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Aspects of Heuristic Method of Forming and Assessing the Plan of Contractor Works

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ABSTRACT

Background: In market conditions, approaches to planning construction operations have fundamentally changed, forcing construction companies to independently form production plans for contract work, seek financial resources and purchase means of production. **Objective:** Is to select and justify the optimal technology that are in good agreement with the level of information systems of construction companies. **Methods:** Studies have been carried out using general scientific methods - system analysis, logical and mathematical modeling, systems theory, as well as methods of operations research and economic and mathematical methods, economic-visual modeling, research methods of operations. **Results:** The necessity of reducing the problem of efficiency criteria and limitations to a system-target model based on the structure hierarchy of the system under study and the corresponding modeling of the reconstructed system of creating a sound statistical choice. **Conclusion:** The elements of multicriteria and system optimization methods, simulation modeling, etc. used in the formation of contract work plans do not allow obtaining rational decisions due to the lack of complete and reliable information. The whole process of planning, and especially the mechanism of annual (current) planning, has become much In this regard, it is advisable to use heuristic approaches.

KEYWORDS: programme content of work experience programmes, leadership of the construction industry, work environment, chronology of the construction industry, minimum wage of resources conservation.

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Aspectos del Método Heurístico para elaborar y evaluar el plan de obras del contratista

RESUMEN

Antecedentes: En las condiciones del mercado, los enfoques para la planificación de las operaciones de construcción han cambiado fundamentalmente, lo que obliga a las empresas constructoras a elaborar de forma independiente planes de producción para trabajos por contrato, buscar recursos financieros y comprar medios de producción. Objetivo: Seleccionar y justificar la tecnología óptima que concuerde con el nivel de sistemas de información de las empresas constructoras. Métodos: Los estudios se han llevado a cabo utilizando métodos científicos generales: análisis de sistemas, modelado lógico y matemático, teoría de sistemas, así como métodos de investigación de operaciones y métodos económicos y matemáticos, modelado económico-visual, métodos de investigación de operaciones. Resultados: Hay la necesidad de reducir el problema de los criterios y limitaciones de eficiencia a un modelo de sistema objetivo basado en la jerarquía estructural del sistema en estudio y el modelado correspondiente del sistema reconstruido para crear una elección estadística sólida. Conclusión: Los elementos de métodos multicriterio y de optimización de sistemas, modelado de simulación, etc. utilizados en la formación de los planes de trabajo de los contratos no permiten obtener decisiones racionales por falta de información completa y confiable. Todo el proceso de planificación, y especialmente el mecanismo de planificación anual (actual), se ha vuelto mucho más complejo. En este sentido, es aconsejable utilizar enfoques heurísticos.

PALABRAS CLAVE: Contenido de los programas de prácticas laborales, liderazgo de la industria de la construcción, clima laboral, cronología de la industria de la construcción, salario mínimo de conservación de recursos.

Introduction

The objective of the article:The ideology of the heuristic approach for determining the organizational and technological parameters of a comprehensive plan for organizing work at all objects of the annual production program is to identify the main leading works of a construction company, ensuring their continuous implementation by a permanent team of workers and then linking the remaining general construction works to the leading works with such a rhythm of execution, at which the minimum cost is achieved. At this stage of economic development, and especially in conditions of uncertainty of the initial information, it seems

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appropriate to use heuristic approaches, which, as a rule, are in good agreement with the level of information systems of construction companies (Podolski, 2017;Hejducki1, Tzarenko, Kamolov &Yurgaytis,2021; Hejducki &Łodożyński, 2019).

The most important condition for the effective operation and development of construction companies is the planning of construction operations, which allows not only taking into account the influence of external and internal environmental factors in advance, but also using the maximum achievements of science and practice in the field of rational use of all types of resources.

Nowadays, there are about 280 thousand construction companies in the construction industry, of which 99.1% are privately owned organizations. The scope of work performed by construction companies is constantly growing (Table 1), but at the same time, their structure remains basically stable.

Table 1. Dynamics of the scope of work performed by construction companies

Years	Scope of work	
	actual (billion rubles)	in relation to the previous year (%)
2005	1754.4	113.2
2010	4454.2	105.0
2015	7010.4	96.1
2018	8470.6	106.3
2019	9132.2	102.1
2020	9553.1	100.7

The transition to market relations has significantly changed approaches to planning construction operations, setting new priorities, and forced construction companies to independently form a production plan for contract work, seek financial resources and acquire means of production. As a result, the entire system of investment activity has fundamentally changed, ensuring the implementation of a wide range of products and services, from project marketing to guaranteed maintenance of commissioned buildings and structures (Oleinik&Yurgaytis, 2020).

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In this regard, the planning of construction operations becomes the most important condition for the effective operation and development of construction companies, since, on the one hand, it takes into account the influence of the entire set of factors of the external and internal environment, and on the other hand, it makes the most of the achievements of science and practice in the field of rational use of resources – financial, labor, technical, material, energy, etc. But at the same time, the entire planning process, and especially the annual (current) planning mechanism, which is directly affected by fierce competition, a constant lack of working capital, economic system failures, has become significantly more complicated. It is also actively affected by a high degree of uncertainty with the use of leased mechanization equipment, insufficient qualifications of workers, and the quality of domestic building materials and raw materials. As a result, construction companies are forced to form a contract work plan for the entire current period, including volumes of even non-core construction and installation works (Oleinik&Yurgaytis, 2017).

In many, especially large, construction companies, elements of multicriteria and system optimization methods, simulation modeling methods, and various man-machine methods are used in the formation of contract work plans (Arashpour, Wakefield, Abbasi, Lee&Minas, 2016; Krzeminski, 2016; Pournader, Tabassi&Baloh, 2015; Avisoa, Mayolb, Promentillaa, Santosc, Tana, Ubandob&Yud, 2018; Yi Su, Lucko, 2016). But the use of most of these methods requires clear formalized criteria and complete and reliable information on all aspects of annual planning, which is practically impossible, and therefore the modeling results are unsatisfactory (El-Abbasy, Elazouni, & Zayed, 2016; Markou, Koulinas& Vavatsikos, 2017; Francis, 2015; Krzeminski, 2017; Venkrbec, Galić, Klanšek, 2018).

1. Materials and Method

1.1. Plan formation procedure

Nowadays, during the construction of facilities, software systems are widely and universally introduced into the design process, which make it possible to simulate a constructed object in three-dimensional space (3D). These software systems allow you to further automate the receipt of layout drawings. Each adjustment that is made to the model is

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automatically changed in the corresponding drawings. Modeling in 3D space significantly improves the quality of products by personnel, organizational and technological solutions become well-developed, which in turn minimizes the likelihood of collisions in the area of matching spatial models. Using the calendar and network schedule (CNS) of the project as a process model, which reflects the sequence and dependence of the work, allows calculating the most time-efficient way to efficiently perform the most complex work, especially at large facilities and with a large number of construction and installation works.

The vast majority of construction companies to some extent use in their activities the entire arsenal of the planning system, which consists of four levels – general, strategic, annual (current) and operational planning (Fig. 1). The need for such an approach is dictated, first of all, by economic feasibility, maintaining a balance of interests of the company and society, taking into account the conjuncture and development trends of the construction market. At the same time, the continuity of the planning level ultimately becomes the decisive factor in ensuring the high efficiency of management decisions of a construction company regarding the use of all types of resources.

The annual production program of the construction company is formed on the basis of the concluded contracts. At the same time, the receipt of state construction orders is carried out through contract tenders (competitions). But in any case, obtaining a contract takes place in conditions of fierce competition. Of particular importance is the form of the contract price, which can be accepted both on the basis of the project price and on the terms of reimbursement of the actual cost of construction at current prices for material and technical resources.

To determine the contract price, as a rule, current methodological materials, construction cost calculations for the project, feasibility studies, price lists tied to local conditions, data on the actual cost of analogue objects and other information convincing to the contracting parties are used.

Prior to the conclusion of a construction contract, a construction company, as a rule, conducts pre-contractual work with a potential customer, which consists in mutually establishing the intentions of the contracting parties.

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At this stage of negotiations, the construction company assesses its capabilities, the contracting parties agree on a list of mutual services, the term for the implementation of the contract, the preliminary price of the object or the principle of its establishment. For this, the following activities are carried out:

- The estimate documentation or the estimated cost of the object's construction is checked if the contract is concluded on the basis of a preliminary design or a feasibility study.
- Preliminary considerations for the organization of construction are developed for the preliminary design or feasibility study, the additional costs associated with this are determined.
- The possibilities of using for the construction of the facility their own means of mechanization, equipment, the need to attract them from outside are assessed, the costs for these purposes are determined.
- Protocols of intent with subcontractors, suppliers of basic building materials, if necessary, with design enterprises are coordinated and signed.
- The list of mutual obligations of the contractor and the customer is specified.
- The duration of construction is substantiated.
- A rationale and a proposal for the amount of the contract price are being developed.

As a result of this pre-contractual work, it is desirable to have a protocol of intent signed by the contracting parties, which has legal force and gives grounds for including the construction of the facility in the production program, obtaining or developing project documentation, drawing up similar protocols with subcontractors and suppliers.

The construction contract specifies and details the decisions made in the protocol of intent. After signing the contract, all previous agreements on the subject of the contract become invalid.

Under a capital construction contract, the contractor undertakes to build and hand over the object specified in the contract within the established period or to perform the

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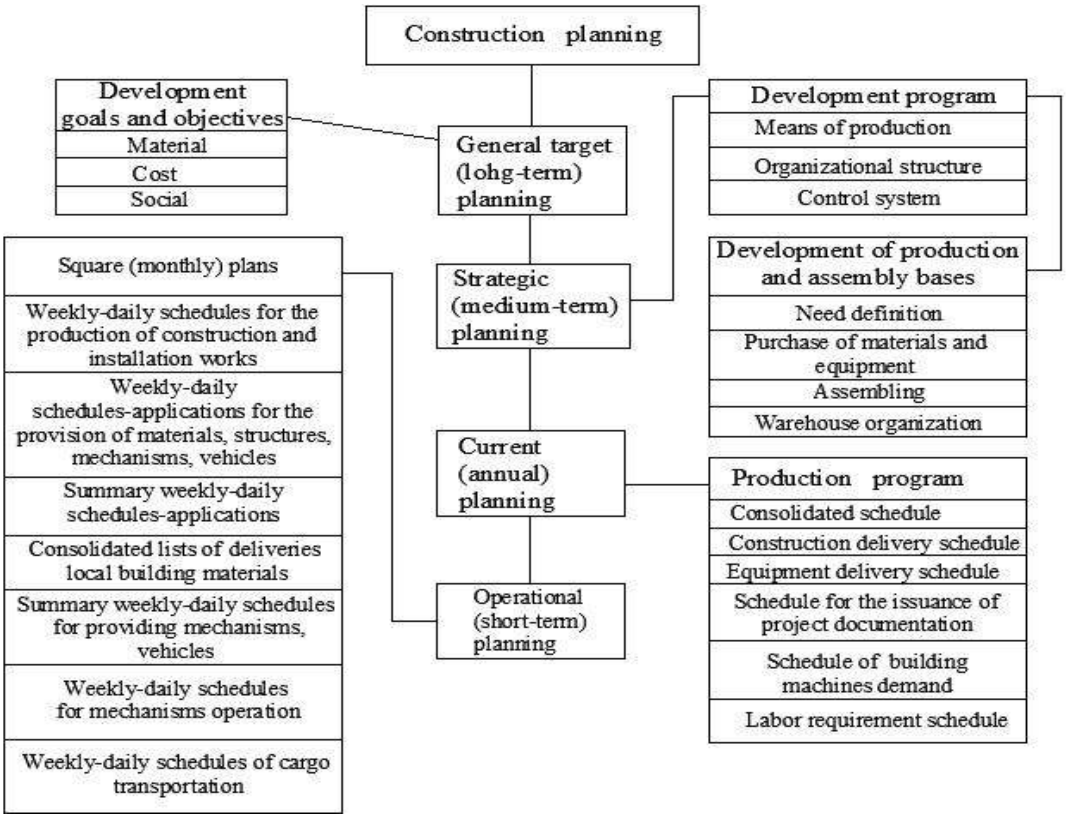
construction work stipulated by the contract, and the customer undertakes to provide the contractor with a construction site or provide a range of work, accept them and pay.

Figure 1. The structure of the planning system in the construction industry



The contract contains general and special conditions. The general conditions are determined by the current legislation and remain unchanged, as a rule, for all cases. The contracting parties include additional agreed obligations in the special conditions.

Special conditions of the contract are formed on the basis of the balance of economic interests of the customer and the contractor, determine their further production and economic relations and can be revised only with their mutual consent.

The rights of the contracting parties are protected by the legislation of the Russian Federation. For this, the construction contract must be legally correct. Its provisions should cover the necessary scope of relations between the customer and the contractor, avoiding their double interpretation.

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In the course of entering into significant construction contracts, it is advisable for the general contractor to consult with the main specialized construction companies, which he intends to use as subcontractors in the future.

When forming the production program, the general contractor is recommended to reserve the scope of work in accordance with his specialization, the implementation of which will ensure the disclosure of a wide range of work for the involved subcontractors.

As a model for determining the organizational and technological parameters of the construction of the entire set of objects, a comprehensive (consolidated) calendar plan for the organization of work for the annual program of the construction company is being developed. Such a plan allows determining:

- The total volume of construction production, broken down by type of work performed both on its own and by subcontractors.
- The optimal sequence, duration and timing of the construction of start-up facilities, stages, quarters.
- Rational sequence, duration and intensity of production of certain types of work.
- The general need for material and technical resources, broken down by objects and types of work, and the timing of their delivery.
- Volumes and terms of delivery and installation of process equipment for each facility.
- Terms and volumes of development and issuance of design, working, organizational and technological documentation.

1.2. Ideology of the Heuristic Approach

The ideology of determining the organizational and technological parameters for the construction of all facilities included in the annual production program is as follows:

- The main leading works are selected; their volume for all objects of the annual program is summed up, and the need for workers for each time period is calculated; a balance is made between the need and the actual availability of workers of the corresponding profession in a construction company; the need for workers for the remaining general construction work is established for each time period; such works are linked to leading works according to

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organizational and technological parameters; the degree of rationality of the resulting variant is assessed; the baseline is accepted (or revised) and submitted for approval.

This ideology is realized under the following conditions:

- The duration of the construction of facilities should not exceed the deadlines specified in the contract agreements (contracts), i.e.

$$T_i \le T_i^D i = 1, 2, 3, \ldots n (1)$$

where T_i, T_i^D –the estimated and directive duration of construction of the i-th object, respectively;

- The need for workers to perform leading general construction works is constant in each time period and corresponds to their actual availability in a construction company with their full equipment with appropriate means of mechanization and labor protection, i.e.

$$\sum_{i=1}^{n} \tau_{ij}(t_k) = a_j(t_k) \begin{matrix} i = 1, 2, 3, \ldots, n \\ j = 1, 2, 3, \ldots, m \\ k = 1, 2, 3, \ldots, p \end{matrix} (2)$$

where $\tau_{ij}(t_k)$ – a function that determines the need for workers to perform the j-th leading work on the i-th object in the t_k time period;

$a_j(t_k)$ – a function that determines the actual availability of workers to perform the j-th leading work in t_k time period.

- The need for workers for the remaining general construction work should not exceed the calculated value for each time period.

$$\left[a_l(t_k) - \sum_{i=1}^{n} \tau_{il}(t_k)\right] = d_l(t_k) \begin{matrix} i = 1, 2, 3, \ldots, n \\ l = 1, 2, 3, \ldots, q \\ k = 1, 2, 3, \ldots, p \end{matrix} (3)$$

where $\tau_{il}(t_k)$ – a function that determines the need for workers to perform the remaining l-th general construction work on the i-th object in the t_k time period;

$a_l(t_k)$ – a function that determines the actual availability of workers to perform the remaining l-th general construction work in the t_k time period.

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At the first stage, the main processes leading the construction company's own forces, which have the largest volume and duration of execution, are established. For example, during the construction of the above-ground part of multi-storey residential buildings, such processes are the installation of load-bearing and enclosing structures, including welding of connecting elements at the junctions of structures and the arrangement of joints of enclosing structures. These processes are then linked to the remaining general construction works, such as the installation of partitions, the installation of door blocks and railings for balconies and flights of stairs, the preparation of floor, the installation of elevators and equipment rooms, as well as the first stages of sanitary and electrical work.

When performing finishing works, the leading work is painting, which, as a rule, is carried out in two stages – surface preparation and their final painting. The rest of the finishing work is adjusted to the pace of this leading work – tiling, carpentry, wallpaper, flooring, as well as the final stages of sanitary and electrical work.

The leading process in industrial construction is the process of erecting load-bearing and enclosing structures. Therefore, the chosen method of erecting the building frame and the installation of technological equipment determine the essence of the technology for erecting an object.

1.3. Building the Model

Further, the volumes of the leading process are summarized for all objects of the annual program of the construction company on a time scale (day, week, month), taking into account the duration of the construction of objects. Based on the total annual volume of work, expressed in terms of labor intensity, and the annual fund of working time, the estimated value of the workforce required to complete the leading process is determined:

$$a_j(t_k) = \frac{\sum_{i=1}^{n} V_{ij}}{T} = b_j(4)$$

where V_{ij} – annual volume of work (labor intensity) for the leading process at the i-th object;

T – annual fund of working hours.

b_j is a constant value during the year under consideration (Fig. 2)

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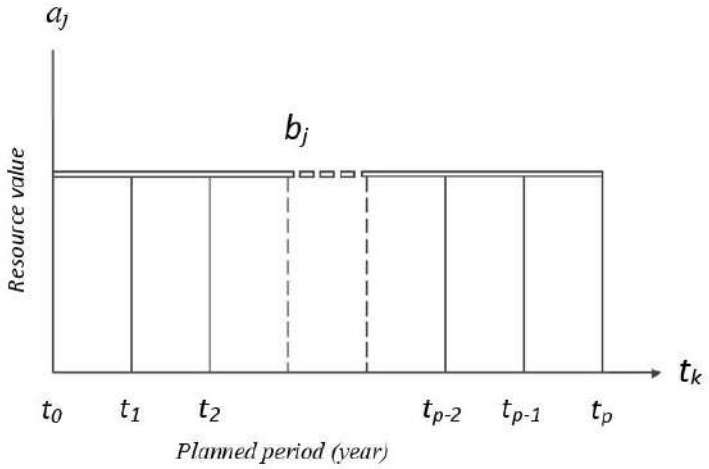
Figure 2. Distribution plot of $a_j(t_k)$ over time

$$b_i \Longrightarrow const(5)$$



The remaining l-th general construction work will be carried out by workers

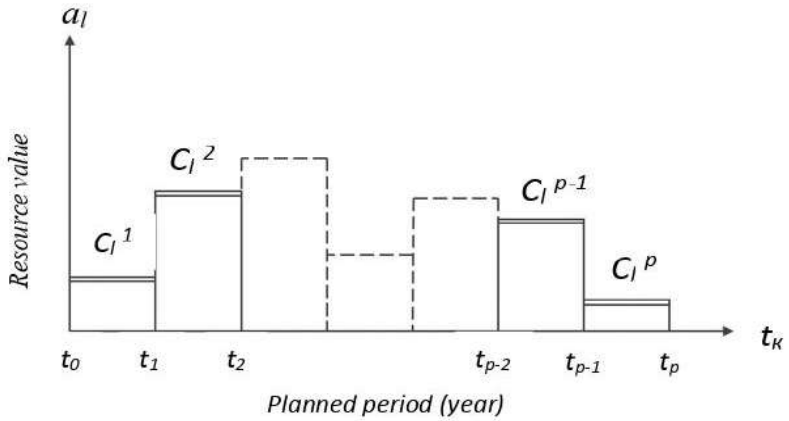
$$a_l(t_k) = C_l^o \Longrightarrow const(6)$$

But this requires careful coordination of the rhythm of their work with the rhythm of the leading process. As a result, the workforce demand schedule will be expressed as a piecewise linear function of the workforce distribution over time

$$\tau_l(t_k) = C_l(t_k)(7)$$

Within each time interval, the value of working frames will be constant (Fig. 3).

Figure. 3. Distribution plot of $\tau(t_k)$ over time



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The analytical expression for a piecewise linear function has the form

$$a_l(t_k) = \sum_{k=1}^{p} \left[C_l^{k+1} - C_l^k\right] \psi(t - t_k) (8)$$

where $\psi(t)$ – Heaviside function taking the following values:

$$\psi(t - t_k) = \begin{Bmatrix} 1, \text{at } t \geq t_k \\ 0, \text{at } t < t_k \end{Bmatrix} (9)$$

Outside the planning period, the values of C_l^k are:

$$C_l^o = C_l^{p+1} = 0 (10)$$

Now we can proceed to the mathematical formulation of the task of organizing the work of the annual program of a construction company in the form of linear relationships consisting of a goal function and constraints. The conditions of such a problem can be represented in the form of a functional

$$[C_l^o - C_l(t_k)] \rightarrow min (11)$$

under the following constraints

$$\left.\begin{matrix} a_j = b_j \\ T_i \leq T_i^D \end{matrix}\right\} (12)$$

2. Results

If these conditions are met, the resulting work organization plan is satisfactory and can be used as the basis for the annual production program of the construction company.

If

$$\begin{matrix} C_l^o > C_l(t_k) \\ a_j > b_j \\ T_i \leq T_i^D \end{matrix} \quad (13)$$

then, consequently, there are resource reserves for additional inclusion of new objects in the plan.

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The most difficult cases arise when $C_l^o < C_l(t_k)$. In this case, the following solutions may take place:

1. When constraints (12) are met, the plan can be accepted if

$$C_l(t_k) - C_l^o < q(t_k) \quad (14)$$

The value "q" characterizes the reserves for performing the l-th work due to the combination of professions. The professions of an installer and a carpenter, a carpenter and a concrete worker, an electric welder and an installer, an insulator and a roofer, etc., are well combined. The normative labor intensity of work performed in combination should not exceed 15% of the total labor intensity.

2. When restrictions (12) are met, the plan must be adjusted in the direction of reducing the amount of work, if

$$C_l(t_k) - C_l^o(t_k) > q(t_k) \quad (15)$$

In this case, the magnitude of the reduction in the volume of work should be proportional to the indicator Δq, which determines as

$$q(t_k) - q^o(t_k) = \Delta q(t_k) \quad (16)$$

where $q^o(t_k)$ – the number of workers corresponding to the maximum standard labor intensity of work performed in combination.

In addition to these most common cases, there may be others with various combinations of (11) and (12). So, for example, when

$$\begin{gathered} a_j > b_j \\ T_i \le T_i^D \\ C_l(t_k) - C_l^o < f(t_k) \end{gathered} \quad (17)$$

The resulting plan can be supplemented with new objects until the following values are obtained

$$\begin{gathered} a_j = b_j \\ f(t_k) = q^o(t_k) \end{gathered} \quad (18)$$

In the event that at

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$$\begin{gathered} a_j < b_j \\ T_i \le T_i^D \\ C_l(t_k) - C_l^o > f(t_k) \end{gathered} \quad (19)$$

then the resulting plan needs to exclude a certain amount of work before reaching

$$\begin{gathered} a_j = b_j \\ C_l(t_k) - C_l^o < q^o(t_k) \end{gathered} \quad (20)$$

In addition, in cases where for some i-th objects the inequality $T_i > T_i^D$ is observed, then this indicates the unacceptability of the decisions and the need to revise them before restoring $T_i \le T_i^D$.

3. Discussion

The decisive stage in the planning of construction operations is the formation of an annual production program of contract work, the model of which, ultimately, is a comprehensive plan for organizing work at all objects of the annual program with the definition of organizational and technological parameters that link all types of general construction, installation and special work on resources in time and space.

The plan for organizing the work of the annual production program is considered satisfactory when the minimum costs for the use of workers in the production of non-basic works are achieved with the obligatory fulfillment of the following restrictions – the duration of the construction of each facility should not exceed the directive deadlines, and the total need for workers for all major leading works of the annual program must correspond in each time period to their actual presence in the construction company. If the above conditions are met, the resulting plan is taken as the basis for the annual production program of the construction company(Kazaryan,2021a, 2021b).

Conclusions

To date, there is vast and unique domestic and foreign experience in pioneer development of territories and the construction of a wide range of concentrated and linearly extended objects. The concept of aggregating material resources into large industrial units on factory floors, delivery to construction sites and their subsequent in-line installation has become a

new technical basis for the construction of enterprises, buildings and structures. The ideology of the proposed heuristic method is based on the continuous and uniform performance of the leading work on all objects of the annual program by a permanent team of workers, while linking the remaining works to the leading work with such a rhythm that ensures the minimum of all costs. At the same time, a prerequisite is compliance with the construction deadlines specified in the contract agreements (contracts). Due to the rapid progress in mobile construction methods, the level of industrialization in building projects has significantly risen. This is primarily due to the practice of preassembling construction materials into sizable units and transportable blocks. This approach serves as the foundation for future large-scale construction projects (Garanin, Lukashevich, Chernorutsky, et al, 2022).

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