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Methods and variations of creating organizational and technological model of renovation objects

Azariy Abramovich Lapidus *

Dmitriy Vladimirovich Topchiy **

ABSTRACT

This article presents a study of links in organizational and technological structures and information support in construction control in the Russian Federation and other countries, including Great Britain, the USA, Germany, etc. It describes particular features of interconnection between the customer and the general contractor in construction product quality management abroad and substantiates the need for development of an automated design system of construction quality management. The study presents the structure of the state construction supervision in Russia at the objects of industrial and civil purposes. It reveals the features of conducting supervisory activities in construction and presents the main aspects of such activities. The article describes in detail the differences between the implementation of supervision and construction control on capital construction projects. The article gives an example of methods and variations of creating organizational and technological model of renovation objects. Creating an organizational system for the completion of construction of non-preserved and unfinished facilities is based on identifying and creating basic coefficients affecting the production organization efficiency. It also forms the basis of a single organizational and managerial model which enables a project to be implemented in the very short term and at minimal cost.

KEYWORDS: construction, organizational model, work organization methods, schedule, renovation

*Doctor of Technical Sciences, Professor, Moscow State University of Civil Engineering, Yaroslavskoe highway, 26, 129337, Moscow, Russia SPIN-code: 8192-2653, Author ID: 364784, azariy.lapidus@yandex.ru
**Ph. D. in Technical Science, Associate Professor, Moscow State University of Civil Engineering, Yaroslavskoe highway, 26, 129337, Moscow, Russia SPIN-code: 3956-9376, Author ID: 631269

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Métodos y variaciones para crear modelos organizativos y tecnológicos de objetos de renovación

RESUMEN

Este artículo presenta un estudio de enlaces en estructuras organizativas y tecnológicas y soporte de información en control de construcción, en la Federación de Rusia y otros países, incluyendo Gran Bretaña, Estados Unidos, Alemania, etc. Describe características particulares de la interconexión entre el cliente y el contratista general en la gestión de calidad de productos de construcción en el extranjero, y confirma la necesidad de desarrollar un sistema de diseño automatizado de gestión de calidad de construcción. El estudio presenta la estructura de la supervisión estatal de la construcción en Rusia en los objetos de fines industriales y civiles. Revela las características de llevar a cabo actividades de supervisión en la construcción y presenta los aspectos principales de tales actividades. El artículo describe en detalle las diferencias entre la implementación de la supervisión y el control de la construcción en proyectos de construcción de capital. El artículo da un ejemplo de métodos y variaciones para crear modelos organizativos y tecnológicos de objetos de renovación. La creación de un sistema organizativo para la finalización de la construcción de instalaciones no conservadas y sin terminar se basa en la identificación y creación de coeficientes básicos que afectan la eficiencia de la organización de producción. También forma la base de un modelo organizativo y de gestión único que permite implementar un proyecto a muy corto plazo y a un costo mínimo.

PALABRAS CLAVE: construcción, modelo organizacional, métodos de organización del trabajo, cronograma, renovación.

Introduction

In legal terms, the term “construction in progress” does not describe constructive features of a property nor the functional goals of its implementation, but merely indicates that the model of the construction program – the main element of which being the rhythmic creation of a property in a timely manner – is not violated. A distinctive feature of a facility under construction is the lack of a completed construction or engineering networks, which means that the operation cannot fully begin and leads to accelerated wear and a decrease in the operational reliability of the whole facility. Moreover, a facility under construction cannot be used either for residential purposes, nor for hosting administrative offices, nor for industrial production development (Petrenko et al., 2019; Amraoui et al., 2019). Thus, a facility under construction is a facility that does not meet its original purpose. It can be used only for further construction, since, in this regard, a facility under construction (FUC) cannot fulfil the functions of a fully-fledged real estate facility – that of a building or structure. In order to achieve and strengthen long-term competitiveness, companies are forced to adjust their activities, focusing on the changing demands of the time. The world is constantly changing, so it is very important to respond appropriately and quickly to these changes.

This article presents a study of links in organizational and technological structures and information support in construction control in the Russian Federation and other countries, including Great Britain, the USA, Germany, etc. It describes particular features of interconnection between the customer and the general contractor in construction product quality management abroad and substantiates the need for development of an automated design system of construction quality management. The study presents the structure of the state construction supervision in Russia at the objects of industrial and civil purposes. It reveals the features of conducting supervisory activities in construction and presents the main aspects of such activities. The article describes in detail the differences between the implementation of supervision and construction control on capital construction projects. The main issues arising in the performance of construction quality control are formulated.

The authors have theoretically identified, proposed and scientifically justified the feasibility of using integrated teams in low-rise multi-apartment housing construction. The analysis revealed the weight of the criteria, indicating the degree of influence of a criterion on the final result. By means of a method of an expert assessment data on the basis of which the most rational for use, by all criteria, crew is revealed are received. The measure of consistency of expert opinions was confirmed by a statistical test, which involves the calculation of the variance coefficient of concordance W and the evaluation of its significance by Pearson's criterion of agreement χ^2. Also presented and calculated the required number of experts for scientific and technical research. In the conclusion of the work the percentage ratio of the advantages of the selected type of teams compared to other types is presented, as well as further directions of research of this issue are indicated. To date, international practice and experience of re-profiling in the Russian Federation indicate that this is one of the most difficult management tasks. When implementing this process, it is necessary to take into account many limitations and the specifics of the company in which it is held. Therefore, it should be carried out only if there are clearly defined goals, the concept of re-profiling, an understanding of each stage and the methods by which to act.

1. Literature Review

In order to get acquainted with the current state of affairs in the issue under consideration, as well as to study the latest developments in the given field, it is necessary to refer to scientific publications by Russian and foreign scholars. The paper considers the articles by such authors as D.V. Topchiy, A.I. Meneiluk, L.V. Lobakova, I. Abramov, A. Lapidus, S. Newton, V.A. Pukhkal, A.B. Mottaeva and others.

Organizational structures are usually classified into the following structures:

1) situation analysis and restructuring program planning;

2) implementation of the enterprise re-profiling program;

3) control of the process of re-profiling and evaluation of the effectiveness of activities.

However, Zueva et al. (2019) argue that neither at the planning stage nor at the implementation stage in Russia there are no effective, scientifically based systems. To solve this problem, the authors consider the use of information "complex interaction system consisting of a large number of different functional subsystems and modules that are investment, organizational, technological and information" (Lapidus and Topchiy, 2019). Meneylyuk and Lobakova (2016) state that "the technology of re-profiling or changing the purpose of the building is significantly different from new construction and has its own characteristics", which confirms the conclusions made in this work.

As the most general factors that influence the planning of the re-profiling process and have interrelation, such parameters as the cost of the project, the number of working shifts a day, the number of working days a week, the coefficient of combination of works, and financing conditions are specified. In their publication, Meneylyuk and Lobakova (2016) recommend to perform the relationship between these parameters by using the mathematical theory of experiment planning, which is a fundamental part of the theory of experimental and statistical modeling.

Thus, as a result of the literature review, the relevance of the topic under analysis is confirmed, as well as the most important factors determining the process of re-profiling at the planning stage and the possibility of finding a relationship between them are determined. The main indicators, based on the scientific sources discussed above, include economic efficiency, intra-shift loss of time, the amount of work in the conversion. Dependencies between them will be established by using the known graphs of the relationship between the values under consideration, or on the basis of the study, if there is no known relationship.

This study is aimed at improving and facilitating the first stage of the life cycle of industrial conversion, i.e. planning. The methods and algorithms developed in the work will allow analyzing and planning future events more effectively.

2. Methodology

A model, in general, is an abstract manifestation of the most essential characteristics, processes and relationships of real systems. A model is a conditional image of a facility designed to simplify its study. There are two types of models: physical and symbolic (abstract). *A physical model* is a certain material system that differs from the modeled facility in terms of dimensions, materials, etc. The physical model can be large-scale (for example, a model of a building, building structure, etc.) or analogue, based on a physical process (Zueva, *et al.*, 2019). *Symbolic (abstract) models* are created using linguistic, graphic or mathematical means of description and abstraction. *An organizational and technological model* of erecting a building and structure involves a description of the list of construction and installation works, an order of their implementation and the nature of the relationship between the works, construction technology, compliance with its building codes, rational use of resources, etc (Jaber, 2019; Li et al., 2017).

Modern construction is a complex system with many participants and resources used. The nature of the relationship between them depends on dynamic processes that are largely probabilistic. When making decisions on the construction and production of works, the whole variety of influencing coefficients, which can be considered only in the case of developing multiple ways to achieve the intended goal, must be considered (Topchiy, *et al.*, 2019).

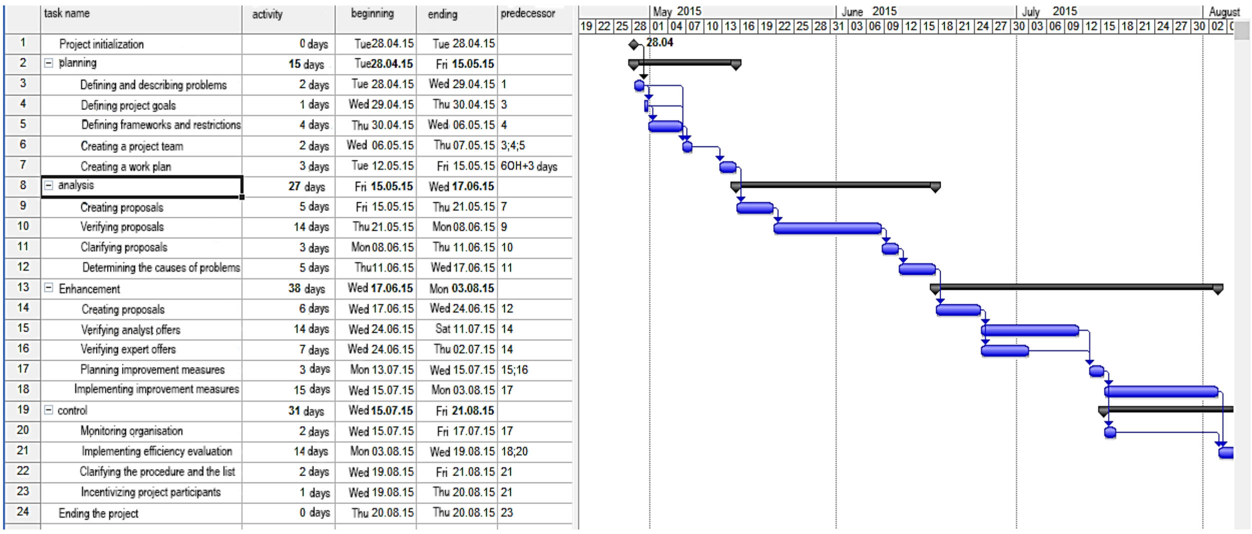
The optimal result at the end of construction should be expected only if, before the construction, its entire course is analyzed as to the possible influence of all coefficients in all cases. To this end, various types of organizational and technological building and structure construction models have been developed over recent years, and they are still being improved. When choosing a model, an assessment of the effectiveness of its application must be conducted in the first place.

Among these are graphic construction models such as (Abramov, 2018):

- linear graphs (graphs by H. L. Gantt);
- cyclograms;
- tables (matrices);
- network graphs.

Let us consider each of the classifications in detail (Newton, 2016).

Linear models (graphs) were first introduced in the early 20th century by professor and management consultant Henry Lawrence Gantt to graphically describe the construction sequence and timing (Figure 1). Gantt studied management using the example of ship construction during World War I and proposed his diagram consisting of segments (tasks) and points (final tasks or milestones), as a means of representing the duration and sequence of tasks in a project (Abramov, *et al.*, 2016).



	task name	activity	beginning	ending	predecessor
1	Project initialization	0 days	Tue28.04.15	Tue 28.04.15	
2	planning	**15** days	Tue**28.04.15**	Fri **15.05.15**	
3	Defining and describing problems	2 days	Tue 28.04.15	Wed 29.04.15	1
4	Defining project goals	1 days	Wed 29.04.15	Thu 30.04.15	3
5	Defining frameworks and restrictions	4 days	Thu 30.04.15	Wed 06.05.15	4
6	Creating a project team	2 days	Wed 06.05.15	Thu 07.05.15	3;4;5
7	Creating a work plan	3 days	Tue 12.05.15	Fri 15.05.15	6OH+3 days
8	analysis	**27** days	Fri **15.05.15**	Wed **17.06.15**	
9	Creating proposals	5 days	Fri 15.05.15	Thu 21.05.15	7
10	Verifying proposals	14 days	Thu 21.05.15	Mon 08.06.15	9
11	Clarifying proposals	3 days	Mon 08.06.15	Thu 11.06.15	10
12	Determining the causes of problems	5 days	Thu11.06.15	Wed 17.06.15	11
13	Enhancement	**38** days	Wed **17.06.15**	Mon **03.08.15**	
14	Creating proposals	6 days	Wed 17.06.15	Wed 24.06.15	12
15	Verifying analyst offers	14 days	Wed 24.06.15	Sat 11.07.15	14
16	Verifying expert offers	7 days	Wed 24.06.15	Thu 02.07.15	14
17	Planning improvement measures	3 days	Mon 13.07.15	Wed 15.07.15	15;16
18	Implementing improvement measures	15 days	Wed 15.07.15	Mon 03.08.15	17
19	control	**31** days	Wed **15.07.15**	Fri **21.08.15**	
20	Monitoring organisation	2 days	Wed 15.07.15	Fri 17.07.15	17
21	Implementing efficiency evaluation	14 days	Mon 03.08.15	Wed 19.08.15	18;20
22	Clarifying the procedure and the list	2 days	Wed 19.08.15	Fri 21.08.15	21
23	Incentivizing project participants	1 days	Wed 19.08.15	Thu 20.08.15	21
24	Ending the project	0 days	Thu 20.08.15	Thu 20.08.15	23

Figure 1. Gantt graph example.

Each step of the work is depicted as a line, and its length depends on the duration of the work. It must be noted that such an image depicting the adopted sequence of work required developing labor cost standards and improving the entire regulatory construction organization framework. The scope of linear graphs for displaying organizational decisions is the construction of simple facilities, as well as linear structures (roads, utilities, fences, etc.).

The advantage of such graphs is the simplicity of the image, the relative ease of reading, the availability of information on the volume of work, labor, duration, etc. Yet, even though it is relatively simple to develop linear models, they do have several disadvantages (Pukhkal and Mottaeva, 2018):

- there is no relationship between works;
- the main works predetermining the total duration of construction (complex of works) are not allocated;
- it is impossible to determine the time reserves for works;
- for large and complex facilities, linear models turn out to be cumbersome and difficult to read, which in many cases gives grounds for not quite competent engineers and technicians to talk about the uselessness of organizational and technical construction modeling.

The second type of models considered in this paper – **cyclograms** – were proposed in the mid-1930s by Mikhail Sergeyevich Budnikov, a Soviet scientist in the field of construction technology and construction organization, and they have been widely used up to the present day. The cyclogram presents not only the technological sequence and deadlines but also the working site. The display of private plots and the procedure for performing work on them in a cyclogram, the simplicity, schedule clarity, the ability to show the resource requirements for each unit of time and plot are important advantages that determined its widespread use in workflow organization.

A cyclogram is a work scheduling form, in which the same construction and installation works are constantly repeated (Lapidus and Abramov, 2018). A cyclogram reflects the flow development in time and space. Inclined lines of the flows on a cyclogram developed in strict technological sequence may not have intersections (Cha and Lee, 2015).

A cyclogram is a vertical graph in which time parameters are plotted on the abscissa axis, and spatial parameters (captures) are plotted on the ordinate axis. On a cyclogram, inclined lines show flows (processes). A type of a cyclogram for different types of flows is also different (straight or broken lines), while the angle of their inclination to the abscissa axis depends on the duration of capturing processes (Figure 2) (Kim and Park, 2006).

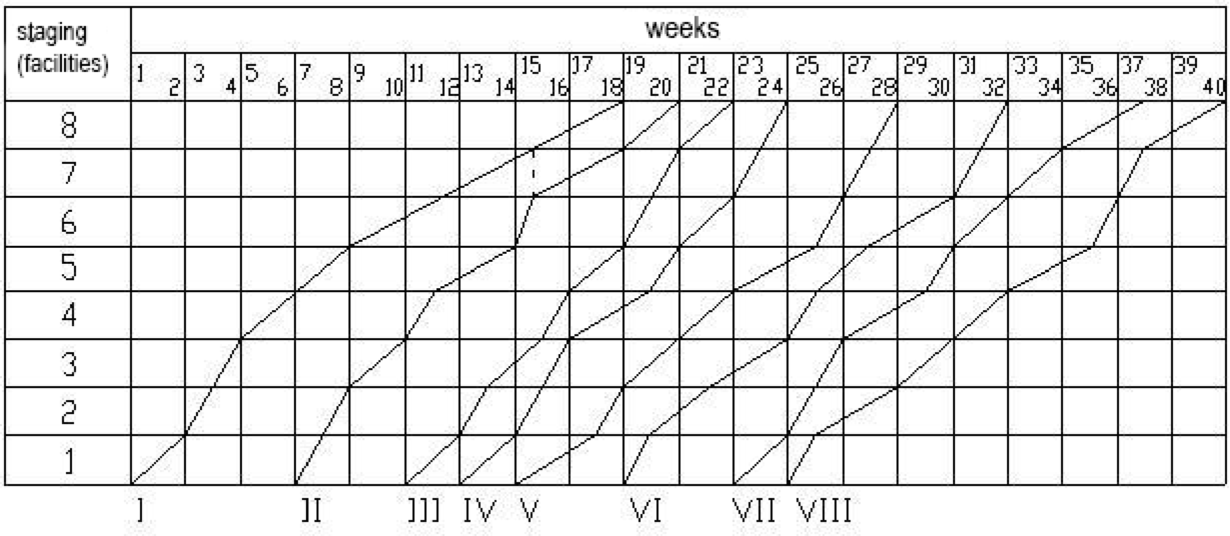


Figure 2. An example of a cyclogram.

3. Results

The procedure for developing a complex flow cyclogram during construction for a given construction period at the technical design stage is as follows:

1. Drawing up the facility flow nomenclature.
2. Calculating the necessary development of capital investments for all facility flows at the beginning of the main flow and the end of the first stage of construction and the launch of subsequent phases.
3. Drawing up a scheme for linking facility flows over time when coordinating the work completion at the facilities with the construction order and the readiness of engineering networks and communications for the start of basic work at the facility.
4. Determining the duration of individual facility flows and the time of their inclusion in the complex flow.
5. Drawing up a construction flow cyclogram.

The purpose of designing a complex flow cyclogram is to calculate the parameters ensuring the development of investments within the deadlines set by construction duration standards and determine a facility construction and commissioning order (Pezeshki and Ivari, 2018).

To draw up a complex flow cyclogram, the following main issues must be solved (Hasik, *et al.*, 2019):

- an enterprise under construction or a complex of buildings and structures must be separated into facility flows and work stages while determining the cost of each flow. The number and composition of flows depends on the construction decisions of the buildings and structures and the construction and installation technology. If the facilities with the main production purpose have approximately the same design and planning solutions, they comprise one facility flow. With various design solutions, construction is designed with several flows. A facility flow may consist of only one facility;
- the terms for constructing a facility as a whole and the terms for constructing individual buildings and structures, including the construction, installation and equipment installation duration, must be established;
- the preparatory period duration must be determined;
- the scope of work in the preparatory period and the timing of individual works in their technological sequence must be established;
- the sequence of construction and commissioning of facilities for basic production purposes must be set;
- the possibility of combining facilities with the main production purpose into one combined facility flow or several flows must be determined;
- the cost of capital investments must be distributed by years of construction;
- the work performed off-flow must be identified;
- the main characteristics of a complex flow cyclogram must be estimated.

When developing a complex industrial facility construction flow cyclogram, the creation of the following flows must be determined:

- the first flow (can be separated into several flows) includes facilities with the main production purpose at a cost of P1;
- the second flow of buildings and structures with auxiliary and service purposes at a cost of P2;
- the third flow is intended for the construction of external engineering networks at a cost of P3;

- the fourth flow of energy facilities at a cost of P4;
- the fifth flow of transport and communication facilities at a cost of P5 and so on.

Cyclograms have several drawbacks like the drawbacks of Gantt linear graphs.

Matrices are the third type of organizational and technological construction and installation models (Figure 3).

When using the matrix model, it is easy to determine the work duration of each team, the total construction duration, the delay of each team and the work combination level.

The advantages of this model include the ease of formalization, i.e. the simplicity of displaying the model contents in sign-symbolic form for the convenience of processing data on electronic computers.

The disadvantages are the lack of a visual display of the construction process. All the main characteristics must be sought in the explanatory note attached to the matrix calculation (Kamar, *et al.*, 2019).

land plots	private flows			
	1	2	3	4
1-2	0 10 10	1+2+1 4 12 16 13	16 8 24	25 2 27
2-3	10 12 22	13 16 10 26 23	24 4 28	28 1 29
3-4	22 7 29	23 26 -2 4 30 27	28 5 33	33 3 36
4-5	29 4 33	27 30 7 37 34	33 12 45	45 2 47
5-6	33 10 43	34 37 +1 8 45 42	45 15 60	60 1 61

Figure 3. An example of a matrix for calculating building flow parameters.

The final type of models considered in this work are network graphs which allow the user to best display a complex facility construction order, implement scientifically based construction methods, and identify and resolve many problematic situations arising during construction.

A network graph is a document allowing the user to quickly manage construction and redistribute resources depending on the practical construction state. They are especially effective in the case of construction, as well as the redeployment of complex industrial and other complexes, where many organizations are engaged.

Network models are used in construction to solve long-term planning tasks, determine the duration and timing of the main facility creation stages (design, construction and installation, technological equipment supply, production capacity development), as well as planning capital investments during facility construction.

The network method is based on the PERT system developed in 1958 in the USA: the "program review and evaluation technique" or the "Critical path method". In the USSR, network methods had been widely used since 1962. Network modeling methods for solving construction organization issues provide the opportunity to consider almost all construction features allowing to increase the construction efficiency (Figure 4).

A network is based on such concepts as "*work*", "*event*", "*dependence*", "*waiting*".

Work is a production process requiring time and material resources and leading to the achievement of certain results (for example, excavating pits, laying concrete for foundations, installing supporting structures). The work is depicted with one solid arrow, the length of which may not be related to the work duration.

An event implies completion of one or more work steps, which are necessary and sufficient to start the next one. In any network model, events establish a technological and organizational work sequence. Events are represented by circles or other geometric shapes, inside of which (or next to each other) a specific number is indicated, depicting the code of an event. Events limit the work considered and can be initial or final.

Dependence (fictitious work) is introduced to reflect the technological and organizational relationship of works and does not require time or resources. Dependence is represented by a dashed arrow. It determines a sequence of events.

Waiting is a process requiring only time and does not consume any material resources. Waiting is a technological or organizational break between works directly performed one after another.

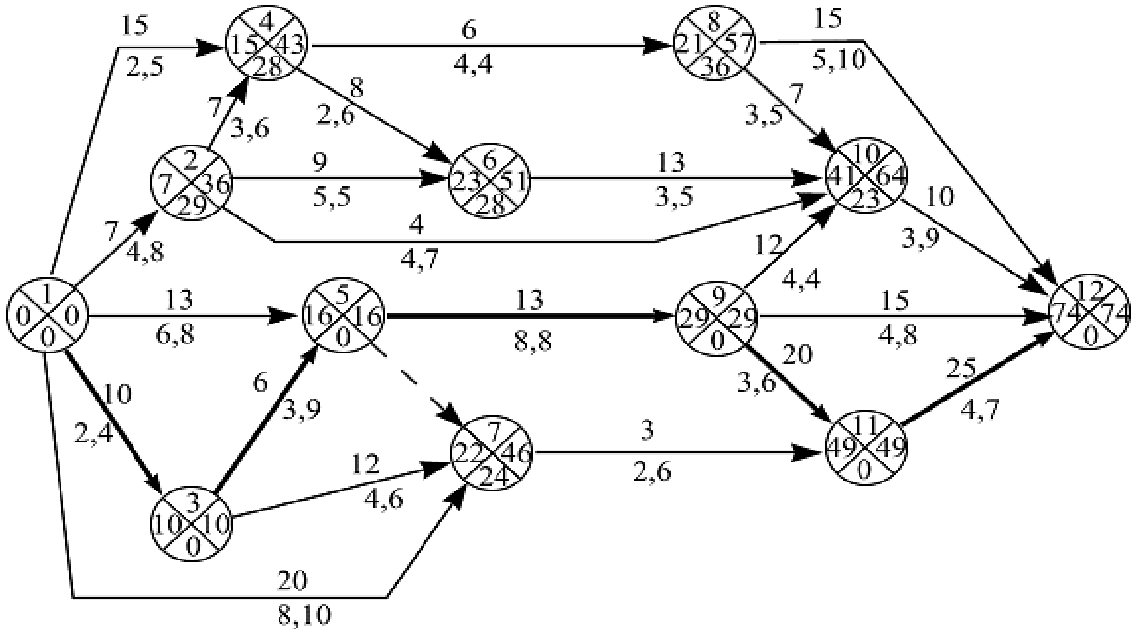


Figure 4. An example of a work network graph.

4. Discussion

The advantages of network methods are as follows:

- through the system of events and technological dependencies, the accepted interdependence of works may be seen 100% reliably;
- critical and non-critical works may be identified, and the critical path, as the longest, describing the construction duration may be found;
- for non-critical works, possible time reserves may be estimated and used, if necessary.

All the above models are mutually complementary and can be used when it is most appropriate.

When choosing organizational and technological schemes and solutions, the following must be considered:

- completeness of a separate technological cycle (redistribution) in the general construction technology;
- constructive completeness of a facility;

• spatial stability of a structural element;

• parallelism (simultaneity) of the construction of individual facilities in a complex;

• straightforwardness of the work, excluding excessive, long-distance, returnable, oncoming production movement directions; other construction organization flow form conditions.

The main task of organizational and technological modeling is to find various options with a rational relationship between production elements and a reasonable sequence and interlinked work in production and time provided they are performed continuously, resource consumption is continuous and production space (workspace) is continuously utilized. In the industrial facility redeployment projection onto the plane, the process of developing these models has several features. Now, there are no strict algorithms nor fully informative recommendations in Russia to consider them, so, during redeployment, situations unforeseen in the model may arise, leading to economic losses and reducing the facility redeployment potential.

Technological and organizational facility redeployment features are as follows:

• redeployment design features;

• increased safety requirements;

• exceeding the established reconstructed facility sanitary-hygienic environment standards (dust, noise, gas contamination, etc.);

• providing the reconstruction area with existing technological equipment and utilities;

• the degree of combination of construction and installation works with the activities of a facility;

• cramped working conditions;

• narrowness of the passage within the intra-facility road network;

• inaccessibility of elements and structures of reconstructed buildings and structures for detailed examination.

The main goal of this study is to determine the main coefficients affecting the development of organizational and technological construction and installation models, as well as to determine the degree and nature of this influence.

Conclusions

Creating an organizational system for the completion of construction of non-preserved and unfinished facilities is based on identifying and creating basic coefficients affecting the production organization efficiency. It also forms the basis of a single organizational and managerial model which enables a project to be implemented in the very short term and at minimal cost.

In this paper, using the analysis of normative and scientific documentation, conducting research by expert evaluation, mathematical processing of the results and practical application of the results, an algorithm for creating an organizational and technological model of construction and installation works at the industrial conversion facility was developed.

As a result of the study, the following tasks were solved:

* World literature sources were studied for innovations;

* The factors influencing carrying out construction and installation works at re-profiling of industrial objects are defined;

* The relationships between the factors of re-profiling were investigated;

* An algorithm for the development of organizational and technological model based on the results of the study;

* Approbation of results of work is carried out.

As a possible direction for further research, we are planning to conduct a more detailed analysis of the factors influencing the duration of work in the conversion or other circumstances affecting the performance of construction and installation works and to establish the extent of this impact.

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