Chapter 6

Reflex-Adaptive Organizational Structure in the Implementation of Large-Scale Projects

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Additional information is available at the end of the chapter

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Abstract

This work reflects the results of research on the study and creation of a new class of highly effective organizational structures of the reflex-adaptive type in the context of the implementation of a large-scale project. The research is based on the information paradigm of organizational structures' formation. From this perspective, any manufacturing company is represented as a system that converts resources into a final product on the basis of an information imperative. The structure of the production management and executive subsystems is selected. The composition and functions of the subsystems and the formation of system elements' feedbacks are described. Also, the development methodology of the management and executive subsystems is presented along with synthesis of these subsystems into the cybernetic type organizational structure. The chapter focuses on developing enterprise substructure of the executive subsystem, which is called the project matrix, which factually is its network model. Its properties, and transformation rules are described, and the algorithm of its formation is presented. The system properties of the organizational structure are examined in detail. The methodology for forming the reflex-adaptive organizational structure is presented. Particular attention is paid to the quantitative estimation of flexibility and stableness of organizational structures.

Keywords: reflex-adaptive organizational structure, cybernetic model of organizational system, synthesis of organizational structures, logical and functional connection, informational flexibility index, project matrix, life cycle of the project

1. Introduction

Current trends in the development of world production are characterized by socioeconomic instability, a significant turbulence in the services market which requires from organizations implementing large-scale projects to use additional competitive advantages that ensure their reliable and sustainable development. The complex of measures to improve the efficiency of enterprises includes various areas: the introduction of new materials and technologies, the use of productive machines and mechanisms, raising the technical level of personnel, etc. However, the modern science of management emphasizes the possibilities of the organizational structure, since its properties have a decisive influence on the efficiency of any company's activity.

The scientific substantiation and development of the scientific and methodological foundations of the formation of the enterprises' reflex-adaptive organizational structure with specified qualities of flexibility, stableness, and safety, their introduction into production practice represent an actual problem in modern conditions, the solution of which will significantly increase the efficiency of the enterprise's functioning.

The aim of the research, the results of which are reflected in this chapter, is to study the properties of the reflex-adaptive structure and to determine the qualities of its main components as system elements in the implementation of large-scale projects.

The study also aimed to find ways of forming the organizational structure of a large-scale project fully meeting the requirements of the project's life cycle. The formulated problem is considered on the example of investment and construction project in which the stages and phases of the life cycle are clearly expressed and the necessary transformation of the organizational structure is well traced.

The scientific community has long and fruitfully engaged in researching various aspects of organizational structures, their effectiveness in various conditions of functioning, researching the internal environment [1–3]. The level of problem's research related to the formation of highly effective organizational structures for large-scale projects is determined by the scientific and practical experience of the scientific school of the Moscow State University of Civil Engineering [4–8], where this problem has been comprehensively studied for many years by the university's scientists in cooperation with the world's leading specialists in this field, and research materials are presented at scientific conferences and in the scientific press.

The result of the research was the concept of an organizational matrix for the large-scale construction project which is a network model of the stages of the project's life cycle.

On modern views, progress of highly effective organizational systems is based on the concept of information approach to studying and forming complex engineering facility's organizational structure. Based upon the idea of reflex-adaptive systems of investment and construction project (ICP), we will consider the features of this structure.

2. Cybernetic model of ICP organizational structure

The main thing that distinguishes highly effective organizational systems is a pronounced structure which manifests itself as an ICP having a number of relatively stand-alone production

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units that execute typical for them piece of work. These units appear as backbone elements of the organizational structure and in the technological conception—functional blocks.

It is relevant to make the following observation. In all research papers that observe reflex-adaptive organizational structures, we have always referred to its belonging with the investment and construction project. This is not quite true. We have chosen the investment and construction project as a vivid example of the full-cycle construction: from the idea to the commissioning for the customer. Of course, the ideas explicated in the reflex-adaptive paradigm can be applied at any stage of the construction, but the greatest effect will be obtained by using a reflex-adaptive organizational structure when developing full-life cycle projects.

So, the full-cycle (or a turn-key project) construction's organizational structure is a set of functional blocks united by a sole production program that manages their activities, synchronizes their work, and controls the processing of program tasks (**Figure 1**).

Thus, in the organizational structure of the project, two subsystems are separated out: management and executive. The executive system includes functional production blocks.

Such production links organization within the enterprise allowing it to solve the problems of gaining such advantages as flexibility, stableness, safety, and resistance successfully as a participant of relations. Let us briefly consider the ways of solving these problems from the standpoint of the information imperative.

A general notion of enterprise flexibility is the ability to conform to changing market requirements for produced goods. The information paradigm allows eluding inaccuracies and solely qualitative characteristics of an important property of industrial production. We can identify the backbone of this quality and numerically estimate its significance using the pragmatic information concept [9], which was introduced in the middle of the last century by Russian scientist A.A. Kharkevich. If the analysis of goods realization reveals its negative trend, considering that its causes are determined, then we can interpret this situation as a production program deviation from the target values. Further based on measures adoption, we stabilize or increase realization volumes. This adjustment process to the changing market can be expressed as:

$$I = \log P_1 - \log P_0 - \log \frac{P_1}{P_0} \quad (1)$$

where I is the pragmatic information, P_0 is the probability of achieving the goal before receiving information, and P_1 is the probability of achieving the goal after receiving information.

In other words, based on the obtained information of goods market functioning changes, managing decisions are elaborated that parry the detrimental effect of this developments. The management system of the reflective-adaptive organizational structure is designed precisely to analyze changes of the external and internal environments of the enterprise as a system. On this basis, it is necessary to develop managing solutions.

A similar approach is possible when forming the quality of the system's reliability. In the information view, system reliability is the probability of its efficiency in case of internal environment system's changes. System efficiency condition is the permanence of its internal environment or its restoration from adverse effects on the system.

$$\frac{dI}{dt} = R \tag{2}$$

where I is the information about the state of the internal environment and R is the resource that is necessary in parrying the changes in the internal environment.

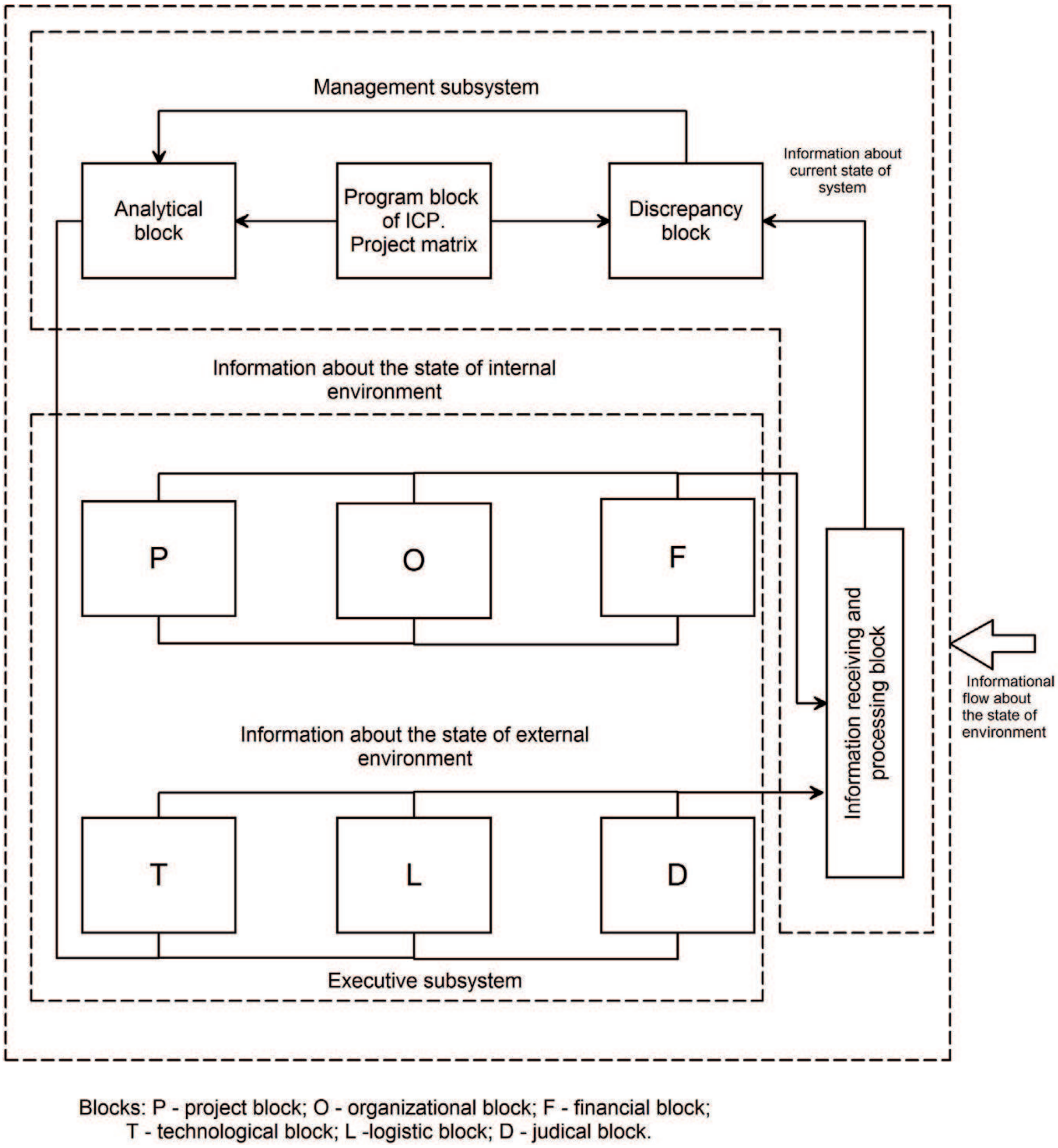

Figure 1. Cybernetic model of reflex-adaptive organizational structure. Source: own.

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Task of the internal environment permanence assurance is also guaranteed by the organization's management system. It produces managing decisions, and if the external resource is involved, then the decision is strategic for the system; on the contrary, if the resource is redistributed within the system, then the solution has a tactical level. The decision is operational if the resource was not involved.

Underneath the simple condition of enterprise work reliability, there are big problems of permanence assurance of internal environment characteristics. Permanent work with members of the work collective is crucial considering that any manufacturing enterprise is a socioeconomic entity. The issues of increasing work culture level, organizational culture, and organizational climate are the subject of executive's constant attention seeing that they are important and directly influence the enterprise efficiency.

Man is the source of productive labor. His educational and cultural level, commitment to self-realization, and inner self-esteem become the force that moves man to perfection, the active realization of his views and needs. And first of all, this is reflected in social work.

If the manager of any level wants his team to work successfully, he should see in his subordinates not soulless operators, but interested supporters, implementers of given tasks.

This is achieved by a wide armory of educational work, by whole system of moral and material stimulations, the creation of hospitable companionship in the team. All these relationships and activities strengthening complex of the personnel create a specific atmosphere of work, which is called the organizational climate [3]. Organizational climate, which is cultivated by the leaders of the organization, generates the organizational culture that is carried by all members of the collective.

In all our considerations about the reflex-adaptive organizational structure, we mean organizations with a high production and corporate culture.

3. Disadvantages in the established practice of implementing large-scale projects

In case of production and technological problems, successful solution, as well as increasing the improvement of design and engineering quality, the bottleneck in the complex engineering facilities construction is the problem of managing solutions' control and rational envisioning [10].

A rational solution is to minimize the use of resources while the system performs its target function. Let us briefly explain this definition. The intention of any production system is the achievement of certain state parameters, which are called the goal and appear as the result of the target achieving process. During the implementation of the target function, the system is affected by internal and external influences that angle the theoretical path of the system in the phase field of variables and do not allow the system to achieve target parameters. The ideology of any management system is to parry the negative results of external and internal influences in order to restore the desired trajectory of system's movement toward the target. The solution to this problem develops a mechanism that is capable of executing the decision-making algorithm, which is shown in **Figure 2**.

The nature and structure of the construction work determine the organization structure of the facility. A special feature of the modern construction process organization is the change in the composition of the functional blocks and their interconnection that depends on the specific phase of the project's life cycle. Let us illustrate this with the example from scientific research [9].

The interaction of the functional blocks in the design phase is described by the orgraph "a," while during the preparation for construction and installation works (CIW)—by the orgraph "b," and the actual construction—by the orgraph "c" (**Figure 3**).

We have already drawn attention to the fact that the nature and features of the planned work determine the construction process' organization structure. In fact, the forming of the construction project's organizational structure begins with the predesign or design works on the formation of design specifications and estimates. If works are carried out in the construction's full-life cycle, then this should be preceded by the structure formation of the "zero" implementation phase, when the project operates not with the composition of the construction works execution but with the development of target characteristics and project indicators.

Currently, the implementation of large-scale construction projects involves a great number of organizations. However, the design documentation does not define the project organizational architecture, let alone the mutual interaction during the project implementation. The only thing that can be noted is that modern ICP requires the obligatory presence of the construction management plan (CMP) and the construction execution plan (CEP) in the list of project documentation. However none of them contain any directions for creation of any organizational structure. It is assumed that it exists by default. Indeed, in the modern project implementation practice, the project organizational structure is not specifically formed, but created on the basis of existing arrangements of past experience and all that irrelevant to effective organizational structures.

In addition, CMP focuses on the technological aspects of construction installation works. Its structure includes the layout of construction site, the manpower, and machinery requirements computation, progress schedule, and so on. All components of the organizational design are presented in CMP, but it describes only one phase of the life cycle—construction and installation works (CIW), and even during them, there are no clear mutual interactions between contractors and their units on construction site of facility. To some extent, this can be tolerated in case of building a simple standard construction, where the only one phase is realized: construction and installation works, where the functions of the developer are delegated to the general contractor by the customer, who, in fact, forms the organizational structure according to its own understanding and takes into account its own interests.

To adopt such practice in a large-scale construction project even within a single phase of construction and installation works means to accept all confusion, irresponsibility, vanity, and system mistakes that will lead to time-consuming delays and can significantly increase construction cost.

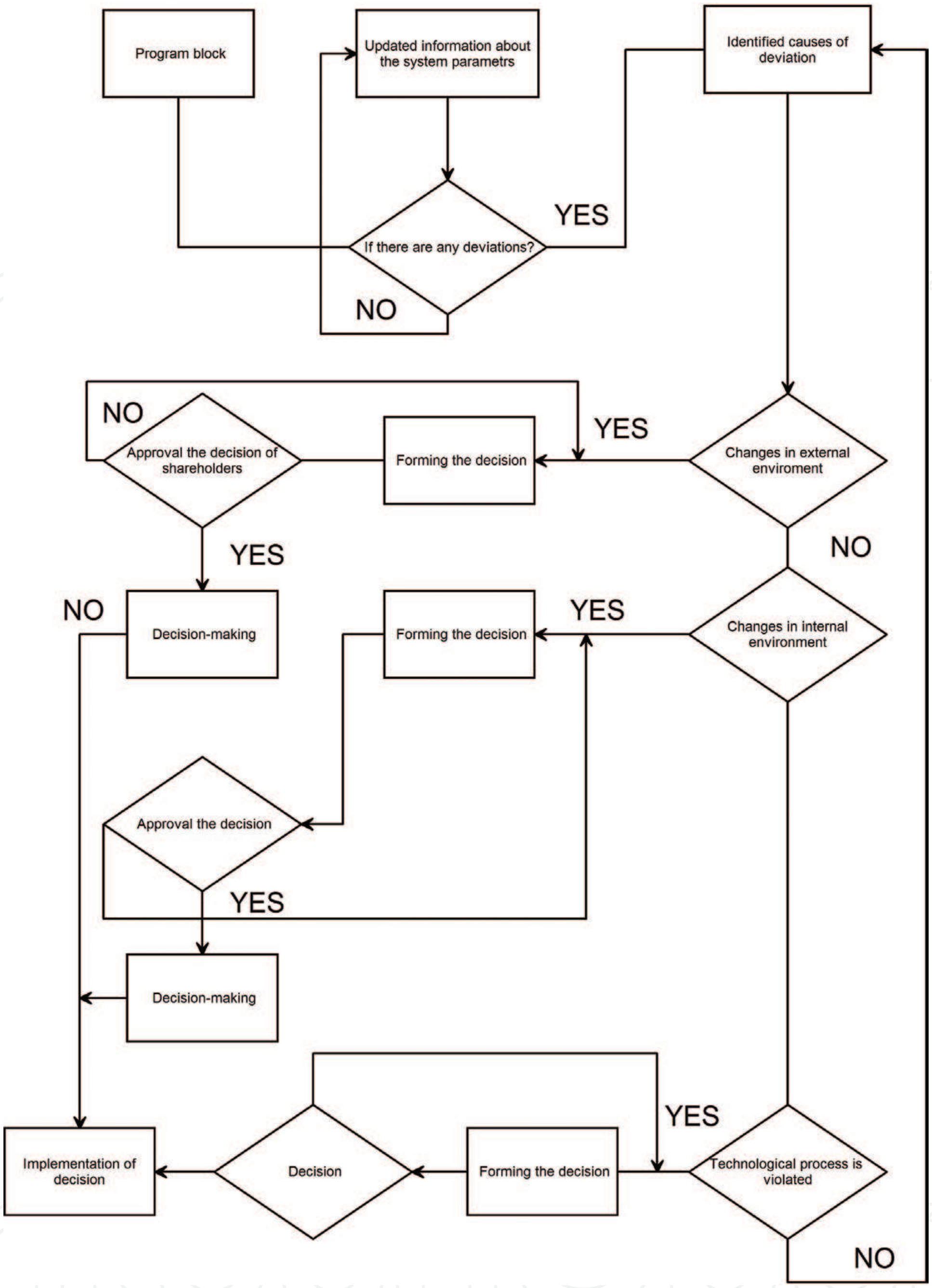

Figure 2. Decision-making algorithm in reflex-adaptive organizational structure. Source: own.

For creation of a highly effective organizational structure of the project, it is absolutely necessary to consider all the phases of the project life cycle and the full range of work that needs to be done to create the project product.

An example of the implementation of the complex engineering turnkey facility construction is indicative. Within it, the project goes through all stages of the life cycle and the question of the organizational structure formation and adaptation is very crucial.

Generally, new projects are implemented in the existing "parent" structure of the company, which implements a large number of projects that are currently in different stages of the life cycle.

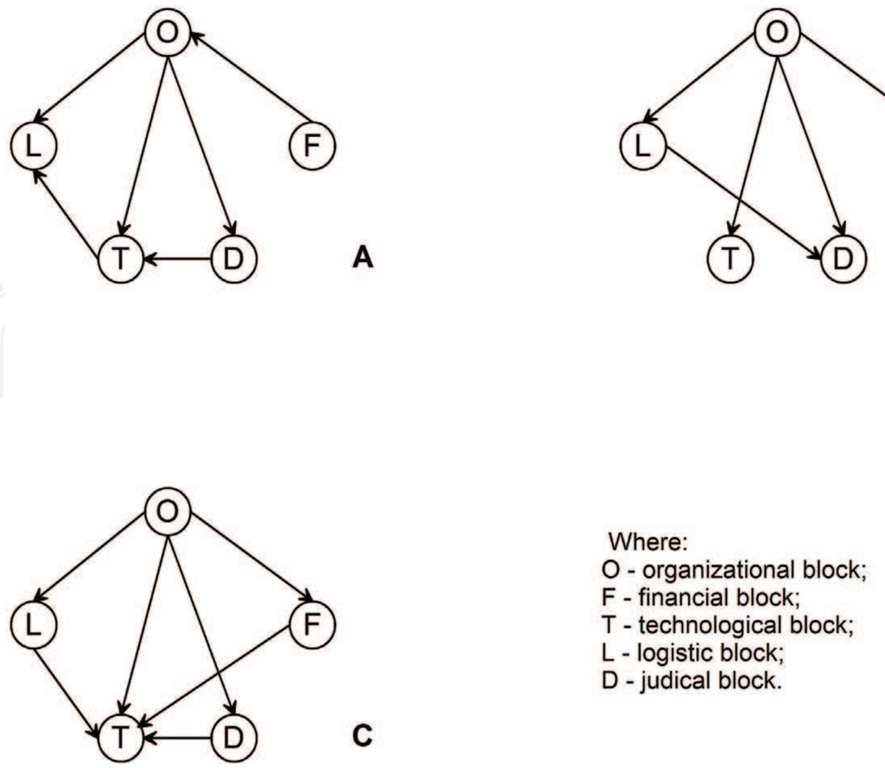

Figure 3. Orgraphs of project's functional blocks at different stages of life cycle. Source: own.

It is not just the process of forming a static organizational structure that is too complex, but the planning of its transformation process during the projects' progression from stage to stage and maintenance of financial resources and required number of labor and materials.

In organizational structure formation, the main problem of resources availability estimation is modern organizational development of engineering and construction companies.

The work on the staff requirement number estimation and planning is developing, but not intensively enough, because it covers a very narrow range of directions and functional blocks of construction projects. Obviously, for the implementation of construction and installation works along with the commissioning works, there are calculations of labor force requirement that are carried out, also number of project designer is preplanned and calculated but that is all. However, this is not nearly enough for the implementation of a reflex-adaptive organizational structure. Comprehensive approach to the planning is essential, beginning with a detailed elaboration of the work scope that should be performed at each phase, and ending with all types of support for their implementation.

For a large-scale project, especially if there are several of them and they are implemented in parallel, this is a rather topical and complex issue. Experience has proven that it is inefficient and disadvantageous to deal with this issue during the project implementation, neither from the cost and quality terms point of view, nor from obtaining effective experience in the construction projects implementation and management process.

Inattention to the project organizational structure formation and to its management at all stages of the life cycle is a serious omission in achieving goals of the investment and construction project.

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This chapter helps in closing the gap by using the project matrix concept, which is based on the methodology of its formation.

4. Matrix of project key events is the modern paradigm of organizational structure formation

By the term "project matrix," we shall basically mean a scheme of directive planning and management of functional blocks activity that have a form of oriented graph and based on project key events, their structure, and interrelations. The project matrix does not resolve itself to proximity tables of the network orgraph or assembly of Gantt bar charts. The project matrix is an oriented graph, in which the vertices display events in the project life cycle, and the arcs—the logical link of these events and their sequence. The special feature of this orgraph is the lack of resource conditions in achieving certain key events. It is a model of functional blocks' logical links at all stages of the project life cycle that uniquely determine its organizational structure. Essentially, project matrix is a graphical representation of the program, which is implemented by the management system in order to provide the appropriate organizational structure of each phase of the investment and construction project. Construction works range separation into technological and logical components thus allow emphasizing the questions of construction participants' organizational interaction into optimal organizational structure that fully accommodates nature, volumes, and features of the construction.

Properties of the project matrix can include all properties of network models [11]. In our case, the most important are network structures' possibilities of "scaling" and "merging." The matrix can be single- or multilevel depending on the amount project scope. The matrix levels are accordingly correlated with construction management and execution plans. Key matrix events of different levels have identical characteristics and appear as control points through checking the matrix and program compiling correctness.

The matrix is an execution document. It is derived from an order (the employer's or general contractor requirements), coordinated with the executors and approved by project administration. On the basis of the matrix, which has the program status after the approval, low-level documentation is elaborated. This work is transferred by the contractor to the project functional blocks. In our considerations a new concept has emerged—a key event. Let us distinguish it in details. The construction process consists of work actions, which ultimately lead to certain events. For example, work, which is carried out in accordance with the technical documentation for ground excavation, leads to the construction of an unlined canal. The work of a bricklaying crew leads to the fact of creating a building or part of it. This is also an event. And so on. The specification of this process allows us to locate all events that provide project target achievement, which is also regarded as an event. From a manufacturing point of view, an event considered as a completion of some work or part of it, which is defined by technical documentation, leads to a concrete material result. From the system point of view, considering the network model of work organization, the event represents orgraph vertex, which describes works' sequence and interrelations, and, therefore, the structure of this project implementation phase. The main difference of events is the size of incoming connections order. The event with the maximum incoming order will be defined as a key event. A key event or a series of them completes the project implementation phase or stage, forms a new organizational structure, or alters the previous one into the structure of a new construction phase.

As an example, we consider the formation of a matrix for a single-phase project (**Figure 4**).

This process is much more complicated for projects with a full-life cycle.

The presented flow chart requires some explanation (**Figure 5**). Firstly, let us emphasize again that the design of organizational structure is a similar stage to an object design or its systems. Therefore, a specialist or a group of specialists called system designers should handle this work on the analogy of IT systems with software engineers and system programmers [12]. Organizational structure formation of a large-scale construction requires greater theoretical skills and sufficient practical experience from developers to comprehend construction logic wholly, to separate the technological process properly into operational and logical links and to prepare clear and understandable construction documentation for the executives. Further, it is necessary to clarify that the main support complex in the project matrix formation is not works, but events. The matrix reflects the implementation of events through the execution of certain works. Therefore, all the attention of project designers should be focused on the correct events sequence and their logical relationship. Matrices of the same project can be formed on different scales, but it more effectual to develop a matrix from a large scale to extremely small one with a detail of events' specification.

As you can see, the matrix of ICP key events determines its organizational structure, but does not define logistics, labor movement, volumes, and period of construction. It is necessary to supplement the key events matrix with comprehensive information about requirements for achieving each key event in order to form design and estimate's real directive documents that define a detailed construction program. This task should be solved by system designers

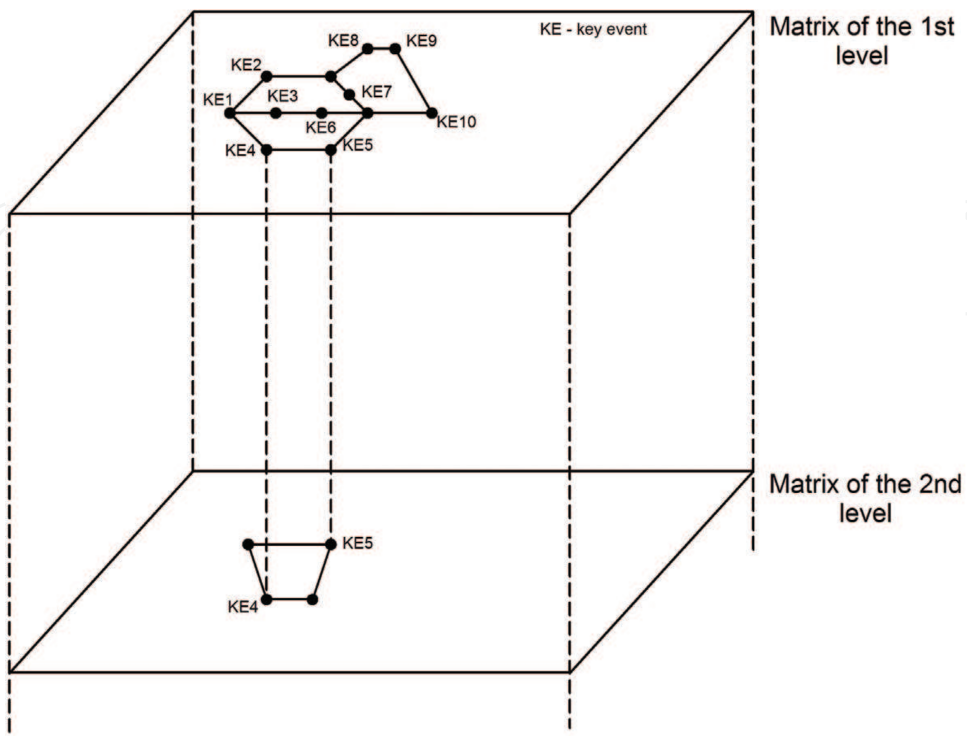

Figure 4. Multilevel matrix of project key events. Source: own.

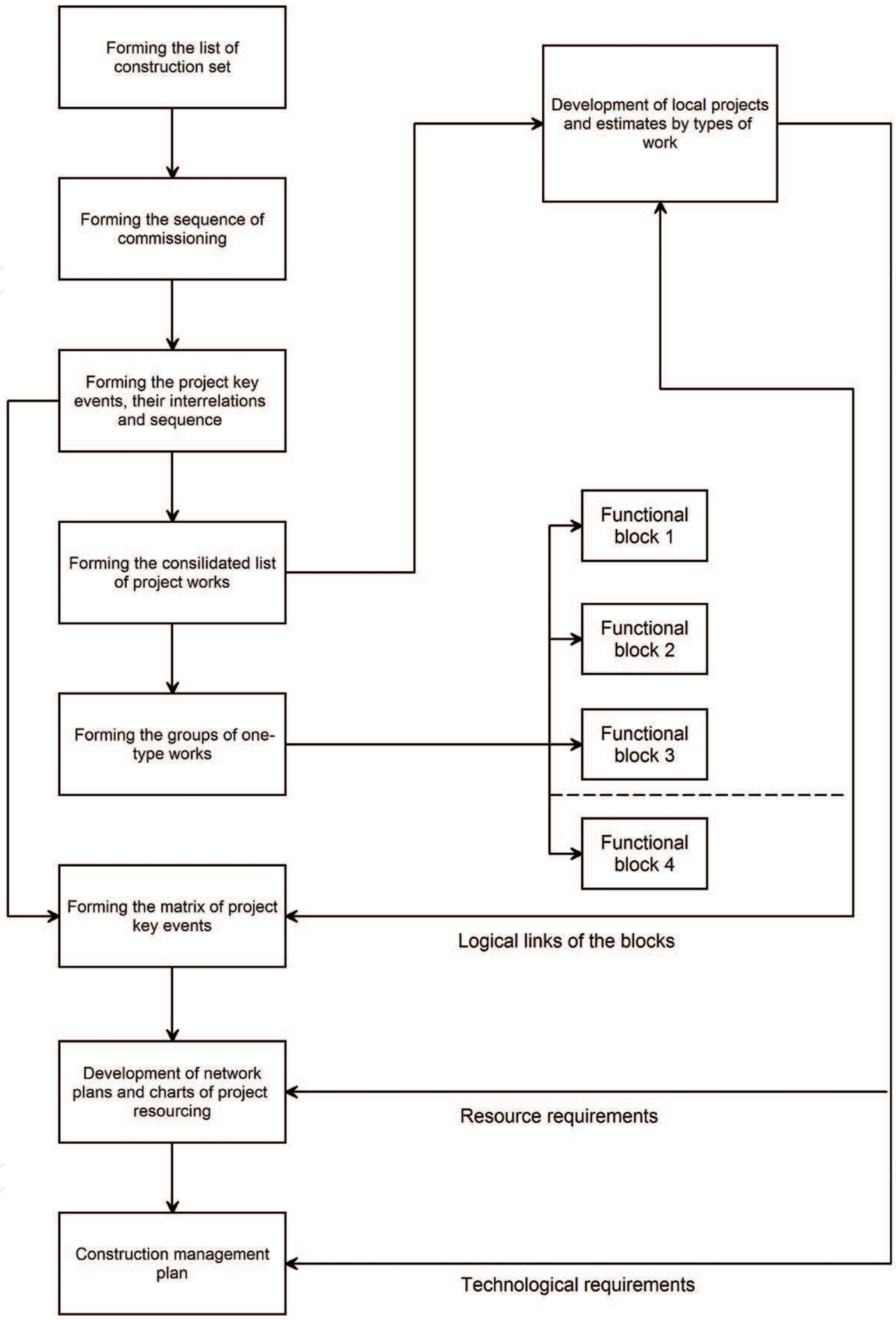

Figure 5. Flow chart of works on formation the matrix of ICP key events. Source: own.

combined with the project functional blocks, i.e., by specialized contracting organizations that should determine each orgraph arc of the "project matrix" by a description of work, which performs between the previous event and the developing one. Work description is carried out according to certain rules that allow operating this information. For that purpose, the operator card is created, which has its own address, where are attributed all types of work, performance periods, list, and amount of resources, that are necessary for work performance. In fact, the entire amount of construction, erection, and finishing works should be divided in elementary operations or by the necessary level of detalization. This is fairly large amount of design work that requires a certain amount of time. By using visual programming methods, it is possible to speed the work of this stage of documentation development. With these methods, developers do not demand a high qualification of programmers to produce technical documentation. The methodology of ICP key events matrix's actualization process is in considering the matrix as a polygonal network system—an orgraph, where the network vertices are events that determine the state of the project, and the arcs define the conditions for the project transition from one state to another, i.e., they are transition operators. In physical representation, the transition is a work or a set of works, which allows transitioning from one state to another through its implementation. Therefore, the transition operator "ω_n" should contain comprehensive information about the work and the execution conditions. The following form determines this requirement:

$$\omega_n = \sum_{n=1}^{n=m} A_n; \sum_{n=1}^{n=m} R_n; \sum_{n=1}^{n=m} G_n; T_{ct} \tag{3}$$

where A is the work that ensures the achievement of a specific event, R is the resource as a condition of relevant work performance, G is the labor contribution that characterizes each works, and T_{ct} is the critical execution time of transition from one event to another.

From this follows the most important operator property: the transition operator "ω_n" from the event "i" to the event "j" equals sum of any decomposition level operators in the same limits, i.e.,

$$\omega_n = \sum_{n=i}^{n=j} \omega_n \tag{4}$$

This property allows switching from low-level operators to high-level ones, i.e., performing operators' connection.

A few words about the visualization problem of the large-scale construction network model. There are limitations of man's abilities in perception of a large information amount. It is even more difficult to identify a trend or its characteristic change from the general data flow quickly enough. The main thing is lost in a large flow of information. By traditional assumption of work construction and executive structures in the form of linear or network charts, they have significant limitations of detalization level of the construction processes. If we increase the chart scale, it becomes unreadable due to the large number of particular elements. The solution of this problem is in applying highly developed visualization informational systems. The introduced construction execution plan can easily be transformed into a quasialgebroidal form, which is easily acceptive by computer technology. By designating corresponding events in a certain way, it is always possible to withdraw from the computer's memory any phase in various detalization levels as an addition to the main, enlarged project matrix.

Thus, it is possible to increase productivity and construction reliability by using visual programming and the methodology of forming the ICP organizational structures on basis of key events matrix and automated calculation method appliance.

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5. Conclusions and recommendations

Limiting the factors under the conditions of large-scale construction, there are unresolved issues of creating effective construction organizational structures that retard economic and financial progress. Current practice of large-scale construction projects is lacking the comprehension of organizational structure formation process, which is goal-oriented on construction at minimum expense. The absence of a convenient model of construction organizational structure does not provide design's variability of main contractors' interaction on the construction site, what makes processes of production organization uncontrolled.

Developers of high-efficient organizational structures focus their attention on cybernetic type of the reflex-adaptive organizational structure, which consists of management and executive subsystems that are covered with feedback. This structure is able of responding to changes in the external and internal environments and can form an optimal organizational structure for each stage of construction.

An effective method of forming the construction project's organizational structure is the method of production process analysis and synthesis. According to this method, construction process is divided into organizational and technological components, what allows to develop organizational structure from production and logical connections between events, works, and executors. Accordingly, this structure is most relevant to the current phase of the large-scale construction project.

The investment and construction project matrix is a network model of production and logical links array of events, which implementation leads to the achievement of construction's target goal. In order to lead to certain events, the matrix defines organizational and production relations of project executors and the sequence of work performance. The project matrix can be represented both in polygonal form of an orgraph, or in a quasialgebroidal notation. The orgraph of the project matrix defines the events by its vertices, and goal-achieving works by its arcs. The digitized vertices and arcs of the matrix orgraph are the reference point or the ICP implementation program.

Specification and scaling of the project matrix is carried out on the basis of the "key event" concept of the project. This reflects on all network schemes, regardless of the model's scale and determines the beginning or completion of certain construction stages. The highest level of the matrix consists only of key events.

In order to form a highly effective ICP organizational structure, it is necessary to execute a complex of works on the system design of the project's organizational structure as one of the stages of the construction documentation general development.

Lack of system design specialists requires the measures in training of system designers of construction facilities' organizational structures. In addition, construction managers of various levels are also required to be trained. This future specialists need to gain basic IT knowledge and acquire foundational skills in programming.

The development strategy of construction management processes requires mandatory infusion of computer information processing, decision-making automation, the creation and implementation of new digital information display systems, and the widespread use of digital media for construction documentation. The solution of these problems opens a new direction for the construction complex development—that is the construction informatization.

It is advisable to conduct further research on the use of a reflex-adaptive organizational structure in the implementation of large-scale projects toward financial and economic efficiency. In view of certain additional costs for the development of a detailed model for the implementation of a construction project, it is necessary to determine the minimum volume of construction production in monetary terms at which the costs of organizational design will be an acceptable value.

It is also desirable to consider the unification of requirements for organizational design, the creation of data banks for standard operations and construction products, the definition of the nomenclature of technical documentation for organizational design.

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