

Optimization of construction parameters using resource scheduling

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Abstract. Reducing the time of production within maintaining the cost of the final product is the main issue in construction organization. This question can be resolved through the development of network and calendar schedules with the correct sequence of work, composition of brigades, optimal technological decisions. The successful correction of schedules is possible by calculating parameters of resource graphics and comparing them with the normal indicators. The effectiveness of the applied methods of optimization by the time and resources depends on technological and organizational parameters of the designed building or construction.

1. Introduction

The main parameters in construction design are time and cost. An optimization of these elements of planning can be carried out using resource scheduling. The main problem of the issue is that the construction of any building includes many diverse works. It is required to have a specific set of different resources: construction materials, arsenal of mechanization, human resources. Generally, the duration and consequently, the cost of the whole project is determined by the level of organization in distribution of these resources.

There are three main phases in calendar and network scheduling: structure planning, calendar scheduling and operational management. On the phase of structural planning occurs the fragmentation of industrial process on legible operations. The network schedule is forming up. It shows clearly the interconnections of technical processes. The critical paths determines, time reserves, proceeding on which it will be possible to optimize graphics in future. The second phase involves designing of calendar schedule, which determines the deadlines of beginnings and terminations of all the operations. The final product of the second phase is a calendar plan. The calendar schedule helps to stake out time reserves of non - critical operations, which can be managed during the optimization of the processes. The third phase consists of operational management, where the calendar and network schedules serve for the provision of reports on the progress of the work. For today, the most effective methodology of construction organization is a flow method of organization. It is included in the basis of scheduling. It is necessary to consider the availability of resources to achieve a stable dynamics. The limited amount of building materials, human resources, mechanization can significantly reduce the efficiency of the

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flow method. It is essential to provide in advance the distribution of resources on the object of construction. This task is designed to solve by resource scheduling. With the aid of full reserves of time on non – critical works, managing them within the limits of reserve time, it is possible to achieve the decrease of maximum demand in resources. In the absence of restrictions in resources, it is possible to achieve their alignment during the building process. The assessment of graphics takes place by finding coefficients and comparing them with the normal parameters.

The issue of the schedule planning of resources:

- 1) An evident representation about absence or excess of resources;
- 2) An evident representation about uniform distribution of resources;
- 3) Correction of distribution of resources depending on conditions of building;
- 4) Efficiency evaluation of selected technological methods of designing by finding the coefficients of resource graphic's parametric data.

Resource scheduling is a part of the section PCP that unscramble as preparation of construction production. This is the complex of organizational, economical, technical documents and events, which are introduced in building construction in order to increase an efficiency of process. This section compose approximately 14% of an estimated cost, 16% of overall labor intensity and 14% of general construction period.

2. Statement of problem

The purpose of the article is an analysis of resource graphics, parametrical analysis of their indicators. On this basis should be selected an optimal method of graphic's correction taking into account the flow method of organization construction and installation works.

3. Analysis of resource graphics and their parametrical indicators

In the development of the flow within the object or complex can be divided into three periods:

- 1) the period of deployment of the flow T_{razv} when the flow, equal to its rhythm, the work consistently includes teams; the time between the beginning of the work of the first and the final processes of the construction flow on the 1st capture.

For a construction flow with the same rhythms for all processes, the duration of the deployment period is

$$T_{\text{razv}} = t_w(n - 1) \quad (1)$$

where n is the number of processes (private threads);

- 2) the period of deployment of the T_{ust} flow which corresponds to the constant and maximum number of workers; this is the time interval during which work is carried out simultaneously on all processes (private flows). The presence and duration of the flow period depends on the ratio of the number of processes and captures on which the work is carried out. The longer the flow period, the more efficient the use of resources. Therefore, when designing, we strive to make the number of captures greater than the number of processes m greater than $n+1$

- 3) the period of coagulation of the T_{sv} stream when from the stream equal to its rhythm crews consistently join; this is the interval of time between the end of performance of works of the first and finishing processes of the stream on the last capture.

For a construction flow with the same rhythms for all processes, the duration of the deployment period is

$$T_{\text{razv}} = T_{\text{sv}} = T_{\text{sh}}(n - 1) \quad (2)$$

In equal-rhythmic flows, the coagulation and deployment periods are:

$$T_0 = t_{\text{sh}}(n + N - 1) + \sum t_{\text{tech}} + \sum t_{\text{org}} \quad (3)$$

If the first team of the flow finishes its work, and the latter has not yet started it, then the flow is called unsteady and Vice versa, the steady flow is called, in the development of which there is a period during which work is simultaneously carried out on all processes. In other words, the period of steady flow is an interval of time during which work is simultaneously carried out on all private fronts (processes). The presence and value of the steady flow period depend on the ratio of the number of processes and the number of captures. At the same time, the longer the period of steady flow, the higher the efficiency of resource use. Therefore, when designing the flow organization of construction should strive to ensure that the number of captures was greater than the number of processes ($m \geq n+1$), which ensures the presence of a steady flow period.

Important characteristics of the spasmodic development of specialized flow are critical points of convergence related processes, reflecting the absence of idle work front for segment: the work of the regular process on the hook starts right after the previous one.

The absence of downtime of work fronts in the rhythmic flow, on the one hand – an indicator of its high efficiency, since non-production losses are excluded due to downtime of performers and fronts of works, on the other hand, such organization of work requires a high culture of production, as a failure in the performance of any work will inevitably have a negative impact on the final result.

According the calendar plan can be determined the needs in mechanisms, human resources, delivery time of construction materials, schedule of funding in units: amount – time (in days, weeks or months).

In the construction design, resource schedules may be presented as linear schedules and cycloramas, table models – matrix. Linear schedule is the simplest and widely used in construction.

1) The schedule of necessity in machines and mechanisms.

Present schedule determines the necessities, arrangement and workload of the main building machine and mechanisms, an amount and deadlines of exploitation of these resources. It is compiled on the basis of technological cards, schemes and calendar schedule. This graphics consists of following information: enumeration of building machines and mechanisms by brands and types, volume of works for every mechanism, shift of works. This schedule may have the form of linear schedule.

2) The schedule of spreading of workers on the object.

For an ensuring of continuity in construction processes, there is a schedule of workers' spreading on the object. In these graphics, the amount of workers for every period of works determines using the technological cards and ENiR. The horizontal axis usually indicates time (days) and the vertical points the number of workers.

3) The schedule of admission of building materials.

The present graphics reflects necessity, delivery terms of materials, which ensure continuity of performing construction and installation works on the building objects. According this schedule the daily and monthly requirement specifies.

4) Cyclogram

Cyclogram – this is one of the forms of calendar scheduling. It is applies for reflection of constantly repeated one – type flows. Cyclogram shows their development in space – time.

Parametric indicators of schedules:

1) Indicator of equitability of the flow k_{eq} determines as the ratio of the average amount of workers to its maximum number per day,

Where $N_{av}=Q_s/T_s$ and Q_s – is the summary laboriousness of the flow (an area of resources epure). The flow is considered to be uniform, if $k_{eq} [1,5 ; 1,7]$;

$$k_{eq} = N_{av} / N_{max} \quad (4)$$

2) Indicator of stability of the flow k_{st} determines as the ratio of the period of established flow to its general duration:

$$k_{st} = T_{st} / T_{sum} \quad (5)$$

The flow is stable, if $k_{st} \leq 1$;

3) Indicator of works combination at all the divisions the coefficient of density k_{den} determines as the ratio of the summary duration of works of all the brigades on the divisions to the summary value of organizational intervals between the brigades operations. It should aim to the density, equal to one.

$$k_{den} = \sum t_{ij} / (\sum t_{ij} + \sum t_{br}) \quad (6)$$

4) The intensity and power of the flow l determines by an amount of production, which is produced per time unit and measured in physical terms. It is characterizes as the value of the angle's tangent of the cyclograma's flow line to the abscissa: $l = \text{tg}\alpha$. The more is the value of $\text{tg}\alpha$, than larger volume is doing in time unit.

In addition to all these indicators, the static parameters are using for an efficiency evaluation of the flow method:

- 1) The volume of the works V_i ;
- 2) Specific labor intensity of works Q_{spec} ;
- 3) The cost of every specialized flow C_i .

Dinamic parameters:

- 1) Number of workers R_i ;
- 2) Production of one worker per day q_i .

On the basis of these above – stated calculated parameters, the cyclogram of the flows can be designed, linear diagrams and the schedule of the labor force's movement.

Assume having source data, then:

$$\left\{ \begin{array}{l} N_{av} = N_1 \\ Q_{spec} = Q_1 \\ k_{eq} = k_1 \\ k_{st} = k_2 \\ k_{den} = k_3 \\ q_i = q_1 \\ V_i = V_1 \\ C_i = C_1 \\ K_i = K_1 \end{array} \right\} \Rightarrow \left\{ \begin{array}{l} N_{av} > N_{norm} \\ Q_{spec} > Q_{norm} \\ k_{eq} > 1,7 \\ k_{st} > 1 \\ k_{den} > 1 \\ q_1 < q_{norm} \\ V_1 < V_{norm} \\ C_1 > C_{norm} \\ K_1 > K_{norm} \end{array} \right. \quad (7)$$

4. Methods of correction production works schedule

There are the following ways, in which it is possible to achieve optimization of construction schedules:

- in order to achieve the best time constraints of works' producing (it is called an optimization by the time)

- based on optimization of the resources.
- The main issue of correction calendar schedule is reducing the critical path. If the duration of the critical path exceeds the standart period, it would be most expedient to conduct a range of operations, such as:
- reduction of the critical path period at the expense of time reserves, which have non-critical works;
 - reduction of the critical path period of works at the expense of involvement an additional labour force;
 - changing project decisions or organizational and technological requirements.

The most acceptable method of reducing the critical path is a method, which is based on resource scheduling. An additional attraction of labor forces must be performed in accordance resource schedules, on which it is possible to trace maximum saturation of labor resources.

- The general principles, which should be followed while correcting schedules, are:
- organization of two -, three – shift works on the most critical construction parts;
 - ensuring of works combination;
 - splitting the front of works on smaller divisions;
 - carefully planning technology and order of work organization.

- To adjust the production schedules on resource graphics, it is possible to highlight the following algorithm:
- rational allocation of limited resources;
 - minimization of resource consumption per unit of time;
 - minimization of peaks and failures.

5. Resources and correction of network schedules

During of process of production, the graphs are often corrected by time, less often for labor resources and materials.

Table 1. Resources and correction of network schedules

No.	Name	Comparison criteria	
		Expenses	Application area
Optimization by the time			
1	Redistribution of labor resources	Transfere of brigades from non – critical to critical sections of the network	Construction of residential buildings and constructions with the simultaneous introduction of the supplied central heat station
2	The combination of technological processes in time	Splitting the front of works on smaller divisions	In the construction of buildings and constructions with several planning sections and iterative floor plans
3	Mobilization of additional resources	Augmentation of shifts with an attraction of additional labor force and other resources	In cases of necessity of continuous production
4	Changing of design decisions	Involvement of measures which may lead to increasing of the industrialization level	The buildings with reinforced concrete frame (replacement of monolithic reinforced concrete for the prefabricated)

Optimization by the resources			
1	Movement of works implementation on the later dates	The ability of using the time reserves on the non – critical works	If there is a necessity in keeping constant composition of the brigade. It happens when the flow method of organization is used on construction of residential squares and industrial facilities
2	Augmentation of works' duration	Within the limits of time reserves with simultaneous decreasing number of workers	The necessity in minimization of labor force
3	Using both methods at the same time	Using of time reserves and resources on non – critical works	On the objects where it is necessary to have equable distribution of workers

6. Resources and correction of network schedules

After calculation of the network and calendar schedules, there is the necessity of optimization the resulting models by the labor resources and time reserves. The main issue is an ensuring of uniform consumption of resources on all stages of implementation works' packages. Thus, the task of correction is reducing to the compilation of the optimal schedule of work, providing the uniform of the resources.

The correct optimization of the schedules is basing on the calculation of the coefficients and parametric indicators of resources graphics. Comparing them with the normal indicators we can conclude if the optimization was successful or not.

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