

# Optimization of the annual construction program solutions

*Pavel Oleinik\** and *Alexey Yurgaytis*

Moscow State University of Civil Engineering, 129337, 26, Yaroslavskoye Shosse, Moscow, Russia

**Abstract.** The article considers potentially possible optimization solutions in scheduling while forming the annual production programs of the construction complex organizations. The optimization instrument is represented as a two-component system. As a fundamentally new approach in the first block of the annual program solutions, the authors propose to use a scientifically grounded methodology for determining the scope of work permissible for the transfer to a subcontractor without risk of General Contractor's management control losing over the construction site. For this purpose, a special indicator is introduced that characterizes the activity of the general construction organization - the coefficient of construction production management. In the second block, the principal methods for the formation of calendar plans for the fulfillment of the critical work effort by the leading stream are proposed, depending on the intensity characteristic.

**Keywords.** Annual production program of the construction company, scheduling, annual (current) planning, optimization solutions, optimization, the coefficient of construction production management, intensity of work performance, human resource, labor

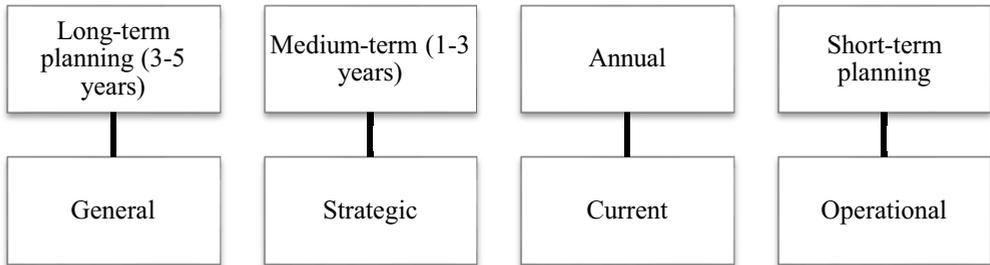
## 1. Introduction

Production planning plays a decisive role in the development of a construction organization, and as a system, it consists of separate planning complexes (subsystems), which include general planning (3-5 years, long-term planning), strategic planning (1-3 years, medium-term planning), Current (annual) planning and operational planning (up to 1 year, short-term planning) (Fig. 1). In the conditions of the modern economy, it is the current (annual) planning of the production program of a construction organization that is a particularly complex multifactor task, often solved intuitively and chaotically in organizations, without an established system and methodology. Such an extensive production and economic program envisages the implementation of the concluded construction contracts during the reporting period, compliance with the requirements of the codes, mobilization of production resources and obtaining the maximum possible profit from the activities (Fig. 2). Within the framework of such planning, we can isolate the

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\* Corresponding authors: [aljurgaitis@gmail.com](mailto:aljurgaitis@gmail.com)

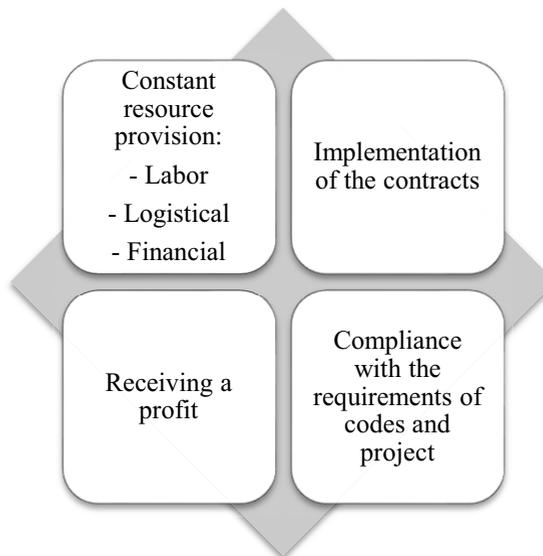
planning of using the labor resources with the aim of ensuring the output of finished construction products of high competitive quality in a timely manner.



**Fig. 1.** Scheme of Production Planning

The optimization instrument of the annual planning can be represented in the form of a two-component complex, shown in Fig. 3.

The principal task of planning, on the one hand, is to withstand the timing of the commissioning of construction projects; on the other hand, - to ensure a constant, uniform and, as far as possible, maximum full mobilization of the resources of all production units. In addition to the available algorithms for constructing and optimizing the calendar plans, mainly considered in the works of foreign authors [1-10], this article proposes a two-stage instrument that allows the General Contractor Organization to first isolate the permissible amount of work for transfer to the subcontractor balance, and then proceed to the formation of a calendar plan and resource schedules (Fig. 3). On the basis of heuristic methods that have become widespread in planning practice, it is possible to develop a clear scientific methodology for each stage for production implementation.



**Fig. 2.** Matrix of the current (annual) planning

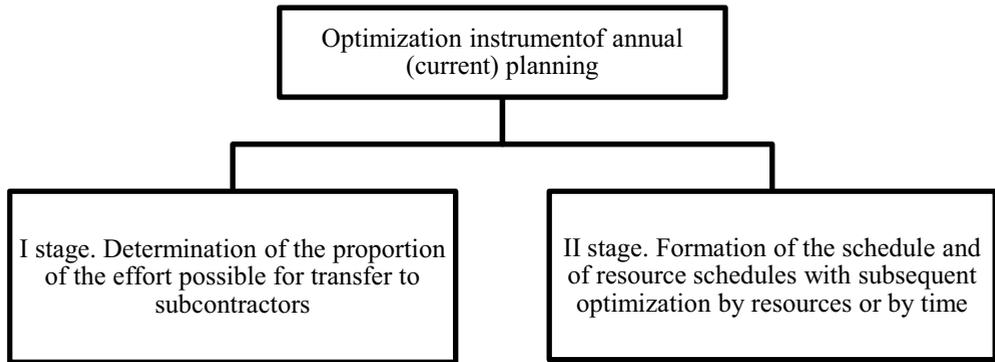


Fig. 3. Optimization instrument

## 2. Methods, Results and discussion

### 2.1 Stage I

The construction project effort or production program (a collection of objects) is generally represented as a sum of two components that form an integral binary system (Figure 4). We call such system a schematic diagram of the construction works binary separation (SDSW) and mathematically represented as a sum of two terms (formula 1).

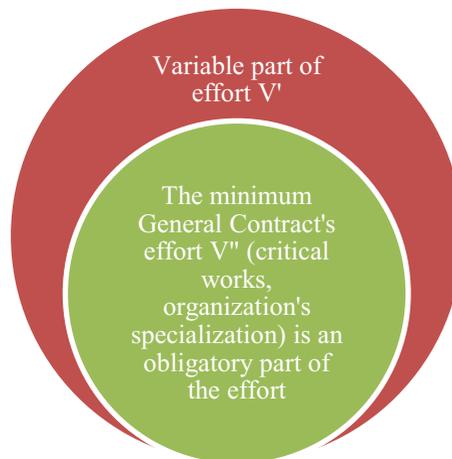


Fig. 4. A schematic diagram of the construction works binary separation (SDSW)

$$V = V' + V'', \quad (1)$$

где  $V$  - the total effort of the construction object or the annual production program of the construction company (a set of efforts);

$V'$  - a certain proportion of the effort, realized at the discretion of the General Contractor with the involvement of another resource - the so-called Variable Part of SDSW;

$V''$  - the minimum proportion of the effort, which is necessarily realized directly with the involvement of the General Contractor's resource (includes the effort performed by the leading flows)  
 - the so-called obligatory part of the SDSW.

As a result of the analysis of the production activity of a significant number of objects-representatives of a certain general population (construction organizations of various capacities), it is possible to obtain empirical dependences of the effort performed directly by the General Contractor and the amount of work that, for various reasons, is transferred to a subcontractor, from the General Contractor's capacity and total effort of the production program. The limiting factor in this distribution will be the need to maintain production control over construction sites for general contracting facilities and to avoid such distribution of volumes within the binary system, in which production management is transferred to subcontractors in fact absolutely. For a numerical description of this factor, we introduce a relative indicator - the coefficient of construction production management ( $K_{csm}$ ), describing the nature of the efforts distribution between the General Contractor and the subcontractor and establishing the minimum allowable value of the General Contractor's effort to provide management control over the production process.

We define the term "capacity of a construction organization" as the amount of work on the objects of the production program performed by the labor resource (all production teams of the organization) per unit of time - index CF (company facilities).

So, let's select the first (formulas 2, 3) and the second (formulas 4, 5) principal cases of distribution of effort inside a binary system:

$$\begin{cases} V'' \rightarrow \max(V'') \rightarrow 1 \\ V' \rightarrow \min(V') \rightarrow 0 \end{cases} \Rightarrow V \approx V'' \quad (2)$$

$$K_{csm} = \frac{V}{\max(V'') + \min(V')} \approx 1'' \quad (3)$$

$$\begin{cases} V'' \rightarrow \min(V'') \rightarrow 0 \\ V' \rightarrow \max(V') \rightarrow 1 \end{cases} \Rightarrow V \approx V' \quad (4)$$

$$K_{csm} = \frac{V}{\min(V'') + \max(V')} \approx 1' \quad (5)$$

Case 1. The case of absolute production control. In the first case,  $K_{csm}$ , equal to one, indicates that the production process is under absolute control of the General Contractor ( $\approx 100\%$  of  $V$ ).

Case 2. The case of the absence of production control. In the second case,  $K_{csm}$  is also equal to one (execution  $\approx 100\%$  of  $V$ ), but the performer (or a group of performers) will be the subcontractor, which ensures that there is no actual production control by the General Contractor.

The empirically established range of permissible values of the coefficient  $K_{csm}$  is illustrated on Fig. 5.

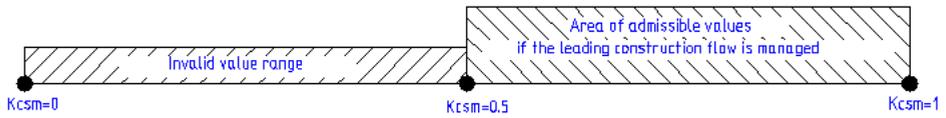


Fig 5. The range of admissible values of the coefficient  $K_{csm}$

Table 1. SDSW components description

<i>SDSW component</i>	<i>Obligatory part of the General contractor's effort, <math>V''</math></i>	<i>Variable part of the General contractor's effort, <math>V'</math></i>
<i>How to determine the share of the SDSW component from the total effort <math>V</math>?</i>	It is determined depending on the capacity of the General Contractor Organization ( $CF$ ) and the total amount of contracts effort ( $V$ ) according to empirical dependencies: $V'' = f(CF; V) \quad (6)$	$V' = V - V'' \quad (7)$
<i>How to evaluate the admissibility of calculations?</i>	Characterized by the input indicator - the coefficient of construction production (construction site) management $K_{csm}$ : $K_{csm} \in [0.5; 1] \quad (8)$	
<i>Resource availability of the component</i>	Own labor resource	Own labor resource due to the implementation of the effort $V''$ Labor resource of the subcontractor
<i>Additional burdensome actions</i>	Are absent under condition of provision by a constant resource on the given volume of works	None -Hiring additional workforce; -Training of workers; - Provision with snap; - Creation of domestic production conditions; - The maintenance of an additional labor resource after performance of effort $V''$

2.2 Stage II

The main conditions for the "correctness" of the calendar plan are: the fulfillment of the contractual terms of the technical customer (developer) and stable continuous loading of labor.

The achievement of these conditions is provided in various ways. At the same time, the process of formation and updating of the calendar plan is carried out continuously and not only because of the inclusion of new objects in the plan, but also for a number of other reasons (shortage of workers, disruption of financing, etc.). Nevertheless, several basic approaches to the formation of calendar plans can be identified. But at the same time for all approaches, as a rule, the principle of internal coordination of the efforts parameters is observed. For example, object construction flows can include both combined and non-combined specialized flows. But even from the number of non-combined specialized flows that make up the object flow, the leading stream, which determines the total duration of the entire object flow, is allocated, as a rule, according to the labor input, and the leading private stream is already allocated in it. Therefore, the task of isolating and linking the leading flows among themselves is primary, and the task of subordinating the found intensity of other flows is secondary. At a minimum, such flows have reserves (temporary, resource), which provide the possibility of optimization actions. The main approaches to the formation of calendar plans can be grouped into the following principal schemes (Table 2).

**Table 2**

Number of the scheme in order	Attribute	Initial condition	Algorithm
Scheme 1	Constant intensity of work performed $J_i^B \rightarrow const,$ where $J_i^B$ - work intensity of $i$ -leading flow.	The intensities of the leading flows have a constant value throughout the calculation period	<ol style="list-style-type: none"> <li>1. The contractual terms are checked.</li> <li>2. Determine the need for labor <math>R_i^B</math>.</li> <li>3. Linked <math>R_i^B</math>.</li> <li>4. Schedules of labor's movement.</li> <li>5. The schedules are corrected.</li> <li>6. Determine <math>R_i^B</math> for another efforts</li> </ol>
Scheme 2	The varying intensity of the work performed	The intensity of the leading flows is set by the variable throughout the calculation period.	<ol style="list-style-type: none"> <li>1. The contractual terms are checked.</li> <li>2. The intensities for the time periods and the technological stages are calculated.</li> <li>3. Determine <math>R_i^B</math> of leading processes.</li> <li>4. Adjustment is made in the workforce</li> <li>5. Determine the size of the need for labor for other, non-leading processes.</li> </ol>
Scheme 3	With the prioritization of	1. The intensity of the execution of the	1. All objects are allocated by priority

Number of the scheme in order	Attribute	Initial condition	Algorithm
	objects	<p>leading streams can be either constant or variable.</p> <p>2. The lead time should not exceed the prescriptive (normative) duration</p>	<p>2. Contractual terms are checked for all objects lying on the critical path</p> <p>3. The intensity of the leading streams is calculated</p> <p>4. Determine <math>R_i^B</math> with the necessary adjustment</p> <p>5. Determine other <math>R_i</math></p>

### 3. Conclusion

3.1 Authors proposed a two-component instrument for the formation and optimization of calendar plans and resource support for annual production programs of construction organization, capable of promptly responding to fluctuations in the economic and construction systems under the influence of destabilizing factors (addition of new contract, etc.).

3.2 In the practically widespread intuitive scheme of transferring the share of effort to a subcontractor, a scientific methodology is developed that allows, depending on the organization's capacity and the total amount of effort, to determine the required minimum amount of General Contractor's effort that provides management and control over the construction sites.

3.3 The indicator  $K_{csm} \in [0.5; 1]$  is entered with the range of admissible values, which establishes the boundary conditions in determining the Variable part of the SDSW.

3.4 The minimum value of the indicator  $K_{csm}$ , necessary and sufficient for the General Contractor's management instrument, is proposed.

3.5 Three principal schemes for the formation of calendar plans are proposed depending on the parameter of the intensity of the work performed by the leading stream on critical works.

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