The organizational-technological decisions acceptance support system in the investment and construction projects management

L B Zelentsov*, L D Mayilyan, N G Hakobyan, D V Pirko
Don State Technical University, 1, Gagarin sq., Rostov-on-Don, 344002, Russia
E-mail: Zelentsov@rgsu.ru

Abstract. The article discusses the problems of making organizational and technological decisions in the investment and construction projects (ICP) management using intelligent construction management systems (“IMS Construction”).

The relevance of the study is due to the fact that in economic instability conditions in the Russian Federation, the construction organizations need to increase the organizational and technological decisions efficiency in order to reduce production costs.

The ISU “Construction” introduction allows the managerial decision-making of two independent areas integration in the implementation of ICP, based on the rules and precedents related to the methods of generating new knowledge, which allows to get a new impetus in the intelligent control systems development.

The greatest interest in using the proposed methodology formalized in the IMS “Construction” development is the possibility of accumulating knowledge about the ICP control system possible behavior, which is more likely to predict the right decision adoption in the event of any situations that have not been previously met or recognized.

Introduction
The contract market of the Russian Federation is currently characterized by: a decrease in demand for construction products from the population, a reduction in the number of investment and construction projects (ICPs) of federal and regional significance being implemented, and, as a result, a competition intensification between the contractors for receiving an order. In these conditions, the participants in the contracting market have become interested in introducing a methodology for managing the time and the ICP cost at all stages of its life cycle and, on this basis, to really reduce costs in the work performance.

Main Part
The process of ICP managing is influenced by many factors, many of which are caused by the construction production peculiarities (Table 1).

| Feature List | Impact on the organization of production |
|--------------|----------------------------------------|

Table 1. The construction production features and their impact on the organization and production management


| products’ uniqueness | development of design estimates for each object (DE) and the entire cycle implementation of the preparation for construction production; |
|----------------------|-------------------------------------------------------------------------------------------------|
| territorial disunity | design of logistic models and logistics schemes (LMS) for each object, the need for relocation of construction equipment, temporary buildings and structures, and the construction site arrangement; creation of a system for collecting and transmitting information from the construction site. |
| high cost and long construction | creation of specialized management and accounting systems, budgeting and financing systems that take into account the long construction cycle. |
| the construction products’ stationary nature and the production tools and performers’ mobile nature | the specialized tasks solution in the field of management to synchronize production processes and their resource support. |
| seasonal production | restrictions on a number of works at low temperatures or the use of special technologies for their implementation; calculation of the cost of construction costs of the facility. |
| high material consumption and labor intensity of construction and installation works in combination with low labor productivity | development of a system for automated recording the workers’ time use, accounting and write-off the materials at a construction site. |

The listed features of creating construction products lead to a number of restrictions in the construction technologies and control systems’ development.

The internal risks of implementing ICP in the Russian Federation include: the design quality and estimate documentation, complex procedures for the ICP interaction participants, insufficient organization of production processes at the construction site.

The external risks of ICP managing are mainly associated with the financial resources management system coming from the federal and municipal budgets (delays in the financial resources allocation) and with the credit organizations high interest rates.

Thus, decision-making in the management of complex infrastructure projects is associated with a high degree of uncertainty requiring the consideration of a large number of internal and external factors.

There are two directions in the decision support systems development:

• rule-based conclusion;
• case-based conclusion.

Almost all early expert systems modeled the expert decision-making process as a purely deductive process using the rule-based inference. This meant that a set of rules of the form “if ..., then ...” was laid down in the system, according to which, based on the input, this or that conclusion was generated on the problem of interest. Such a model was the basis for the creation of expert systems of the first generations, which were convenient enough for both the developers and expert users. However, over time, it was realized that the deductive model models one of the rarest approaches that an expert follows in solving a problem.

The inference idea by the rules is attractive because it implies the presence of a well-formalized problem for which there are scientific methods that have proved their applicability and allow to get a solution that does not require any additional evidence.

There are many poorly formalized tasks for which the solutions are to be found. The urgency of the problem is due to both the multiplicity of such problems and the practical need to find at least one solution that is somehow suitable where, due to the formalized method lack, it is impossible to find the optimal solution.
In fact, instead of solving each problem on the primary principles’ basis, the expert often analyzes the situation as a whole and recalls what decisions have been made earlier in such situations. Then he either directly uses these solutions, or, if necessary, adapts them to circumstances that have changed for a particular problem.

The simulation of this approach to solving problems based on past situations led to the emergence of case-based inference technology (Case-Based Reasoning, or CBR). A use case is a description of a problem or situation in conjunction with a detailed indication of actions taken in a given situation or to solve a given problem.

In this approach, the current state of ICP control parameters is compared with the cases from a previously accumulated knowledge base (Figure 1).

![Figure 1. Block diagram of a decision-making algorithm based on a use-case](image)

The objects classes cases knowledge base is built on the basis of the information selection from databases of state options for specific construction objects. A class of objects is understood to mean a subset of construction objects with close constructive solutions.

Such classes in the construction of residential buildings (buildings), depending on the structural solutions of the supporting structures, can be:

- panel from prefabricated reinforced concrete structures;
- frame from monolithic reinforced concrete (monolithic frame);
- brick supporting walls, floors, staircases from precast or monolithic reinforced concrete, etc.

In addition to the supporting structures of the aboveground part of the building, they can differ in the zero cycle constructive solutions, number of storeys, space-planning decisions, etc.

Therefore, when creating a knowledge base, it is necessary, first of all, to carefully classify the buildings and structures and group them into classes and subclasses. This will allow better quality selection and comparative analysis of precedents as well as the creation on this basis of a regulatory framework for the resources’ consumption, the buildings construction duration or their individual parts. Based on this, in parallel with the knowledge base, a database of objects is created - analogues, which is built on the same classification criteria as the knowledge base.

On the proximity measure basis, one of similar cases is chosen. The control action associated with it is used directly or adapts to the current case, based on the precedent proximity degree. The impact result is also predicted by the precedent. The impact result is recorded in the use case database for subsequent use. At the same time, a more particular problem of choosing a proximity measure to determine the similarity of a managed object with precedents is posed. The sought measure should help to limit the possible options enumeration, their ranking when choosing the control actions, and also facilitate the control action adaptation from a precedent to the control object’s current state.

Thus, the control action is defined by us as the effect on the object in order to achieve the optimal or close behavior.

With this approach, the control object’s behavior, both in the presence of a control action and without it, is a discrete process, each step of which, in the general case, is a transition of an object from one class of states to another.
It should be noted in advance that the set of states of an object does not have to be ordered, so the transition from one state to another is not always an approximation of a step toward a goal or moving away from it.

The essence of the proposed management model is as follows. Our knowledge about the control object - ICP and the environment in which it operates are uncertain. We only know that the object belongs to a certain states class. The goal is to achieve the optimal behavior of the object, expressed in the form of a certain states sequence. It is necessary to find a control algorithm ensuring the goal achievement for a finite number of control actions.

The work to create an intelligent construction management system (IMS “Construction”), one of the distinguishing features of which from the existing software products on the market is the ability to model decision-making, both using deductive modeling technology and using a knowledge base based on precedents is underway at Don State Technical University.

The IMS “Construction” implements a technology that ensures the recording of information arising in the production process at the construction site and its transmission by the foreman in electronic form to the central office of the construction organization at the end of the working day.

The detailed information aggregation on the volume of work performed, labor costs, the use of construction machines and mechanisms and material resources by structural elements creates an information basis for organizing a management accounting system and taking the informed management decisions.

It is necessary to distinguish the decision-making procedures and their corresponding indicators at the operational and tactical management stages. Interval of review (planning): at the operational management stage it is a month, a week, a day, and at the tactical management stage it is a quarter, a year.

At the operational management stage in the IMS “Construction” an expert decision-making system, which is aimed at preventing violations in the given rhythm of work, localization of the causes leading to unproductive losses at the construction site, is used.

The detailed daily information on labor costs and the volume of work performed, recorded in the time sheet and the work log, is grouped by the structural elements and by the performers - teams of workers. After that, a detailed analysis of the working time use and calculation of labor productivity indicators is carried out, the utilization rate of workers in the main jobs is carried out and the work duration is predicted. A similar analysis is carried out on the construction machines and mechanisms use.

The total balance of actual time spent $Q_z^0$ (1) (in accordance with time sheets) for a certain period of time $t_i$ for the object $z$ includes the costs of performing basic work in accordance with the project $q_z^{pr}$, additional work $q_z^a$ and unproductive losses $U_z$.

$$Q_z^0(t_i) = q_z^{pr} + q_z^a + U_z$$ (1)

When making the management decisions the following indicators should be guided:

The coefficient of working time productive use (2):

$$K_z^q(t_i) = \frac{q_z^{pr}(t_i) + q_z^a(t_i)}{Q_z^0(t_i)}$$ (2)

Coefficient characterizing the working time loss (3):

$$K_z^{q(l)}(t_i) = \frac{U_z(t_i)}{Q_z^0(t_i)}$$ (3)
The planned production rate fulfillment coefficient is the actual labor costs ratio to the planned ones according to completed structural elements (4):

\[ p_{z,k}^q = \frac{Q_{z,k}^{pl}}{Q_{z,k}^{act}} \quad k \in K_z \]

where \( Q_{z,k}^{pl} - Q_{z,k}^{act} \) - are accordingly, the planned and actual labor costs for k constructive element.

Production in physical terms for the completed set of homogeneous structural elements for the construction object:

\[ p_{z,k}^q = \frac{V_{z,k}^{act}}{Q_{z,k}^{act}} \quad k \in K_z \]

where \( V_{z,k}^{act} \) is the amount of lead work j type of work k structural element.

The leading work concept is necessary for the correct choice of unit production measurements. So, for example, when erecting the reinforced concrete structural elements, the leading work in calculating the output is concreting. In this case, the actual complexity includes the complexity of all the work and processes performed during the creation of the considered structural element.

At the tactical level, the managerial decisions development and adoption in the IMS “Construction” is carried out using a model that allows predicting the future system state on the basis of macro-indicators and a knowledge base - precedents.

When considering a new problem (current case), a similar precedent is found as an analogue, which can be used by adapting to the current case, instead of looking for a solution each time first. After the current case is processed, it is entered into the use case database along with its solution for its possible subsequent use.

The knowledge base presupposes the accumulation in a systematic form of indicators characterizing the fully developed or already adopted options for managerial decisions.

Such decisions at the tactical level of ICP management can be the changes in the temporal the performance parameters of individual works or the construction object as a whole by adjusting the interconnections of work (combining, parallelizing), increasing or decreasing the intensity of their implementation. Each state of the construction object corresponds to a network model \( G \), which is a directed graph, between the work (vectors) the relationships of which are established, and according to the work, characteristics are set: duration, laboriousness, implementation intensity, resource requirements.

At the concluding a contract stage for the construction object \( z \), a network model \( (G_n) \), which sets the organizational and technological normal for the construction of the object in accordance with the terms fixed in the contract is developed and on its basis a schedule is calculated. During the construction process, the parameters of the network model under the influence of various factors can change. Thus, each construction object state can correspond to its own graph – network schedule (6).

\[ G_z(t_i) = \{G_z(t_i)_1 \rightarrow G_z(t_i)_2 \rightarrow G_z(t_i)_3 \rightarrow \cdots \rightarrow G_z(t_i)_n \} \]

Where \( G_z(t_i) \) is the state vector of the construction object at \( t_i \) time instant of the discrete planning interval.

At the ICP tactical level control, the knowledge base is a set of options for system states at \( t_i \) planning intervals. In construction, corrective management decisions that affect the timing and cost of construction are usually taken at the end of the calendar month, therefore, we take a month as the planning interval for which the network model is optimized.
The knowledge base consists of many options for organizational and technological solutions reflected in the corresponding network diagrams \( G_z(t_i) \) and a system of indicators characterizing the ICP state at \( t_i \) planning intervals.

In the decision-making process, first, to analyze the ICP state, a network model is used \( G_z(t_i)_{\text{act}} \), adjusted based on actual progress information. Based on the results of the analysis of the time schedule parameters and the ICP efficiency indicators values, a decision is made whether to take corrective actions in the network model in order to bring it to the specified construction period or not. If it is needed to make changes to the network diagram, then a new, optimized network diagram is entered into the knowledge base \( G_z(t_i)_{\text{opt}} \) and its ICP corresponding performance indicators.

Thus, indicators characterizing the ICP before and after optimization of the network schedule are entered into the knowledge base at the \( t_i \) planning interval \( G_z(t_i)_{\text{act}} \).

When evaluating the state \( z \) variant of the facility, the following integrated indicators are used, calculated on the \( i \)-day of construction:
- the actual construction period deviation from the planned \( \Delta T_i \);
- the actual cost deviation from the planned for finished structural elements in cost \( \Delta S_z(t_i) \) and relative terms in %;

If there are significant integrated indicators deviations from the baseline values calculated at the beginning of the construction of the facility, the project manager has a dilemma: either violate the construction contract period and fall into image and financial losses or not change the construction period with a projected increase in the actual cost of construction.

In the process of optimizing the time parameters of the network model, the work is shifted and parallelized, falling on the critical path. In this case, there is a concentration of labor resources and construction machines at the final stage of construction, which leads to the simultaneous execution of several works on one spatial site (front of work). This operation mode can lead to violations in the technology of work, to the occurrence of working time loss, lower work quality, and all this will contribute to higher costs.

In this situation, to make informed organizational and technological decisions, it is proposed to use two additional interconnected macro indicators characterizing the state of construction most fully: the unevenness coefficient of workers \( K_z^q(t_i) \) and value \( \tau_i - \) offset of the diagram “saddle” corresponding to the max value of the need for labor resources on the \( i^{th} \) day of construction) relative to the initial, basic state corresponding to the beginning of construction (Fig. 2).

![Figure 2. Graphs - diagrams of the need for labor resources at various time intervals for the construction of the facility: \( f_{z,i}, f_{z,i+1}, f_{z,i+2} \)](image)

The coefficient of uneven use of workers is the ratio of the maximum value of labor intensity on the \( i^{th} \) day of construction to average labor intensity per day.
\[ K_2^q(t_i) = \frac{\max q_{k,i}^{pl}}{E_i} \]

Where \( \max q_{k,i}^{pl} \) is the maximum labor intensity \( i^{th} \) construction day;
\( E_i \) – is the average complexity on the day \( i^{th} \) of construction.

\[ \frac{E_{z,i}}{E_{z,i}} = \frac{Q_{z,i}}{T_{z,i}} k \in K_i \]

Where \( Q_{z,i} \) – the total complexity of work on unfinished structural elements on the \( i^{th} \) day of construction for the \( z \) object;
\( T_{z,i} \) - residual duration on the day \( i^{th} \) of the \( z \) facility construction

Offset "saddle" plot \( t_i \) is calculated by the following formula

\[ t_i = T_{z,i}^H(q_{i}^{max}) - T_{z,i}(q_{i+1}^{max}) \]

Where \( T_{z,i}^H(q_{i}^{max}), T_{z,i}(q_{i+1}^{max}) \) coordinates of points max labor requirements respectively at the start of construction and at the \( i^{th} + 1 \) construction day.

The points coordinates are determined not from the start date of the construction, but from the deadline for the construction of the facility specified in accordance with the contract.

**Summary**

The integration of two independent areas, based on the rules and precedents relating to the methods of generating new knowledge and the use of this knowledge in managing the ICP behavior allows to get a new impetus in the development of intelligent control systems in construction. Of greatest interest is the use of the proposed methodology formalized in the IMS "Construction" development which is the possibility of accumulating knowledge about the ICP control system possible behavior, which is more likely to predict the right decision adoption in the event of any situations that have not previously been encountered or previously not clearly recognized. A particular advantage of the method is the possibility of accumulating knowledge about situations (cases) in an external database with respect to objects and the use of this knowledge by other objects connected to the same database.

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