the most convenient form of reflection of the entire interconnection and sequence of construction and installation works is the network model [1-6]. The network model allows you to trace the sequence of execution of construction processes and their interrelationship during implementation.

In such structures as station buildings and structures intended for operation on railway transport, the sequence and timing of work are significantly influenced by taking into account their interconnection in individual parts of structures and organized fronts of ongoing construction processes.

In these cases, the network model becomes very cumbersome and poorly visible in terms of taking into account the interconnection of processes and coordinating their movement along the work fronts. In addition, on such a network model it is rather difficult to consider the options for applying various methods and technologies of work organization.

These methods, first of all, include the method of the critical path, the method of continuous use of technical and labor resources, the method of continuous development of work fronts and the method of the fastest deployment of work (the method of rank connections).

2. Materials and methods

At first glance, in the case of interconnection of the complex of works, it is desirable to apply the matrix method of reflecting the technology of performing works on various fronts. However, the
matrix provides for a strict sequence (technology) of work. It seems impossible to reflect the complex spatial interrelation of works (network topology) on such a matrix without special algorithms and schemes. One of the possible approaches to solving such problems may be the use of matrix-network planning.

In our opinion, it will be more convenient for practical calculations to build a matrix model based on a simplified and compact network model of the entire set of works.

The proposed matrix model in such a complicated version reflects the breakdown of the structure into separate sections (work fronts) in relation to each technological process and the entire complex of works performed. In the published works, such a matrix is considered as a matrix with different-sized fronts of works [7-10].

The complex of construction processes performed is reflected in such a matrix in a sequence corresponding to the topology of the developed network model for the construction of the structure under consideration.

The sequence of work execution in the matrix is fixed by layers corresponding to the main paths of the graph (network model). Jobs connecting the main paths of the graph are reflected by the presence of several layers in the matrix for these jobs. The calculation of the timing of work at each seizure is determined based on the readiness of the work front and in the corresponding topological sequence.

The start and end dates of the «j work» on the «i front» can be described by the following expressions:

\[ T_{st\ ij} = \max(t_{f in\ i(j-1)}, t_{f in\ (i-1)j}) \]

\[ T_{st\ ij} = T_{f in\ ij} + t_{ij} \]

where:

\[ T_{st\ ij} \] - start date of the «j work» on the «i front»,
\[ T_{f in\ ij} \] - end date of the «j work» on the «i front»,
\[ t_{ij} \] - duration of «j work» on the «i front».

3. Results and discussion

As an example, let us consider a model for the construction of a station complex. The main technological processes for the construction of the station complex necessary for serving passengers are summarized in Table 1.

| №  | Name of the type of work                                      | Duration of work, days |
|----|---------------------------------------------------------------|------------------------|
| 1  | Installation of reinforced concrete frames                   | 16                     |
| 2  | Installation of cover plates                                | 18                     |
| 3  | Installation of wall panels                                 | 17                     |
| 4  | Roofing device                                              | 22                     |
| 5  | Rough floor covering                                        | 13                     |
| 6  | Construction of aerated concrete partitions                 | 14                     |
| 7  | Installation of door blocks                                 | 13                     |
| 8  | Preparatory work for the installation of window blocks      | 4                      |
| 9  | Installation of window blocks                               | 19                     |
| 10 | Installation of ventilation equipment                       | 14                     |
| 11 | Installation of demonstration equipment                     | 7                      |
| 12 | Installation of power supply system equipment               | 14                     |
| 13 | Rough finishing of premises                                | 23                     |
| 14 | Installation of roof equipment                              | 10                     |

This complex of technological processes was linked by the sequence of their execution using the network model shown in Figure 1, the work numbers are highlighted, for each work the start and end
This network model does not take into account the combination of work performed in different sections (captures) of the structure. It takes into account only the timing of completion of work in accordance with the accepted technology (topology) of the construction of the structure. On the basis of this network model, a matrix model of the construction of a structure has been developed, taking into account the division of the structure into separate processes into a number of work fronts (seizures). This is a model of streamlined organization of work, which reduces construction time by combining work.

Such a model is shown in Table 2. Lines show the sequence of technological processes. In each cell, the timing of work on the corresponding grip is calculated. The critical path is shaded.

**Table 2. Matrix model of erection of the station complex**

| graph paths | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|-------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|
| fronts      |   |   |   |   |   |   |   |   |   |    |    |    |    |    |
| 1           | 4 | 4-9| 8 | 13-21| 6 | 32-37| 4 | 37-41| 1 | 44-45| 5 | 50-53| 3 | 71-75| 3 | 75-78| 5 | 78-83| 4 | 89-93|
| 2           | 4 | 4-8| 4 | 9-13| 5 | 27-32| 3 | 41-44| 1 | 47-54| 4 | 54-59| 7 | 64-71| 4 | 66-71| 6 | 68-71|
| 3           | 4 | 8-12| 4 | 13-17| 5 | 32-37| 4 | 37-44| 1 | 55-59| 5 | 56-64| 3 | 75-78| 4 | 82-86| 6 | 89-101| 6 | 101-107|
| 4           | 4 | 12-16| 5 | 17-22| 6 | 33-43| 4 | 43-51| 1 | 57-58| 5 | 64-71| 3 | 86-95| 6 | 95-101| 6 | 95-101| 6 | 101-107|
| ∑           | 16 | 18 | 17 | 22 | 13 | 14 | 13 | 14 | 4 | 19 | 14 | 7 | 14 | 23 | 10 |

The network model does not take into account the breakdown of processes into separate seizures (work fronts), but when it was drawn up, the possibility of simultaneous execution of some work on certain parts of the structure was taken into account. To reduce the construction time, it is advisable to
determine the work fronts (seizure) for each process and organize the flow technology of the construction.

For this example, we will build a matrix indicating the layers according to the sequence of work execution with the selection of grips for each work (Table 2). On the matrix, the paths of the graph are shown by layers (lines).

Here are the following paths from the beginning of the fork to the final work (graph arcs):
-1-2-3-4-14; -2-5-6-7-9-13-14; -3-8-9-13-14; -5-10-11-12-13-14.

As can be seen from the example (Table 2), taking into account the sequence of work and observing the possibility of working on one front of only one brigade, the construction period was reduced from 126 days to 107 days.

When calculating on the matrix, the critical path method was adopted in the same way as on the network diagram, but a reduction was achieved due to the stream organization of work on the selected work fronts. On the network model (Figure 1), the possibility of simultaneous execution of several jobs on one front is accepted. Then, when constructing and calculating the matrix model in full accordance with the network model with the flow organization of work, we get a reduction in construction time from 126 days to 65 days (Table 3). Lines show the sequence of technological processes. In each cell, the timing of work on the corresponding grip is calculated. The timing of the work is calculated in accordance with the established technology and when working on the capture of only one specialized brigade. The critical path is shaded. The reduction was achieved due to the ability of several brigades to work on one front.

**Table 3. Matrix model of erection of the station complex**

|   | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1 | 0-4| 4-9| 13-21| 6 | 5 | 13-27| 18-22| 22-25| 22-30| 3 | 12-33 | 36-36 | 36-41 | 47-54 |
| 2 | 4-8| 9-13| 27-32| 5 | 7 | 32-28 | 22-33 | 23-39 | 22-29 | 4 | 36-40 | 41-47 |
| 3 | 8-13| 22-31| 32-25 | 4 | 3 | 32-28 | 37-44 | 39-33 | 33-65 | 4 | 40-44 | 59-53 |
| 4 | 5 | 12-17 | 37-28 | 6 | 4 | 44-53 | 44-58 | 44-59 | 44-65 | 4 |
| Σ | 18 | 16 | 17 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 |

Based on this matrix model (Table 3), a normalized matrix was built based on the works of prof. V.A. Afanasyev [1] (Table 4). The timing of work on the normalized matrix fully corresponds to the timing of the matrix in Table 3.

The normalized matrix shown in Table 4 is calculated by the method of continuous development of work fronts. The term of the work is 107 days. Calculation according to the normalized matrix execution of works according to the method of rank relationships leads to a duration of 122 days.
Table 4. Normalized matrix model for the construction of the station complex

| Graph paths | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|-------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|
| fronts | 1 | 4 | 0.4 | 5 | 4.9 | - | - | - | - | - | - | - | - | - |
| 2 | 4 | 4.8 | 4 | 9.13 | 8 | 13-21 | 6 | 21-27 | - | - | - | - | - | - |
| 3 | 4 | 9-13 | 4 | 13-17 | - | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 6 | 4 | 17-21 | 5 | 21-26 | 9 | 26-35 | 5 | 35-40 | 4 | 10-44 | 3 | 44-47 | 7 | 47-54 | 4 | 54-59 |
| 7 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 8 | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | 79-83 |
| 9 | - | - | - | - | - | - | - | - | - | - | - | 4 | 85-89 | 6 | 89-93 |
| 10 | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 92-95 | 6 | 101-107 |

4. Conclusion
1. The proposed method for constructing a matrix model based on a network model is simple and allows us to consider several options for organizing work and choose the best one.
2. The criterion for choosing a method of organizing construction can be the construction period, the cost of performing the work under consideration, the operating time of the leading machines and others.
3. The construction of a matrix model can be carried out by observing the accepted topology of the work performed without building a network model.

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