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Assessing the readiness of mobile construction organizations for project execution

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Abstract: Active development of remote hard-to-reach areas obliges construction organizations to significantly increase the mobility of their units, capable of autonomously functioning in difficult natural and climatic conditions. For these units to perform production and public utilities functions, appropriate labor and material and technical resources are required. At the same time, almost every job can be performed by various combinations of resources, the options of which differ from each other in technical and economic indicators. The development of such options depends on the type and conditions of the facility construction, the level of specialization and concentration of resources, the availability of these resources, etc. In this regard, the principle of resource substitutability is especially significant for mobile units the proficiency of workers in related trades, the creation of sets with various means of technical equipment for teams. To select resources for mobile units, a scheme for assessing the readiness of a construction organization for work execution is proposed, which provides an assessment for each brigade and an overall assessment of the construction organization. At the final stage of assessment, integral parameters are established separately for labor resources and technical means of their equipment.

Keywords: *Indicator of readiness to perform a brigade work package, Integral indicator of a construction organization's mobility level, Labor resources, Mobile units, Selection of resources, Technical equipment.*

1. Introduction

Nowadays, many construction organizations are significantly increasing the level of mobility of their units to fulfill various orders outside their permanent locations and construction industry bases. In many cases, such orders are large-scale and multi-year, which ensures high stability of construction organizations in the face of high competition. Of course, transferring a construction organization to the mobile category requires a whole range of administrative, organizational, and technical measures, including the development and approval of the relevant regulations, maintaining an order on the transfer of employees to mobile forms of work organization, concluding additional agreements to employment contracts, developing work schedules, and determining the procedure for remuneration, etc. Among all these activities, the most complex and difficult to implement is the selection of the composition of work brigades and sets of their technical equipment. The problem is that the mobile unit will have to operate autonomously throughout the entire contract period, typically under difficult natural and climatic conditions, performing a full range of production and support tasks [1-5]. At the same time, their significant remoteness from the places of permanent deployment and logistics bases does not allow for an optimal set of relevant resources in each time period.

2. Materials and Method

The activities of the mobile unit in the area of development of new territories begin with the pioneer period, intended for the implementation of measures on life support, deployment of the material and

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technical base, and preparation of territories for future objects and routes of off-site communications. As part of the basic nomenclature during this period, work is carried out on:

- Housing, providing workers with food, medical care, utilities, and living conditions;
- The establishment of receiving and storage areas, the reception of workers, machines, equipment, materials, and structures from base centers.
- Deforestation, drainage of swamps, assembly (erection) of residential, industrial, storage, and auxiliary inventory buildings, laying of utility lines.

Almost from the first days, the activities of mobile units include a full range of production and public utility functions, which are grouped into the following areas: labor, production, non-production, and engineering (Table 1).

To perform the above-mentioned works and functions, appropriate labor, materials, and technical resources are required in the form of brigades, complexes, sets, kits, etc [6-9]. For labor resources, such organizational forms as a link, brigade, section, and management are used. Grouping options for the use of technical resources are much more complex due to their great diversity in nomenclature, productivity, etc. For example, in the engineering sphere, a wide variety of power plants and energy complexes can be used (Table 2).

In this regard, each job (function) can be performed by various combinations of resources that differ from each other, primarily in technical and economic indicators [6, 10-18].

Table 1.
The main non-production functions of mobile units.

Field of activity	Main functions
Non-production	• Provision of housing conditions. • Utility services (electricity, water and heat supply, water disposal, provision of furniture sets, showers, dryers, television and radio receivers, etc.). • Household services (bath services, provision of services for repair and washing of linen, dry cleaning, creation of metal repair points, watch repair shops, hairdressers, etc.). • Food (organization of at least three meals a day). • Trade services (sale of food products, industrial goods, etc.). • Medical services (organization of health centers, provision of medical care, preventive measures, etc.). • Transport services (delivery of workers to and from work, travel to cultural events, etc.). • Cultural services (creation of a library collection, provision of newspapers and magazines, equipping premises with television and video equipment, creation of visual propaganda stands, etc.).

The development of such options depends on the type and conditions of the facility's construction, the level of specialization and concentration of resources, and finally, the availability of this resource in the area of work. To date, technological complexes of technical means for construction, installation, and specialized types of work have been developed, along with equipment inventories for work brigades, including small mechanization tools and hand tools. For example, to perform work on cutting down trees and clearing the territory, workers of different specialties are required (Table 3). In this case, the composition of technical means, taking into account the coefficient of their use (0.46 thousand sq.m./person-year), will represent the technological set presented in Table 4.

Technological equipment in construction includes, for example:

- Containers, packaging equipment, storage units for construction materials;
- Formwork, devices, and equipment for sealing and monolithing joints and seams;
- Lifting devices and equipment, assembly equipment, attachments for soil compaction;
- Inventory means for storage, fencing;

- Scaffolding for construction;
- Special technological equipment (chemical, metalworking, forging and pressing, thermal, welding, and others);
- Control and testing equipment and apparatus (stands, panels, models of finished products, test stands);
- Technological kit for the performance of work on deforestation, clearing, and planning of the territory.

Table 2.
Power plants and energy complexes used in construction.

Type (Model) of the installation	Performance (power), kW
Diesel power plant KAS-500 BAM and AES-500 BAM	500
Diesel power plant PE-5 (railcar)	1050
Automated gas turbine power plant PAES-1600	1600
Gas turbine power plant GTE-2500	2500
Gas turbine power plant GTE-4000	4000
Energy complex 504-34M	465
Diesel power plant PES-100	100
Automated diesel unit ASDA-10	100
Automated diesel unit PSDA-200	200
Power plant 420-04-24	27100
Mobile diesel power plant ESD-300030-T/400m	200

Of particular importance for the operating conditions of mobile units is the principle of resource substitutability by functional feature, according to which all resources are divided into interchangeable, replaceable, and individual [14]. The principle of resource substitutability by functional features of mobile units means that the resources of construction production within their type are subject to the principle of interchangeability or replaceability by functional specialization. The effect of this provision extends to almost all types of construction and installation works. Substitutable resources are those that, according to their functional parameters, can perform or service homogeneous construction processes as low-priority resources. With regard to labor resources, the principle of interchangeability and replaceability is expressed by workers' mastery of related trades. For example, workers in a comprehensive general construction brigade widely master such trades as concrete worker, carpenter, installer, bricklayer, and others, while workers in a comprehensive finishing brigade master related trades such as painter, plasterer, grout pump operator.

Table 3.
Brigade staffing calculation.

Name of the specialty	Per brigade	Per specific indicator of work volume
Carpenters (part-time installers and riggers)	2	4
Carpenters	2	4
Joiners	2	4
Plumbers (part-time gas welders)	1	2
Electricians	1	2
Total	8	16

Thus, interchangeable resources are those that, by their characteristics, can equally perform or service homogeneous processes and are therefore resources of the same order. At the same time, replaceable resources are those that, by their characteristics, can perform or service homogeneous processes as resources of a lower order. If a resource, due to the prevailing conditions, cannot be interchangeable or replaceable, then it becomes individual.

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Table 4.
List of technical equipment for workplaces.

Name of technological kits	**Name of technical means**	**Number of standard sets per specific indicator of the annual program, pcs.**	**Number of products for everyday use, pcs.**	**Reserve of technical equipment, pcs.**	**Total, pcs.**	**Amount of means per specific indicator of work volume, pcs.**
Technological kit for production of works on logging, clearing and planning of the territory	Pneumatic chipping hammer					
	Gasoline saws		5	1	6	24
	Inventory transition bridge		4	2	6	24
	Portable ladder					
	Portable lighting installation		9	2	11	44
		4				
			2	1	3	12
			3	1	4	16

The specified principle, as applied to labor resources, is implemented through workers' mastery of related trades. For mobile unit brigades, this indicator is usually very high and ranges from 55% to 92%. For example, in a general construction complex brigade, workers master trades such as concrete worker, reinforcement worker, installer, carpenter, bricklayer, etc., and in finishing work brigades - trades like painter, plasterer, grout pump operator, etc. (Table 5).

Table 5.
Indicators of proficiency in related professions (fragment).

Plot No.	Full name of the foreman	Brigade staffing	Profession of workers	Average job grade	Number by profession	Proficiency in related professions		Output per person-day, m^3		
						Profession	Number	Normative	Actual	Taking into account the labor intensity coefficient
Plot IV	Klimov V.Ya.	16	Installer	3.2	4	Installer	5	1.89	1.83	3.38
			Carpenter		4	Concreter	3			
			Bricklayer		3	Electric Welder	1			
			Electric Welder		3	Fitter	2			
						Rigger	1			
						Tiler	1			
						Transport Worker	1			
	Efremov N.I.	18	Installer	3.05	6	Fitter	5	1.84	2.69	3.65
			Fitter		1	Rigger	5			
			Carpenter		4	Concreter	4			
			Bricklayer		2	Transport Worker	2			
			Electric Welder		5					

The combinations of technical resources are even more varied. For example, cutting the topsoil and uprooting stumps and bushes can be done using a stump collector, bulldozer, excavator, tractor with a winch, stump-pulling harrow, etc.

3. Results and Discussions

This complete list of types of works and services provides an objective basis for the selection of labor resources and their technical equipment. At the same time, the composition of the selected resources depends on the form of work organization rotational, expeditionary, or rotational-expeditionary [6, 18, 19]. In turn, the choice of the form of work organization is influenced by factors such as the characteristics of the construction area, the features of the object being erected, its remoteness from the location of the construction organization, the actual capabilities of the construction organization, etc. Regarding the selected form of work organization, the composition of brigades is calculated, which can be either comprehensive or specialized, using work production projects, process maps, and calculations of labor costs and wages for the construction of the object. The criterion for forming an optimal brigade composition is that the average skill level of the workers corresponds to the average category for the brigade's work complex, with a possible discrepancy of no more than ±0.2. The scheme for assessing the readiness of a mobile construction organization is shown in Figure 1.

The choice of mechanization means for construction and installation works is provided in the form of sets of auxiliary machines operating in the optimal mode. Each set consists of the main machine and

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auxiliary machines. In this case, the main machine determines the rhythm of the flow and the duration of the brigade's work complex.

$$T = 100 \cdot H / m \cdot h \cdot \tau \cdot \eta \quad (1)$$

where T – duration of the brigade's work complex;

H – standard machine time costs for performing a brigade's work complex by the main machine, machine-hours.

m – number of main machines;

h – planned level of performance of the main machine, %;

τ – duration of work shift, h.;

η – number of work shifts.

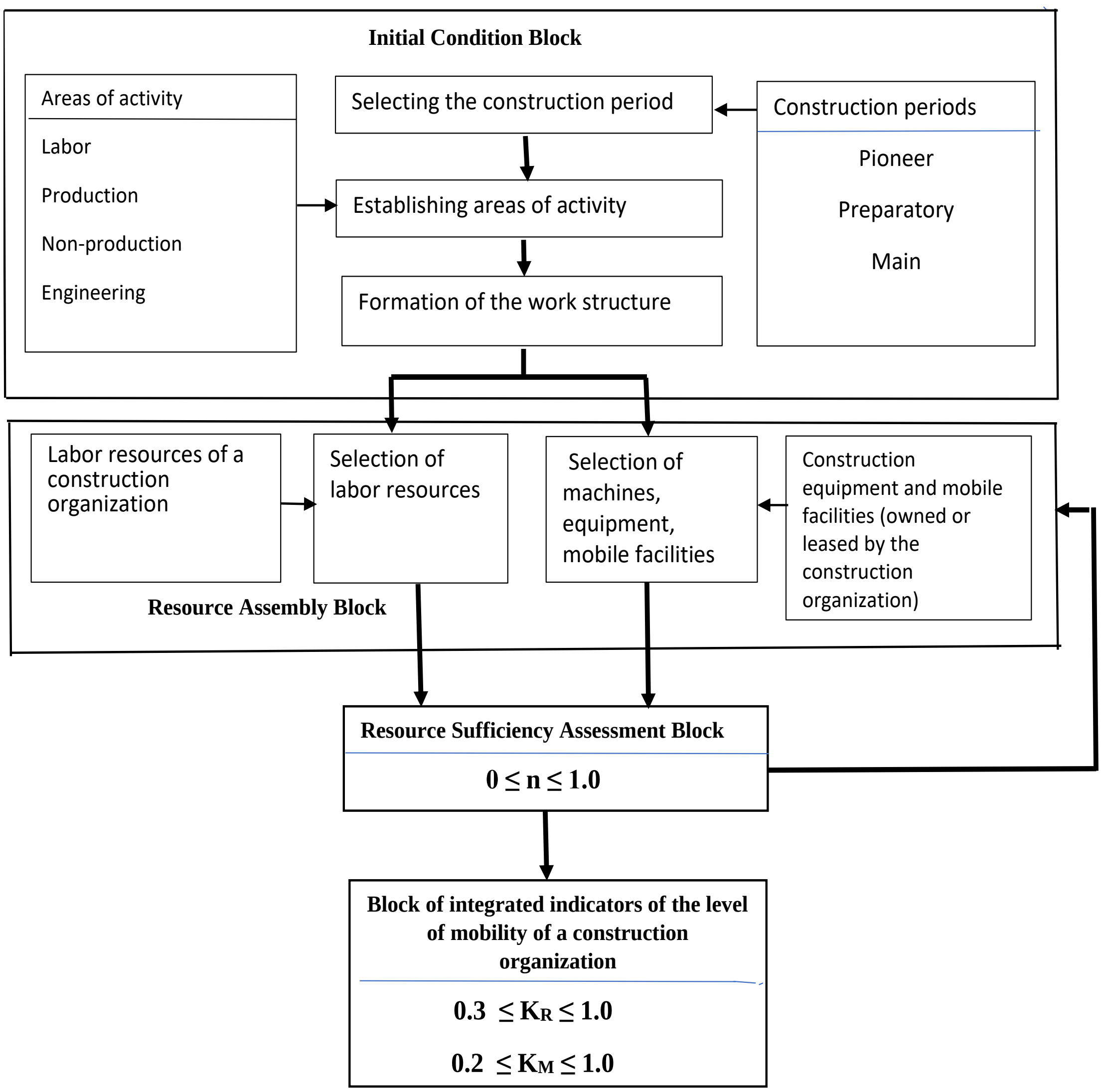

Figure 1.
Scheme for assessing the readiness of a mobile construction organization to carry out work.

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The duration of the brigade work complex can also be determined through the shift-based operational productivity of the main machine:

$T = 100 \cdot V / P \cdot h$ (2)

where V – volume of work in physical units, sq.m., cu.m., t, etc.;

P – shift-based operational productivity of the main machine, sq.m./cm., t./cm., etc.

When performing tasks that do not involve the main machine, their duration is accepted according to the project's calendar plan for work execution.

Full loading of mobile unit brigades, with the achievement of their continuity and uniformity, is ensured by combining professions. Therefore, when designing the structure of mobile units, the following provisions should be followed:

- Mandatory allocation of labor costs by types of work (or operations) from the total labor costs of the brigade;
- Use of technological dependence (connection) between processes performed in the main and combined professions;
- Identification of common elements in the technology and organization of processes performed in the main and combined professions (labor techniques, mechanization tools, devices, etc.).

The results obtained by taking these recommendations into account must be considered when developing a consolidated statement of standard labor costs for the performance of a brigade work complex.

At the next stage, the sufficiency of the selected resources for the production of construction and installation works is checked. For this purpose, an indicator of readiness for the performance of the planned brigade work complex is established for each work team:

$$n = I_1 / I = t / t_1 \quad (3)$$

where n – construction brigade readiness indicator;

I, I_1 – respectively, the design and estimated intensity of the brigade work complex;

t, t_1 – respectively, the design and estimated duration of the brigade work complex.

In this case, if the condition V = const, n = 1 is met, then the selected resource option can be accepted.

If these conditions are not met, the following cases may occur:

a). V = const., $n > 1$, then $I_1 > I$ and $t_1 < t$ and the estimated intensity of the brigade work complex is higher than the design one;

b). V = const., $n < 1$, then $I_1 < I$ and $t_1 > t$ and the estimated intensity of the brigade work complex is lower than the design one.

At the final stage of assessing the mobility level of a construction organization, integral parameters are established separately for labor resources and technical means of their equipment.

For labor resources, the integral mobility parameter is recommended to be defined as

$$K_r = G / R \quad (4)$$

where Kr – indicator of the mobility of a construction organization by labor resources;

G – number of employees of a construction organization working on a mobile basis;

R – number of employees of a construction organization according to the staffing schedule.

For technical equipment of work brigades, the integral indicator can be defined as follows:

$$K_M = \Sigma\Sigma F_{ij}^M / (\Sigma\Sigma F_{ij} + \Sigma M_l) \quad (5)$$

where K_M – mobility indicator of a construction organization based on technical equipment;

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F_{ij}^{M} – the cost of relocating the j-th mobile elements of the i-th group to construction areas;
F_{ij} – the cost of the j-th mobile elements of the i-th group in a construction organization;
M_l – cost of stationary elements in a construction organization.
Groups of mobile elements include machines, equipment, motor vehicles, special motor vehicles, mobile (prefabricated) buildings, formwork systems, prefabricated scaffolding, etc.

As practice shows, the minimum level of mobility of a construction organization is 0.2 - 0.3. Such construction organizations carry out work in the regions of their permanent deployment. A construction organization can be considered highly mobile if its indicators fall within the range of 0.8 to 1.0. An indicator of 1.0 characterizes almost complete mobility of the entire structure of the construction organization. On average, most construction organizations carrying out work in regions remote from their permanent deployment sites have an integral mobility indicator within 0.86 - 0.92.

4. Conclusion

The increase in the mobility of construction organizations is primarily driven by the need to develop new territories in underdeveloped and hard-to-reach regions. The development of such territories begins with a pioneering period, which involves implementing organizational, economic, engineering, and technical measures for life support.

Autonomous performance of production and communal functions by mobile units in harsh natural and climatic conditions can be carried out by various combinations of resources, differing from each other in technical and economic indicators. In this regard, the principle of resource substitutability is especially important for such conditions, which, for example, for labor resources can reach 92%.

Many years of construction practice in underdeveloped and hard-to-reach regions have allowed us to develop the most rational approach to staffing labor and technical resources for mobile units. With regard to the selected form of work organization - rotational, expeditionary, rotational-expeditionary - the number and composition of work brigades are calculated taking into account the replaceability of workers by profession. The choice of technical equipment for brigades is provided in the form of sets with the allocation of the main and auxiliary machines.

The sufficiency of the selected resources for the performance of construction and installation works is checked for each work brigade by determining their readiness indicator. If the readiness indicator values are close to one, the selected resource option can be accepted. The integral parameters of the mobility level of a construction organization are determined separately for labor resources and their technical equipment. Most construction organizations working according to the form of mobile labor organization have integral indicators within the range of 0.86 - 0.92.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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