The importance of automating the "Construction" phase of the construction project life cycle

Nikolay Ivanov1* and Dmitry Ivanov1

1Moscow State University of Civil Engineering; 26, Yaroslavskoe Shosse, Moscow, 129337, Russia

Abstract. Significant innovations in the regulatory framework of the construction industry of the Russian Federation force construction organizations to change their attitude to digital technology in general and automation in particular. The existing objective differences of construction companies, carrying out their activities at different stages of the life cycle of construction products, put them in different initial conditions on the way to solving the problem. In the present study, the authors analyze the level of elaboration of a number of issues that arise at different stages of the construction project life cycle (CPLC). As a result of the analysis, the authors conclude that there is a lack of attention to digitalization at the stage "construction". In particular, it is noted that little attention is paid to the automation of the management activities of companies at this stage of CPLC lifecycle. The authors analyze possible approaches to the automation of management tasks of a construction organization that directly erects buildings and structures. As a result, key features of approaches to the formation of task complexes for automation for two different groups of departments of the management apparatus of a construction organization are formulated. Based on the results of the study, the authors conclude that in order to ensure the effective functioning of construction companies and organizations the use of digitalization technologies at all stages is mandatory.

1 Introduction

Building lifecycle management continuously remains an important area of research. Nowadays the understanding of construction project life cycle (CPLC) as the period of time from the inception of the investment idea to the liquidation of the object is uncontroversial [1]. In addition to the term "life cycle of a construction project," some researchers use another term, "facility life cycle". According to [2], "a facility is planned, designed, constructed, and operated." (Fig.1).

Since the end of the last decade, when works defining the stages of the building lifecycle were published [3,4], and up to now, a considerable part of such works, both domestic and foreign, has been devoted to the issues of information modeling at the pre-
The prerequisite for this was the development of industry-specific digital management decision-making support systems to meet today's demands for efficient planning, design, operation and ongoing management of construction objects. In the Russian Federation, such a system is supposed to base on the wide application of information modeling technology at all stages of the life cycle of capital construction and infrastructure objects [12].

![Facility Lifecycle Phases](source: [2])

The Program for the Development of the Digital Economy in the Russian Federation until 2035 was adopted in July 2018 [13] and the Strategy for Development of the Construction Industry and Housing and Communal Services until 2030 (hereinafter - the Strategy), the draft of which was published on the agency's website on September 30, 2021 [14] added relevance to the above-mentioned topics. In these documents, the digitalization of construction is named as the basis for achieving the stated objectives.

It also identifies the main reasons negatively affecting the process of achieving the stated goal, the main ones being:
- low level of digitalization of interactions between the participants at all stages of the capital construction facility lifecycle;
- lack of opportunity to identify and monitor capital construction objects throughout their life cycle.

The implementation of the measures mentioned in the Strategy is subject to several strategic risks (Table 1).

<table>
<thead>
<tr>
<th>№</th>
<th>Strategic risks types</th>
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<tbody>
<tr>
<td>1</td>
<td>risk of the increased cost of information exchange due to lack of uniform data standards</td>
</tr>
<tr>
<td>2</td>
<td>risk of unreliable data for management decision-making due to the high share of manual data input and the human factor, lack of reliable real-time data (sources)</td>
</tr>
<tr>
<td>3</td>
<td>risk of the substantial increase in labor costs due to potential increase in the volume of information to be processed</td>
</tr>
<tr>
<td>4</td>
<td>risk of deteriorating quality of digital initiatives due to lack of methodological responsibility centers</td>
</tr>
<tr>
<td>5</td>
<td>risk of a longer timeframe for digital initiatives due to the low level of &quot;digital maturity&quot; of participants</td>
</tr>
<tr>
<td>6</td>
<td>risk of increased timeframe for implementation of digital initiatives due to rigid hierarchical management structure and weak horizontal linkages</td>
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</table>
The problems of digitalization of construction can be solved taking into account the above-mentioned risks by developing industry-specific digital management decision support systems that meet modern requirements for efficient planning, design, operation and ongoing management of facilities. In the Russian Federation, such a system should be based on the extensive use of information modeling technologies at all stages of the life cycle of capital construction and infrastructure facilities[14].

The BIM technologies applied in practice by Russian designers until recently were designed to remove the above barriers. They allowed the transfer of a virtual information model from the design team to the general contractor and subcontractors, and then to the building owners or operators [15]. However, the sanctions imposed on the Russian Federation have led to several serious BIM solution providers leaving the Russian market [16], which in turn has led to some reduction in activity in terms of implementing proven solutions. At the same time, it served as an impetus to intensify the work of Russian software developers in the field of engineering solutions [17].

One more another widely discussed area of research has been risk management research in different areas of construction [18,19] and at different stages of the life cycle of a construction object [19,20].

A separate group of publications related to construction object lifecycle management includes research in the area of financial planning of individual stages of construction [21,22].

2 Methods

For most construction companies, digitalization of construction is digitizing all construction processes and using modern technology to reduce construction time and improve quality. This involves the use of information technology both in the implementation of production processes and in the management processes of the construction organization itself. However, the issues of automation of the management apparatuses of construction companies involved in the construction phase have hardly been touched and remain poorly studied.

It is these issues that be dealt with below.

First of all, let's define the start and end points of the phase in question. This phase begins with obtaining a building permit and ends with the commissioning of the facility. It should be noted that if construction is stopped, the facility is mothballed. In other words, the lifecycle of the facility moves to a non-basic but very important stage "frozen object" which has some features similar to those of the operation phase. If we consider the "usual" course of development of the construction object lifecycle, i.e. the full-fledged "construction" stage, it can be represented by a pair of interrelated sub-stages: the preparatory stage and the main stage (Fig. 2).

![Fig. 2. Composition of the "construction" phase.](image)

It should be noted that the composition of the main construction phase depends on the type of facility being constructed. If the object is industrial, two more periods are added to
the main construction period - the period for installation of process equipment and the period for commissioning.

The study of construction companies’ practices with various sizes, organizational and legal forms and types of construction projects allows us to state that the effective implementation of two main groups of tasks is important at the stage of direct construction: preparation of construction and operational construction management.

Tasks, providing realization of preparation of construction, as a rule, are directed on the development of the construction object calendar schedule and formation of a number of the sheets and schedules reflecting the needs of the building organization in manpower, material and technical resources providing object construction in due time.

The composition of operational construction management tasks is determined by the purpose of operational management. This purpose can be defined as follows: to take timely and effective measures to eliminate identified deviations from the normative progress of the current plan caused by external and internal disturbances. Operational management is carried out by sequentially alternating the main functions in a closed loop. These functions, according to many authors, are planning, accounting, control, analysis and regulation. In the practice of construction companies, the tasks aimed at the implementation of these functions include weekly and daily schedules for construction work for an object, daily assignments to teams, preparation of documents KC-2, KC-3, M-29 (reporting forms in Russian construction), preparation of decisions on the adjustment of current plans and schedules.

In the organizational structures of most Russian construction contractors, these functions are realized by several functional units. Each such subdivision focuses its work on solving tasks aimed at the management of a particular type of resource (material, technical, labor), or management of a particular stage of construction and assembly works. In the first case, the set of tasks overlaps all basic and special management functions concerning a specific resource. In the second case, a set of tasks is solved, which makes it possible to implement a closed management cycle.

Table 2 lists the main departments in a typical construction organization, indicating how the list of tasks they perform is formed.

<table>
<thead>
<tr>
<th>Department</th>
<th>Method of forming a set of departmental tasks</th>
<th>Resource management</th>
<th>Construction phase management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logistics department</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Mechanical Engineering Department</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Department of the Chief Power Engineer</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Planning and economics/finance department</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Staff department</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Production preparation/production engineering department</td>
<td>-</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Dispatching department</td>
<td>-</td>
<td>+</td>
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</tbody>
</table>

Today, there is no doubt that the automation of tasks performed by employees in the functional department of construction organizations can significantly improve the efficiency of company management. In this regard, there are several automation-related solutions in the Russian construction management software market. However, it should be noted that a significant part of these solutions is aimed at automating the tasks of the first group of departments. And the main tasks of accounting and control of internal document flow were automated. Tasks of the second group of departments are automated in terms of accounting and control of the volume of performed construction and assembly works. As a
rule, planning of construction and assembly works and analysis of reasons for failure to fulfill planned assignments remain unaffected by automation.

3 Results

Once again, at the stage of direct construction, it is important to effectively implement two main groups of tasks: preparation of construction and operational construction management. The established practice of decomposition of construction organization activities into processes at the process approach and subsystems and task complexes at the functional approach represents the first group of tasks as a complex of scheduling tasks. The composition of this set of tasks is almost entirely determined by the building site organization scheme (BSOS), which is part of the project documentation for the facility.

The main objective is to create an optimum construction schedule. Today, the actual calculation of the network schedule is not too much of a problem and can be done quite easily using, for example, MS Excel or a similar software tool. A problem arises when the calculated duration of the critical path is longer than planned. In this case, a decision needs to be made to modify the technological and organizational model for the facility construction and then re-calculate. However, the sequence described above may have to be carried out many times until a solution is found that satisfies the time constraints of the facility's construction. This sequence is very tedious to perform manually, so the task of iterative calculation of the object construction schedule must necessarily be done in automated mode: a person decides on the changes and enters them into the input data for the calculation and then the corresponding software module performs the calculation.

To a large extent, the number of iterations to obtain a result depends on the optimization criterion and the constraints that need to be taken into account in intermediate decisions about changes in the input data. The most common criterion is the number of incremental costs associated with a change in the organizational and technological scheme of object construction. It is suggested that two main types of change be considered: an increase in the work labor resource level or a change in shift work.

In the first case, the criterion for choosing the work to which labor resource should be added will be the cost of reducing by one day of work duration, determined according to the formula (1):

$$S_i = \frac{(T_i^{\text{old}} - T_i^{\text{new}})}{C_j}$$  \hspace{1cm} (1)

where

- \(T_i^{\text{old}}\) – the duration of work \(i\) at the current labor resource level;
- \(T_i^{\text{new}}\) – the duration of work \(i\) after a change in the labor resource level;
- \(C_j\) – the cost of recruiting a unit of labor resource \(j\);
- \(S_i\) – the cost of reducing the duration of work \(i\) by one day.

The work with the smallest \(S_i\) value will be preferred. If the \(S\) values of the two works are equal, preference should be given to the work which has the longest reduction in duration. If this value is equal, the best of the two alternatives is the one that has the lowest current level of labor resource.

It is important to note that the possibility of changing the labor resource level can be defined by a special parameter in the work description - the "maximum labor resource level at work". As long as the current labor resource level is below the maximum level, the possibility of changing it exists. When the maximum level of labor at a work is reached, the work is excluded from consideration when finding a solution to the option under discussion.
An enlarged algorithm for implementing the considered scheduling optimization option is shown in Fig. 4.

![Algorithm Diagram]

**Fig. 4.** An enlarged algorithm for optimizing the construction operations schedule by increasing the level of labor resources on the work.

In the second case, the criterion for selecting the work whose number of shifts should be changed also will be the cost of reducing work duration by one day of work, determined by the formula (2):

\[
S_i = \frac{(T_{i,old} - T_{i,new})}{Z_j}
\]  

where
- \(T_{i,old}\) – work duration \(i\) at the current quantity of working shifts;
- \(T_{i,new}\) – the costs of changing the shift quantity to work \(i\);
- \(Z_i\) – the costs of changing the shift quantity to work \(i\);
- \(S_i\) – work duration \(i\) after a change in the quantity of working shifts;
The preference rules for this case are the same as in the variant described above.

The shifts of manual work depending on the availability of the work front and the workforce. If there is a sufficient work front, it is advisable to plan the bulk of the work on the first shift as the most productive, with better working conditions and a clearer organization of work, which allows the highest labor productivity to be achieved. Work in the second shift (especially in autumn and winter) requires additional measures such as the lighting of workplaces, passageways, and additional occupational safety measures.

However, some types of work are more convenient to perform during the evening shift when the bulk of the workers are not on site (e.g. work involving concrete heating).

Sometimes it makes sense to deliberately narrow the scope of work by splitting up crews for multi-shift work when a one-off capital outlay is needed to carry out the work in comfortable conditions. For example, work during cold weather in specially heated rooms.

The possibility of changing the work shift can be defined by a special parameter in the work description - "maximum quantity work shifts". As long as the current quantity of work shifts is lower than the maximum quantity of work shifts, it is possible to change it. If the current shift pattern is equal to the maximum shift pattern, such work is excluded from consideration when searching for a solution for the option under discussion.

### 4 Discussion

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### 5 Conclusions

As already noted, the mechanism for determining the work for which parameters (labor resource level, shift rate) are changed is very time-consuming if done manually. Therefore, more often than not, no one in the organization does much of this. Decisions to change parameters are made either based on the practical experience of the construction manager (foreman, foremaster, etc.) or at random. The important thing is simply to meet a directive construction deadline. This is sometimes done simply by rough estimation, sometimes completely inadequate.

The proposed automation of the search for the optimal variant of the construction operations schedule will make it possible to calculate by an order of magnitude, if not several orders of magnitude, more options in less time, thereby ensuring the validity of management decisions.
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