Mobile parks of construction machinery

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Abstract. Research subject: mobile parks of construction machinery. Objectives: substantiation of multifaceted approach to questions of mobile parks formation and functioning. Methods and materials: Considering the linear nature of the certain part of the construction projects development, in order to rationalize the production organization, it is necessary to explain and develop a methodology for establishing mobile parks of construction machinery (MPCM). The methods for stationary parks build-out are widely known, but the specifics of linear construction and new functional conditions require the use of economic and mathematical methods close to the actual production conditions, taking into account the probabilistic nature. Results: a phased, step-by-step approach to the formation of mobile parks of construction machinery with an appropriate feasibility is proposed. Conclusions: a complex, systematic approach to the development of mobile parks in construction will allow the task to use in practice.

1. Introduction

Considering the linear nature of the certain part of the construction projects development, in order to rationalize the production organization, it is necessary to develop and explain a multifaceted method for establishing mobile parks of road construction machinery. As the quality and efficiency of the linear construction depends on a number of factors, including one of the dominant ones, the issue of the condition and maintenance activity of construction machines and mechanisms that carry out a complex of installation and construction works. The level of condition implies the maintenance of equipment for a significant period of operation, high-quality and well-timed maintenance, repair and operation [1-4].

To ensure the above-mentioned characteristics, the most effective form of organizational service for the linear construction is mobile parks for construction machinery (MPCM), which has been repeatedly emphasized by many researchers [5-7].

The use of MPCM is especially justified for dispersed objects, in difficult climatic and geographical conditions, inaccessible, uninhabited regions with a harsh climate characteristic of large territories of the Russian Federation.

There are widely known methods for stationary RCM parks construction based on deterministic approaches in a planned economy. But changing operating conditions requires the use of economic and mathematical methods in a market economy, taking into account the probabilistic nature of the increased number of risks in the implementation of construction activities.

The structure of the MPCM should be formed with the help of the projected volumes of work, the main characteristics of the construction projects, taking into account the probabilistic nature of construction production, which can and should be reflected in the issues of equipment reservation. But
it should be emphasized that in a difficult financial situation, the reservation should be sufficient, but not excessive [10-12].

2. Materials and methods
The analysis of the researchers works involved in the problems of mobile parks use confirms that it is necessary to develop and introduce a complex methodology for organizing mobile parks of construction machinery to increase their efficiency. As a result, this can provide an increase of the works quality, a reduction of the linear objects construction cost and time [8].

Technical maintenance of construction is one of the most important criteria of its effectiveness. The number of equipment, as well as the means of mechanization, its nomenclature, condition is one of the dominant criteria of availability for construction and installation works. The quality of timely maintenance and repair greatly influence on MPCM operation capacity. That’s why the improvement methods of mobile parks organization are the part of the complex task which has a great practical importance.

It is necessary to analyze existing methods of forming organizational structures to develop and justify the appropriate methodology. The following methods are known:
- static;
- modular;
- methods, based on a system-targeted approach.

The static method is based on the fact that in order to design the structure of the RCM park, it is necessary to analyze data of a similar work performed with the help of specific organizations. There is a connection between the equipment and the construction organization structure and the types and volumes of work performed.

While relatively simple, static methods have significant disadvantages. They do not have sufficient flexibility. Based on the existing experience, both the pros and cons of the implemented project are transferred to the new management object.

The modular method considers the creation of production units and controls from standard elements - modules. Modules can vary in production capacity, technical equipment, a number of employees, a level of industrial and economic independence. Their production capacity, quantity depend on the type of work, volume, conditions and the rate of these works completion. The main disadvantage is that the reserves of equipment are not reflected in the modules, the coefficient of use of equipment in time is not traced.

The system-targeted method synthesizes the pros and cons of the above-mentioned methods, it is the most suitable and promising for the mobile parks of the RCM. Although from the scientific and methodological point, it is quite complex, requiring high qualification of project designers in solving the tasks.

The main objective of the "System-Targeted Method" (STM) is to create a system of goals with their subsequent accomplishment.

3. Research results
The solution of the complex task should be carried out in staged manner with the following contents:
- a determination of the park structure;
- a development of its structure of technology, taking into account the effects of probabilistic factors;
- a substantiation of the basic principles of park relocation;
- a substantiation of the optimal frequency of a mobile park of construction machinery movement;
- a formation of the park service systems capacity.

The analysis of the methods showed that the most appropriate is the system-targeted approach for the solution of the indicated problems.

The development of the MPCM implies an appropriate level of technical operating organization, that is, the availability of field sites for maintenance and repair of equipment.
The location of the park is recommended to be determined at the design development phase. At the same time, the main considering factors should include:
- the area of the park, determined by the amount of equipment used at the object;
- the ability to provide the place with temporary communications;
- the presence of a power network, a lighting electrical network;
- accounting of living quarters for workers, with special remoteness of construction.

The structure of the mobile park can be determined enlarged or elaborately using one of the three known methods.

According to the normative indicators for 1 million rubles of construction and installation works estimated cost as part of the construction planning design (CPD):

\[ K_m = M \cdot C \cdot K_r \]  

(1)

where: 
- \( M \) - the requirement rate of this type of machine for 1 million rubles of construction and installation works estimated cost (CIW);
- \( C \) - planned or forecasted volume of CIW in million rubles;
- \( K_r \) - coefficient for natural and climatic conditions accounting.

Based on the amount of work, on the adopted methods of mechanization and operational performance of the equipment used:

\[ K_m = \frac{V}{\left( \Pi_{\text{expl}} \right)} \cdot T \cdot K_{cm} \]  

(2)

where:
- \( V \) - the amount of work of this type in (t, m³, and etc.)
- \( \Pi_{\text{expl}} \) - working capacity of a machine per hour or shift;
- \( T \) - working hours of a machine for the corresponding period;
- \( K_{cm} \) - in-shift machine usage factor.

According to the norms of the machine time cost per unit of work performed and the accepted methods of mechanization:

\[ K_r = \frac{(H_{vr} \cdot V)}{T \cdot K_{cm}} \]  

(3)

where: \( H_{vr} \) – machine time norm.

To ensure the mobility, the following conditions must be observed:
- minimum labor costs for the sites organization;
- the presence of a stationary support base, supplying mobile units with the necessary resources;
- the creation of mobile building industry bases;
- the development of mobile social infrastructure;
- the stimulation of labor resources involved in the expeditionary shift method;
- the effective organizational structures that ensure the accounting of the above-mentioned factors in the conditions of territorial separation.

One of the most important issues while establishing mobile parks is the frequency of their movement. For this purpose, it is necessary to justify the park's area of operation by examining the options for its placement throughout the construction site [13-15].

We denote by \( R_n \) - the construction service area from one place.

It should be noted that cars located in the park can be divided into two groups (for example, in the case of road construction):
- returning to the park by the end of the working day;
- remaining in the inter-shift period on the line.

The first group requires expenses for additional daily movements to the object and back (the expenses increase with increasing service area \( R_n \)).

The costs of the second group will be composed of the size of the salary of the guard, the costs of preparing special parking areas if necessary.

An important issue is the determination of the optimal value of \( R_n \).

The value of \( R_n \) can be expressed through a function:
\[ T_n = f(R_n, C_1) \] (4)

where: \( T_n \) – the working time of the park in one place (the time interval between the relocation of the park);
\( C_1 \) - the cost of 1m2 object.
\( C_1 \) can be determined by the formula:
\[ C_1 = C_m + C_{T_1}^{T_1} + C_{xp}^{T_2} + \frac{C_{m/d}}{k} \rightarrow \min \] (5)

where: \( C_m \) – cost of materials;
\( C_{T_1}^{T_1} \) – the cost of running the first group cars;
\( C_{xp}^{T_2} \) - the cost of storing the second group cars;
\( C_{m/d} \) - the cost of dismantling, relocation and installation of the mobile fleet in a new place.

Let us define the value of each of the addends:
\[ C_{T_1}^{T_1} = \sum_{i=1}^{n} \frac{0.85 \times C_m \times N_{i} \times R_n}{V_i} \] (6)

\( n \) - the amount of the machine types from the first group;
\( N_{i} \) – the amount of car-run machines of \( i \)-type;
\( V_i \) – average speed to the place of work;

0,85 0 coefficient reflecting the share of costs accounting for the movement of machines.

\[ C_{xp}^{T_2} = \frac{C_{syt}^{syt} \times N_{oehr} \times R_n}{V_{pot}} + C_{pl} + N_{plash} \] (7)

\( C_{syt}^{syt} \) – the daily charge of the guard;
\( n_{oehr} \) - the number of guards;
\( V_{pot} \) - building flow rate;
\( C_{pl} \) - the cost of preparing one storage area;
\( N_{plash} \) - the number of parking equipment left on the road when the park is in one area

\[ N_{plash} = \frac{R_n}{3.5} \] (8)

\[ C_{m/d}^{k} = \frac{C_{m/d}}{R_n \times k} \] (9)

Where: \( C_{m/d}^{k} \) – total cost of dismantling and installation of park facilities and equipment, in rubles;
\( k \) – coefficient depending on the structural design of the park (\( k = 1 \) or \( 2 \)).

Accordingly, the general formula will be the following:
\[ C_1 = C_n + \sum_{i=1}^{n} \frac{0.85 \times C_m \times N_{i} \times R_n}{V_i} \left( \frac{C_{syt}^{syt} \times n_{oehr}}{V_{pot}} + \frac{C_{pl}}{3.5} \right) \frac{R_n}{R_n \times k} \rightarrow \min \] (10)

For the convenience of perceiving the formula and carrying out subsequent calculations, we give the following notation:
\[ A = \sum_{i=1}^{n} \frac{0.85 \times C_m \times N_{i} \times R_n}{V_i} \] (11)

\[ B = \frac{C_{syt}^{syt} \times n_{oehr}}{V_{pot}} + \frac{C_{pl}}{3.5}; \] (12)

\[ C_1 = C_n + A \times R_n + B \times R_n + \frac{C_{m/d}^{k}}{R_n \times k} \rightarrow \min \] (13)
Differentiating by $R_n$, we receive:

$$
\frac{dC_1}{dR_n} = A + B - \frac{C_m}{R_n^2} = 0
$$

(14)

Hence:

$$
R_n = \sqrt{\frac{C_m}{d} \sum k (A + B)}
$$

(15)

Thus, the optimal value of $R_n$ in expanded form will be equal:

$$
R_{n}^{\text{opt}} = \sqrt{\frac{C_m}{d} \sum k (A + B)}
$$

(16)

An important issue in developing mobile parks is the construction of an organizational structure. It is based on "clustering" of the union of structural elements into larger elements (according to the production, territorial or technological principle).

The system-target method synthesizes the pros and cons of the above methods, is the most suitable and promising in relation to the formation of mobile parks. Although in scientific and methodological terms, it is quite complex, requiring high qualification of designers in solving the tasks.

The main objective of the "System-Target Method" (SCM) is the formation of a system of goals. The implementation of this approach should be based on the following principles:

- the goals for which corresponding organizational structures are created, are primary, the structures are secondary;
- when creating the organizational structure it is necessary to take into account the conditions of the implementation (economic, legal, social, natural and climatic conditions);
- the main factor in the formation of the structure is a system of goals that have a clear hierarchy. In other words, each level of the structure implements the corresponding level in the hierarchy of goals;
- as a rule, the goals and conditions for their implementation are inconsistent. In this regard, the organizational structure should be regularly reviewed;
- it is necessary to establish a functional relationship between all elements of the organizational structure.

4. Conclusion

The solutions for mobile parks formation should be taken comprehensively, systematically. The issues related to the types and amounts of machines formation. The list of tasks to be solved should include issues related to the formation of types and number of machines based on a feasibility study on the types, productivity and capacity, structure and volume of work performed and projected [16], [17]. Other relevant and significant issues include forming the rational structure of the mobile fleet and its completeness with technical maintenance, establishing the most optimal distance for relocation, taking into account the operation characteristics depending on the climatic conditions and terrain features, etc.. All of the above confirms the need for a comprehensive accounting of all aspects of the activities of mobile parks of construction equipment.

References

[1] Abdrazakov Ph, Gorjunos D, Abdrazakov F, Goryunov D 2002 Construction Mechanization 3 12

[2] Grishakov B 1984 Development of rational production structures of road-building organizations: Abstract. dis.kand. tech. Sciences (Moscow)

[3] Kanyuka I, Pazin V 1986 Mechanization of construction 3
[4] Yaozhong Wu, Weijia Li, Ping Yang A 2015 *Procedia CIRP* **29** 758  
https://doi.org/10.1016/j.procir.2015.01.018

[5] Kapustin D, Yanchuk I, Minkin I 2005 *Scientific - technical collection* (Balashikha: VTU) p 32

[6] Nevstroyev Yu 2004 *Optimization of the modes of mechanical mobility of mobile construction organizations: Diss. Cand. econ. Sciences* (Voronezh)

[7] Nemchinsky A 1987 *Relocated enterprises* (M.: Economics) p 157

[8] Zolotar I 1974 *Economical –mathematical methods in road construction. Monography* (M.: Transport) p 248

[9] Myasnikov A 2006 *Scientific and technical collection* **14** 99

[10] Ruqi Ding, Junhui Zhang, Bing Xu, Min Cheng 2018 *Automation in Construction* **95** 172  
https://doi.org/10.1016/j.autcon.2018.08.001

[11] Tuskaeva Z 2016 *International Journal of Applied Engineering Research* **11**(6) 4369

[12] Tuskaeva Z, Aslanov G 2016 *Procedia Engineering* **165** 1184

[13] Myasnikov A 2007 *Science and technique in road industry* **15** 164

[14] Maltsev Y 2008 *Science and technique in road industry* **4** 21

[15] Tuskaeva Z, Volkov A 2019 *Collection of materials of the All-Russian scientific-practical conference* (Moscow) p 95

[16] Naskoudakis I, Petroutsatou K 2016 *Procedia Engineering* **164** 206  
https://doi.org/10.1016/j.proeng.2016.11.611

[17] Bilal Lukumon M, Oyedele O 2020 *Advanced Engineering Informatics* **43** 101013  
https://doi.org/10.1016/j.aei.2019.101013