Formation of the Organizational Structure Based on Project Matrix

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This article sums up the results of researches, which are aimed at exploring the ways to form an effective organizational structure of a large-scale construction project based on key events matrix. New methodology of organization design is based on informational paradigm that allows to consider production process as the complex of technological operations based on production ties and logical connection that are synchronized in time and realized by different participants of construction project. This allows to introduce a concept of project’s key events matrix which is a functional model of the organizational structure of project’s executive system. The project matrix is considered as a program graphical representation, which is implemented by management system in order to ensure that organizational structure corresponds to a specific phase of construction project’s implementation.

The article reflects the properties of key events matrix, which helps to improve the quality of organizational design and reduce the time of its creation. Depending on the level of construction project’s decomposition or its detalization, the key events matrix can also have several levels of detalization, so key events are always reflected in the matrix, no matter what level it takes. Thus, we find the scaling effect in the properties of the matrix. In addition, the project’s key events matrix has the property of ”stitching”, which means is a possible to supplement it with new events at any stage of the construction project. The use of new methodology in order to form the organizational structure of construction project makes it possible to reduce the production time of design works as well as improve their quality.1. Introduction

1. Introduction

The task of construction production’s escalation is central to construction management since its solution gives the construction organization indisputable competitive advantages. More importantly this task is faced by the organizers of large-scale construction projects, in which huge capital is implemented, dozens and hundreds of contractors are involved, where not only an error, but even an irrational decision leads to tangible losses. Science recognizes that the organizational structure plays a leading role in increasing the efficiency of production, [1-6]. In our case, this is the organizational structure for the implementation of a large-scale construction project. Considering the organizational structure as a reflection of the characteristics and nature of the planned works, we conclude that the foundations of construction’s organizational structure are laid at an early planning stage.

The world practice has gained rich experience in the complex organization of construction [7-10]. For large projects cartels are created. They include design, production, technology, transport and other companies that coordinate their work to create a construction project.

The lack of a well-defined and adapted to each phase [4] organizational structure of a construction project forces division managers to switch to manual control when current issues of contractors interactions are transferred to the construction site, resulting in decrease of a system’s reliability [11-
Fuss is created, wrong decisions are made, as well as alterations, adjustments and changes to design’s decisions, which ultimately leads to higher project costs and increase in construction time.

2. Methods

Scientists’ researches of NRU MGSU allowed to identify new ways to further improvement of large-scale construction projects’ organizational structure [12, 15, 16]. These researches are based on informational paradigm of forming the project’s organizational structure.

The method is based on the concept of project’s key events matrix that defines the production ties, logical connection and sequence of events, the implementation of which leads to the achievement of project’s goals. The key events matrix is a functional model of the construction project’s organizational structure since it contains the logical interrelationships of events and their sequence. The key events matrix can have a form of a network diagram in which the peaks reflect events in the project’s life cycle and arcs represent the logical connection of these events and their sequence. Due to the fact that the event is a specific result of project participants’ activity, the matrix uniquely determines the interaction of project participants or their organizational structure.

It should be emphasized that the key events matrix’s diagram of construction project is very similar to the usual project network but it has little in common with it, since the matrix diagram defines only production ties and logical connection of events. In order to fill the matrix with technological content, the concept of event-to-event transition’s operator is introduced that defines the condition for the next event’s implementation in details. The operator contains full information about the necessary resources and performers.

The important property of the matrix is its scaling [17]. The scale of the matrix changes depending on the construction project’s level of decomposition. As can be seen in Figure 1 the matrix element of level A is decomposed into level B and C with their appropriate detailing. In this example the key event is events A2; B5; C5, which belongs to each level of detailing. It is also easy to see that the top-level operator is the sum of lower level operators, i.e.

\[ BW_{35} = CW_{13} + CW_{34} + CW_{12} + CW_{24} \]  

It is necessary to note that the event with the maximal order of incoming connections will always have the status of the key event. In the example in Figure 1, events B5 and C4 are key events because their input order is two, which is the largest among other events.

![Figure 1](image)

**Figure 1.** Transition from event to event depending on the level of project matrix’s detailization.
It is possible to present the project’s key events matrix as a link between the key event and the functional structure of the construction project. The key event matrix is presented in a three-dimensional system of coordinate planes with executive-functional elements of the project. In Figure 2 the coordinate half-line (OY) defines the project’s events sequence. In planes (XOY) events are decomposed to clarify the details of the project. In the plane (YOZ) functional production units of the project are presented, which determine their mutual arrangement in the organizational structure. In the plane (XOZ) are distributed specific executive participants of the project. It is necessary to use a set of final executive units of functional elements for each event that is defined at the required level of project’s detalization (Figure 3 presents 3 levels of project events’ detalization).

Figure 2. Three-dimensional representation of the project’s key events matrix and its executive-functional elements.

The key events matrix is a joint schedule of project’s implementation that allows setting marks by key events and to lower events’ schedule date and tasks to executives.

A key event or a number of key events complete the phase or the stage of a construction project and it is base for form a new one or modify the old structure into the organizational structure of a new construction phase. Formation of organizational and technological links between performers (project system’s elements) is based on determining the logical sequence of performers’ actions, and also the interaction conditions between performers that is most important for organizational structure.
We applied the laws of mathematical logic to describe the series of project’s participants’ actions with the use of which we can perform parameters of interaction and its properties for organizational structure in the form of logical functions.

Transition operator \( w_i \) performs logical description of set of contact functions for the certain interaction parameters of project structure’s elements with certain properties:

\[
w_i(x_1,\ldots,x_m)=P(g_1(x_1,\ldots,x_n),\ldots,g_m(x_1,\ldots,x_n)),
\]

(2)

where \( g_m(x_1,\ldots,x_n) \) – functions which define the performing of interaction;

\( x_n \) – logical description of necessary actions of elements;

\( P(g_1,\ldots,g_m) \) – logical predicate function of \( m \) arguments that forms the statement about interactions of elements \( x_1,\ldots,x_n \) for achieving the event.

This function is defined on the set of interactions \( M \) and on the set of system’s elements \( N \).

The description of two interacting elements A and B and performed two-way interactions AB and BA is expressed by logical function \( g(A,B) \). The function describes logical algorithm of interaction of both A and B elements in organizational structure based on technological event.

Element A interacts with element B based on the subject of interaction. \( A \rightarrow B, B \rightarrow A, B \leftarrow A, A \leftarrow B \) – statements about incoming and outgoing interactions. Interaction AB is expressed by function:

\[
g_{AB}(A, B)=((A \rightarrow B \lor B \leftarrow A) \land (AB)) \sim (A \rightarrow B \lor B \leftarrow A),
\]

(3)

To perform the event it is necessary to have a set of directed interactions \( (M_m) \) on a set elements \( (N_n) \).

Thus, to describe interacting elements A and B and interactions AB and BA logical function \( g(A, B) \) is expressed:

\[
g(A, B)=(((A \rightarrow B \lor B \leftarrow A) \land (AB)) \sim (A \rightarrow B \lor B \leftarrow A)) \land (((B \rightarrow A \lor A \leftarrow B) \land (BA)) \sim (B \rightarrow A \lor A \leftarrow B)),
\]

(4)

The state of system’s interaction of A and B gives \( 2^n \) variants, where \( n \) – value of function’s quantitative parameters that is initial for systems analyses. The truth value for function \( g(A, B) \) defines the implementation of conditions of event-to-event transition that are depend on elements A and B.

This approach to working out a solution is based on informational analysis of logical interaction system with automatically formed variants of solution under given conditions and is suitable for defining an effective protocol for formation of organizational structure that meets project’s tasks at this stage.

From practical point of view, when using a mathematical description of project’s implementation processes we reach the programmed visualization of investment and construction project’s structural processes that allows to form a flexible organizational structure.

On the assumption of certain tasks assigned to the elements - participants of the project, can be identified the necessary connections for the interaction processes of elements in the project. In the future from these events and the necessary interrelationships of the elements, the necessary resource base of the tasks’ executive elements is determined. Due to the use of certain resource bases, some of which are permanent for the project (for example, a construction crane that operate in many technological actions), the network model of the required resources will be presented in accordance with the network model of the executives tasks.

3. Results

The practical application of the proposed formation’s approaches of organizational structure that based on key events matrix was reflected in the construction project of the Paks II NPP at the Orgenergostrroy Institute. This organization provides design works on the construction and installation base (CIB): complexes of buildings and structures with a total amount of 83 objects.
The methodology was used in working at the stage of accounting new requirements for technical solutions that used in the project, in reliance on specifics of working with a foreign Customer and the modified requirements of the legislation of Hungary during the implementation of this project phase. At an early stage of the project the following key events were presented (Table 1).

**Table 1. Key events of the CIB’s design.**

| TMS ID | Event name                                                                 |
|--------|-----------------------------------------------------------------------------|
| 192    | Conclusion of a contract for design work                                    |
| 193    | Development of design documentation for the objects of the complex of anti-corrosion works |
| 194    | Development of design documentation for concrete mixing facilities           |
| 195    | Development of design documentation for administrative and household facilities |
| 200    | Development of design documentation for facilities of hydraulic assembly organizations |
| 201    | Licensing of objects - obtaining a building permit                          |

In course of the methodology’s appliance, an event matrix, which is a policy plan, is defined. Diagram of the events matrix for this stage is presented in Figure 3.

Technological operations are designing works of CIB objects and events are coordination of project documentation by the customer. These events correspond to finishing of the design works of CIB systems. After providing the customer with the first revision of the project documentation for the key event ID193 customer’s comments were received. To the technological design work was added a work on accounting the customer’s comments.

![Figure 3. Model of production ties and logical connection.](image-url)

During the analysis were identified all elements that involved in these works (a group of construction engineers, a water supply and sewage group, a heating and ventilation group, a fire safety engineer, a
technical engineer, an electrical engineering department, general lay-out’s designers, a translation department, a technical archive and filial branch in Hungary).

![Figure 4. Calculation chart of the elements interaction’s structure.](image)

After receiving comments from the customer, for each subsequent event the tasks of all the involved elements that determined the achievement of the event, were determined to the complexes. Comments were received by all interested elements. After analyzing the comments, each element determined the necessary actions, collected information to determine the configuration of the tasks (interactions) and decisions in each aspect of the comments.

Figure 4 illustrates the calculation chart of the elements interaction’s structure - the quantitative parameters of an event implementation’s function at the moment of all the elements receiving comments on the project and their primary analysis.

Thus, the initial structural project executive subsystem’s interaction model for the key events implementation of the CIB design was modified under the relevant conditions and also detailed for the required level of decomposition of the project’s participants - the elements with decomposition into the performed works. Based on the obtained calculation chart interactions, a structurally-connected diagram was formed (Figure 5). It is necessary for the development of the organizational structure, which most fully meets the requirements for achieving events ID193, ID194, ID195 and ID200, was formed.
Based on proposed methodology, recommendations for improving interaction between elements in organizational structure and its transformation to specific tasks of project’s phase were made. During the analysis of customer’s comments the dependence of comments reduction after applying the proposed methodology of element’s interaction in design organization was revealed. Implementation of research results allows to reduce the number of discrepancies in output product of design company. Thus, the successful approbation of the results in practice at the stage of design work was carried out.

The developed methodology of organizational structure’s formation of the project that is based on key events has improved the adaptive properties of the organization, which is participating in the project, and increased the investment and construction project’s flexibility.

4. Discussion
The results of the study described in this article were the subject of discussion at the Russian Scientific and Practical Conference "Current State and Trends in the Development of Energy Construction", a number of international conferences [4, 15, 18] were widely discussed by experts in this field and received a positive rating.

5. Conclusions
1. Further progress of the organizational structures’ theory is associated not only with the development of traditional systemic and structural approaches but with the use of new research directions based on the informational approach, the use of digital technologies, the development of declarative and visual programming on the basis of logical-mathematical models of organizational structures.
2. Current practice of project documentation’s development does not pay due attention to formation of construction project’s organizational structure. It is possible to improve the quality of organizational structures designing process on the basis on analysis method of the production process with its division into organizational and technological components, which allows forming production ties and logical connection of events, operations and executives into the organizational structure that is the most relevant to the current phase of the project.
3. The most effective tool for the formation of the construction project’s organizational structure is a key events matrix. It is a functional model of production ties and logical connection of the events array, which implementation leads to the construction goals achievement.
4. The properties of organizational structure are defined firstly by links between structure’s elements. As the result of research a universal logical-mathematical model was identified and presented that is
described by logical predicate function $P(g_1,\ldots,g_m)$ in which functions $g_m(x_1,\ldots,x_n)$ defines the execution of system’s elements interaction.

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