

Modeling of construction technology of objects on the basis of technological interaction of works

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Abstract. The problems of sustainability and stability of organizational and technological models of the object construction are revealed. The scientific approach is generalized for the formation of the complex properties of organizational and technological models, based on the consideration of the technology of object construction as a framework for the development of construction models. The technology of construction of buildings and structures is analyzed. The method of the consideration of technologies for the construction of buildings and structures is proposed from the point of view of the connections between technologically interconnected processes and the nature of the interaction of linked simple and complex processes. The dependences between technologically related technological activities and processes are obtained. The qualitative and quantitative estimates of the dependences obtained between technologically related works and processes are determined. The deterministic characteristics of the technical connections between works and processes, giving steady properties and used for the development of object construction models.

1. Introduction

According to the established construction practice, organizational and technological models are used in accordance with the organizational and technological methods adopted in the construction of objects to ensure between the construction processes the established relationships and the developed sequence of their implementation. They have information on such indicators as volumes and calendar terms of performance of works on construction. Organizational and technological models basically are an adequate representation of the real object of construction in all aspects. Therefore, organizational and technological models are considered as one of the most important tools to ensure the implementation of the schedule by one of the criteria of the quality of construction.

Hence, the task of ensuring reliability and resiliency of organizational and technological models is to destabilizing internal and external factors.

Implementation of this task is the main problem of building science.

The issues of ensuring of the stability of organizational and technological models have been and are being paid a lot of attention by domestic and foreign scientists.

Currently, the basis for the formation of organizational and technological models continues to be an approach based on the principles of system engineering construction [1,2]. In the context of this direction, domestic specialists have developed various ways to improve the reliability of organizational and technological models. They include methods for reducing organizational and technological processes in groups undistinguished in terms of reliability [3], the use of the method of



reliable coordination system [4], "project approach", taking into account the market basis of construction design [5], methods for improving reliability taking into account the risk in the design of the organization, technology and construction management in conditions of uncertainty [5], the development of construction organization projects by creating an optimal management plan for the construction company [6]. Methods based on the strategy of buffer management [7], the creation of an integrated metric for quantifying the stability of interdependent systems [8], ensuring the sustainability of processes in construction [9-11], the management of construction processes using methods of analysis and evaluation of programs, statistical tests [12-16], methodological foundations of the design of organizational and technological processes are identified from foreign studies, providing system engineering coordination of functional subsystems and information-analytical tasks in information-computing sphere [17].

If we generalize all these methods, it can be concluded that the basis for the adoption and implementation of these measures is the probability theory, in accordance with the probability of the implementation of organizational and technological solutions as a part of organizational and technological models are determined. This solution of the problem involves the possibility of eliminating negative deviations in the course of construction from the action of destabilizing factors by maneuvering the available resource reserves, and such images can be traced dependence between the reliability of the system at this level of management and the number of subordinated resources. On this basis, it can be argued that the parameters of organizational and technological models should have an area of acceptable changes in the timelines of the CMP. The boundaries of this area are determined by the earliest start and latest end of the work on the calendar plan. All this allows to reveal permissible limits in changes of controlled parameters during construction of objects with the purpose of repayment of negative influences of destabilizing factors and to establish intervals in regulation of the course of implementation of the project. From all the above it follows that the duty of operation of construction systems is associated with the unconditional implementation of the previously adopted organizational and technological models in some area of permissible changes in the timing of the implementation of organizational and technological solutions.

The present level of development of computers allows to reduce time for the development of models of organizational and technological solutions, but still even a slight change in the acceptable time range entails the revision and recalculation of planned technological change in the topology of the adopted organizational and technological models. Ultimately, this leads to frequent adjustments of the entire organizational and technological models, which indicates its sensitivity to external influences. This vulnerability is due to the rigid interconnection of the time, volume and resource parameters of organizational and technological models, and even a slight change in one of these parameters leads to a change in others. Therefore, the task is to revise the mechanism for the formation of organizational and technological models, capable of absorbing various deviations of one of the elements of the system, while protecting others.

2. Methods

The basis for the solution of the stated problem is the theoretical results of the revised internal content of the calendar plan, the basis of which is organizational and technological models, represented in the form of synthesis of three models: organizational, technology and planning, reflecting, respectively, the organization of construction, the technology of erection of the object and planning the volume of work in time [18,19]. This choice is explained by the visual representation in the format of the calendar plan of the mechanism of interaction between the technology of construction of buildings and structures and the organizational component of the construction of the object and the resulting interaction parameters of the calendar plan, which makes it possible to assess the impact of the degree of implementation of organizational and technological solutions on the stability of organizational and technological models in general.

With such scheme of interaction, the technology of construction of buildings and structures model should act as a rigid "framework" on the basis of that organizational decisions are made in order to

give stability to the effects of various factors and the overall stability of organizational and technological models [20,21].

In order to identify the characteristics that are natural for all types of technology of construction of buildings and structures and have the properties necessary to build on their basis a system that creates conditions for stability and ensure reliable implementation of organizational and technological models, technology of construction of buildings and structures is considered by the author as a method, a method of implementation of the defined actions, the feasibility of which is achieved by taking into account the links between technologically interconnected processes and the nature of interaction between simple and complex technological processes, their interconnection in space and time for the functional purpose of technology of construction of buildings and structures for the construction of facilities for various purposes.

3. Results and discussion

Obviously, the interrelationship of technologically connected processes is conditioned by properties of internal processes in relation to the area, i.e. interaction of technologically connected processes is possible only if these processes are in the same environment which is an interval-an exact link in interaction of processes, and possessing the properties providing their interaction (figure 1).

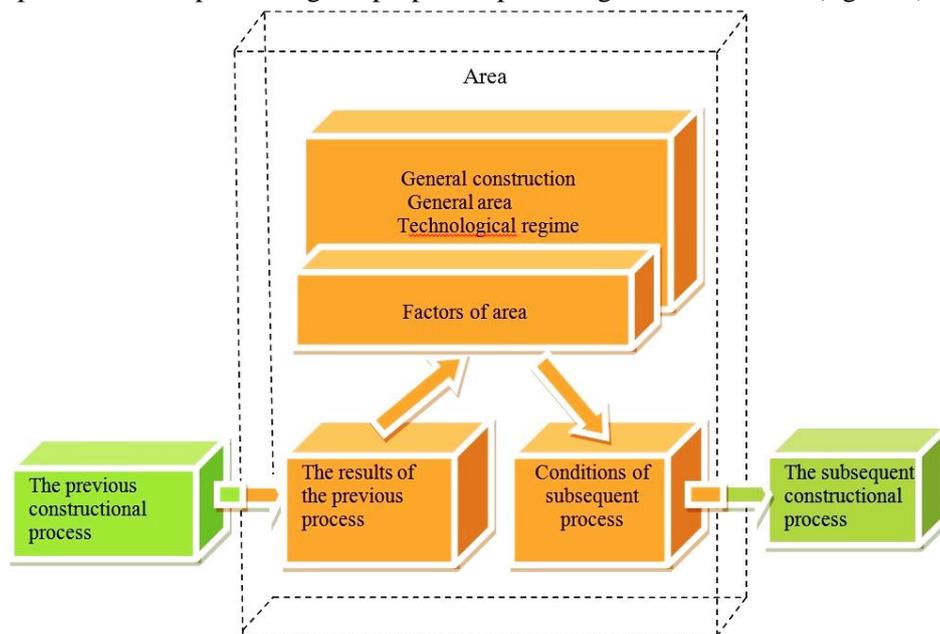


Figure 1. The scheme of interaction of technological connected processes.

Under the notion "environment" is not necessarily some part of space, but some part of surface or part of surface, for example, a node of the support equipment on the foundation, which provides interconnection equipment installation and installation of the foundation.

In this regard, the mechanism of interaction between two processes in general may look as follows (figure 1).

The previous process by its results affects the factors of the environment in which it is located. And since the changes of these environmental factors affect the conditions of the subsequent process, there is an interaction of these two processes.

In the first approximation, you can select several types of environments, and display some characteristic of them, the rules of interaction processes. In particular, a "common environment" may be:

- General construction.

- Common space.
- Technological mode.

A common design as an environment for two or more processes is identified by a common design feature for these activities, or by a common node that includes design-related features. The following factors are possible-transfer links in this environment:

- support unit;
- design as an object of refinement;
- rough and fine machining of the structural element.

The "node of support" factor refers to the group of situations when one of the processes builds a support, and the second - a constructive element based on it. In this case, there are various elements that belong to the same node, foundation and equipment. Condition of structural elements belonging to one node here is the bearing mounted on the support element, respectively, and has the location factor – the transmission link of the "unit bearing". The mechanism of interaction of works in the transmission link "node support" is as follows (figure 2).

Creating a support for a structural element means obtaining the result of process 1 (maintenance of the support), which creates positive conditions for process 2 (erection of the supporting element equipment), and the effect of result 1 continues after the end of process 1. Thus, it is possible to formulate the following rule for determining the technological dependence between the processes in the transmission link "support node":

1. the effect of process 1 is present (the result of process 1 affecting the conditions of process 2 appears and persists after process 1);

2. it turns out that the effect of the result of process 1 after the end of this process (the positive effect of the result of process 1 on the result of process 2 is carried out immediately, as this latter appears, and for this it is necessary that the result of process 1 appears earlier than the result of process 2).

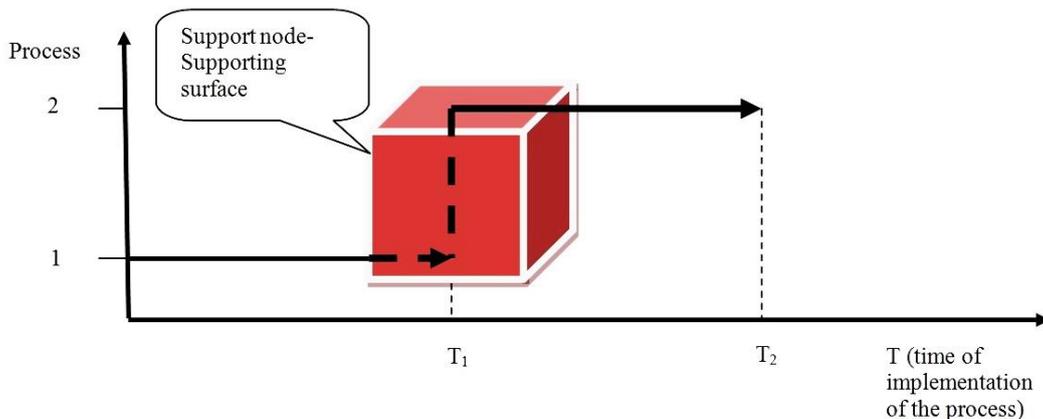


Figure 2. Scheme of interaction of processes in the transmission link "support node".

From the rule we can conclude that the transmission link of the "unit bearing" is the process, building support, creating a front to execute technologically connected process, only after complete your graduation, therefore, precedes the process 1 to process 2. Accordingly, technological advance, reflecting the connection at first $(V_{i,i+1}^e)$, equal to total previous of work, after $(V_{i,i+1}^b)$ – the entire volume of future work.

The "design as an object of refinement" factor refers to the group of situations where one of the two processes creates a design, and the other in any way tries to bring it to the final type envisaged by the project, i.e. the first process creates a front for subsequent processes. To a subset of the types of processes that activates such a transmission link, are the processes associated with the erection of constructions – walls, ceilings, foundations, etc. However, additional prerequisites for identifying the

environment are not required: a general parameter is sufficient – a structural element that designates a built – processed structural element.

The processes in the transmission link "design as an object of refinement" are interconnected both at the beginning and at the end, i.e. it is involved in the relationship between the technological links between the beginning and the technological links between the ends of adjacent processes. Graphic interpretation of the technological interrelations of processes is presented in figure 3.

Vertical arrows reflect the technological sequence of processes. Bold lines highlight the technological developments that make it possible to perform a certain amount of the subsequent process.

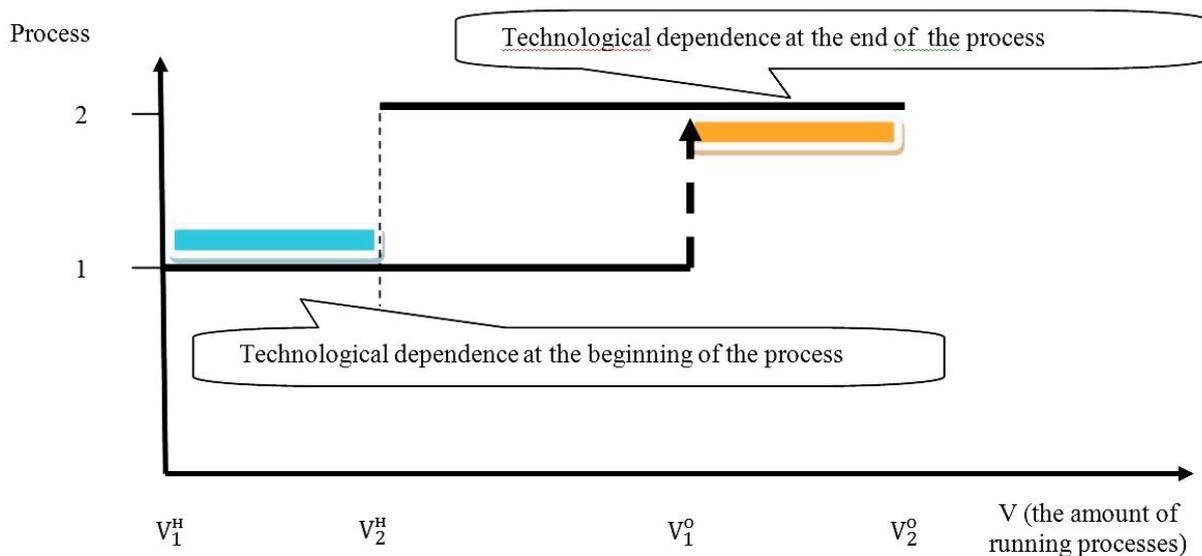


Figure 3. Scheme of interaction of processes in the transmission link "construction as a pre-work object".

That is, for this technological dependency is typical situation, where partial ahead exists and the execution of any single process creates an opportunity to fulfill a certain amount of follow-up process. The second situation determines the fact of dependence of the end of the subsequent process from the end of the previous one.

The rule of establishing a technological dependence between the processes in the transmission link "design as an object of refinement" will look as follows:

-process interactions can be seen as a positive effect of one process on the result of another process (refinement is impossible without the erection), continuing after the completion of the first.

This is the precedence of process 1 with respect to process 2.

Coarse and fine processing of the same feature occurs when one process negative result (performing rough processing) affects the outcome of another (performing the fine processing). Concrete manifestation of this interaction: the device of hidden wiring should precede plaster and painting works, as otherwise plastered and painted surface of walls and ceiling will be damaged by fines; the construction of underground utilities (water, gas, sewerage) should precede AC-falsification and landscaping of the area through which these communications pass. As in the case of "design as a refinement object", there is also a partial advance of the previous process (figure 3).

In accordance with the combination of works, the rule of establishing the technological dependence between the processes in the transmission link "rough and fine processing of the structural element" can be defined as the negative impact of the result of process 1 is limited by the time of the impact on the result of process 2.

Common space as an environment causes two types of process interaction:

- positive - when one of the processes creates the space needed to execute another process;
- negative- due to the presence of a common space, characterized by a negative impact of one process on another.

The creation of space as a factor of interaction of these processes can be of two kinds.

First, the creation of a working surface, i.e. a horizontal plane by one process to accommodate the workforce, machines and mechanisms, materials for the production of another process.

The second type of the created space is a recess in which workers, machines and mechanisms, materials for production of earthwork and works on the device of an underground part of buildings or constructions should be placed.

The meaning of the technological mode as the medium and the transfer link is that one process creates or properties of the environment, thereby affecting the conditions of another process, or its result.

The rules associated with a technological regime are largely similar to the rules of the common space.

Thus, the necessary conditions for interaction, leading to a certain pre-modern relations between some processes, are:

1. The presence of interactive processes in the same environment.
2. The impact of the results of one of the processes on the factors of that environment, thereby changing or activating those factors.
3. The impact of the environmental factors activated by the first process, or modified by them, on the conditions of the second process, or its results.

To identify and establish technological dependencies between processes taking into account the influence of environmental factors on the order of interaction between the processes, the construction process is considered as a process of implementation, at the "input" of which-all conditions that affect or may affect the "output" – the results of the process or its consequences - including negative ones (figure 4).

Moreover, it is possible to influence the conditions on the results, both through the process of work and directly. With this approach, the technological dependence between the works is due to the mutual influence of their conditions and results. Therefore, the analysis of these "inputs" and "outputs" of the work is expected to reveal the general laws of interrelation of works.

Conditions can be characterized by the correspondence of the purpose of the process and the object of influence.

According to the purpose the process conditions can be positive – positively influencing the course of the process, and (or) on its results, or negative – impeding the process, or resulting in violation of its results.

In connection with the division of the necessary conditions – contributing and stopping – worsening it should be noted that it is to some extent conditional and depends on the level of requirements for the technological process of construction.

On the object of influence conditions are divided into influencing the process itself and affecting the consequences (results) of the process.

It should be noted that the conditions of both these classes ultimately affect the outcome of the process. But in the first case, it occurs indirectly through interaction specific to this work, and in the second – directly, regardless of how the process proceeded, the corresponding result is known.

Similarly to the necessary and conducive conditions, the results of the process may be relevant to the process and may be additional, collateral. From the standpoint of compliance with the objectives of the process and from the point of view of their impact on other processes and their results, they can be positive or negative.

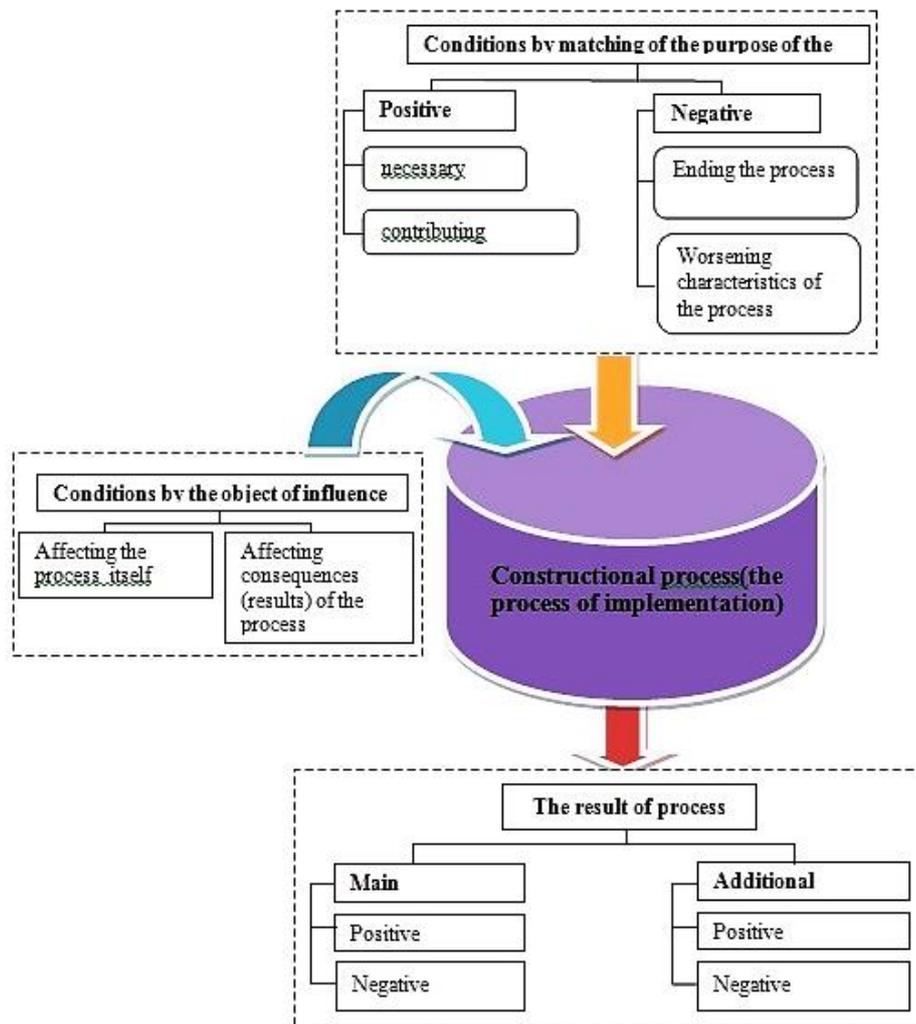


Figure 4. The model of implementation of the constructional process.

It is considered that the "mark" of the effect of the result of one process on the result or condition of another process is determined taking into account the "mark" of the result or condition on which the effect is made. If there is a negative impact on a negative condition or result, it is considered that the impact is positive; if a positive impact on a negative condition (result), the impact is considered negative, and so on. Thus, the positive or negative impact is defined in terms of the "end result".

And the last characteristic of the result of the work in terms of the interaction of processes – is the time of the action of one process on the conditions or the results of another. The outcome of the process can have an impact either during the process or after it has been completed, i.e. the process has an "impact effect".

Thus, the most important characteristics of the process results from the point of view of the interaction of the latter are:

- "sign" of the effect of the result, i.e. its usefulness or harmfulness, positive or negative;
- the direction of the effect of the result-either through the conditions affecting the other process, or the direct impact on the result of another process;
- time of impact of the result: either the impact is terminated at the end of the process, which includes the result (no consequences), or the impact continues after the window of the process (the presence of consequences).

Based on these characteristics of the process results, and displays the basic laws of interaction conditions and results of construction processes.

(I) when the result of process 1 is affected by the conditions of process 2:

Combination 1: positive impact – there is no effect of the result of process 1.

Regularity: If the result of process 1 has a positive effect on the conditions of process 2, and the result is not retained after the completion of the process, the action of process 1 is not late and not premature.

Combination 2: positive impact – the result of process 1 is present.

Regularity: If the result of process 1 has a positive effect on the conditions of process 2, and the result is manifested and maintained after the completion of the process, the action of process 1 is ahead of the action of process 2.

Combination 3: negative impact-there is no effect of the result of process 1.

Rule: If the result of process 1 adversely affects the conditions of the process 2, this effect is limited to the execution time of process 1, then process 2 is not executed simultaneously with the process 1, it must either end earlier than process 1, or to begin after its completion.

Combination 4: negative impact-the result of process 1 is present.

Regularity: If the result of process 1 negatively affects the conditions of process 2, and the result is retained after completion of the work, then to avoid this negative impact, it is necessary to finish process 2 earlier.

II) Under the influence of the result of the process 1 to the result of the process 2:

Combination 5: positive impact-the effect of the result of process 1 is present only during its execution.

Regularity: if the positive effect of the result of process 1 on the result of process 2 occurs only during its execution, process 2 must be completed by the beginning of process 1.

Combination 6: the effects of positive – influence the result of the process 1 after it.

Pattern: whereas the positive impact of the result of the process 1 to the result of the process 2 appears immediately after its completion, the result of process 1 were informed of the result of the process 2.

Combination 7: negative impact-the effect of the result of process 1 is limited by the time it takes to complete.

Regularity: If the result of process 1 negatively affects the result of process 2 only during its execution, it is necessary that by the time the result of process 2 the negative impact is over.

Combination 8: negative impact-the effect of the result of process 1 after its completion.

Regularity: if the result of process 1 negatively affects the result of process 2 after its execution, its consequences must be eliminated.

From the identified patterns of interaction of construction works can be concluded that the work interrelated as at the beginning and at the end, i.e. in the relationship involved the technological links between the basis and the technological links between the endings of adjacent works. Graphic interpolation of technological interrelations of works in the construction of the object is presented in the form of a linear diagram (figure 5).

From the presented graph shows that the reflection of the technological links at the beginning and end of the work, is a certain technological reserve of previous work in relation to the subsequent, expressed in units of volume and having an estimate of $V_{i,i+1}^e$, and $V_{i,i+1}^b$ and most importantly, these parameters are deterministic and constant during the entire period of work.

It can be argued that these parameters symbolize two things:

- first: technological dependence on the beginning suggests that the beginning of the subsequent work is technologically connected with the previous one and thus reflects the priority of one job relative to another;
- second: the necessity of finishing the work until a certain point or state in the course of performing other work and the possibility of starting some of the works after the occurrence of a certain point or state in the course of performing other work.

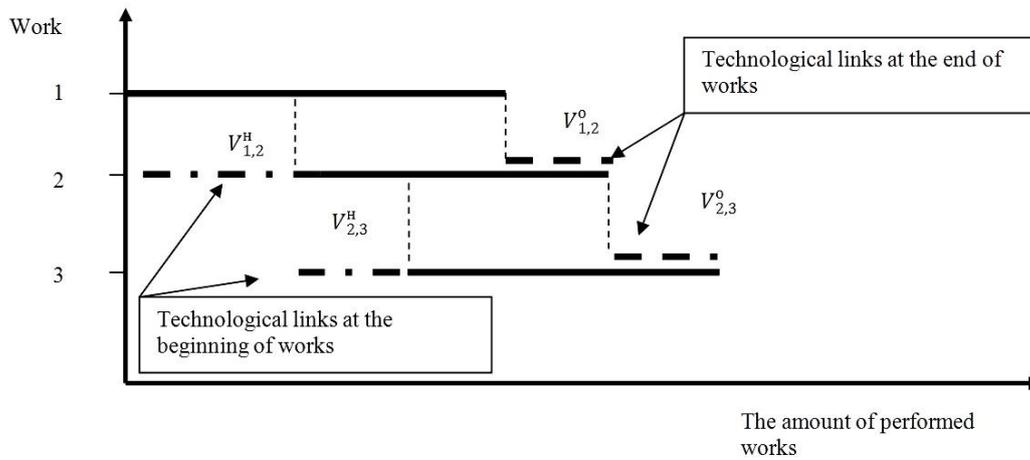


Figure 5. Linear diagram of technological connections between adjacent works in the construction of the object.

Based on this, we can draw the following conclusion.

Identified technological linkages between related works have two scores. The first describes the process sequence that reflects the order of execution of one process relative to another, i.e. captures the qualitative aspect of technological interaction and is therefore called a qualitative assessment.

According to the law of transition from quality to quantity and further to measure, in the study of any object of investigation, and in particular the technology of construction of the object, the transition to knowledge of quantitative characteristics is necessary. Knowing quantitative certainty is valuable in itself. Specific values obtained in the calculation and measurement procedures are processed and summarized in such a way as to reveal the measure of things, to know the law of interaction of properties, in our case, the law of interaction of technologically related construction works. Therefore, the second evaluation of technological interaction, which characterizes the quantitative ratio of this interaction, is advisable to be considered a quantitative evaluation.

Modeling of technological dependences on the basis of qualitative and quantitative assessments of technological dependences between interrelated processes developed in the work is shown by the example of the isothermal tank installation (figure 6).

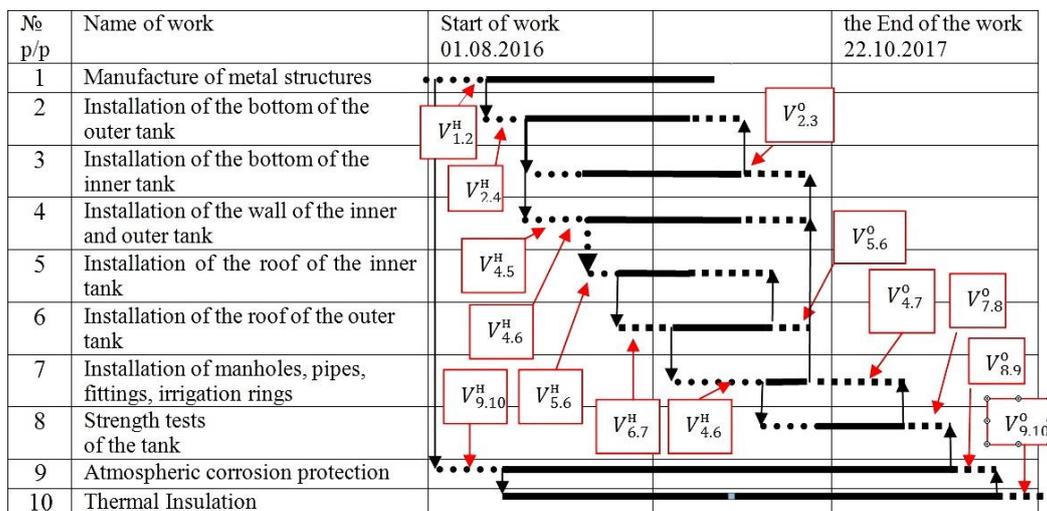


Figure 6. The model of technological dependencies between works in the construction of the object (for example, installation of insulated tank).

The formation of the model begins with the definition of the time zone of the final work 10, which is limited to the target date of completion of construction of the object and the minimum delay of the beginning of work from the beginning 9. Further, by analogy, the distribution of the remaining works is carried out, with the obligatory condition is the observance of the restrictions on the time of execution of works in accordance with the beginning of the previous and the end of the subsequent in accordance with the minimum volumes.

The stability of such a model is achieved by deterministic throughout the solution of production problems of quantitative evaluation of technological connections at the beginning and end of the works, and the duration of the time domain, forming the framework of the base model.

4. Conclusions

1. Identified patterns of interaction of construction works allow to define the dependencies between jobs and processes as at the beginning and at the end, i.e. in the relationship involved the technological links between the basis and the technological links between the endings of adjacent works.
2. Based on the activities and processes at their beginning and end are the qualitative and quantitative public evaluation.
3. Qualitative and quantitative estimation of technological connections between the works and the processes themselves are deterministic parameters, which allows their use for model development of technologies of construction of buildings and structures with the purpose of giving it stability to influence of destabilizing factors.
4. The use of the model of the technology of construction of buildings and structures, developed on the basis of the determined parameters of technological connections, as the basis for the formation of organizational and technological models and allows us to solve the general problem of achieving stability and reliability of models of construction of the object.

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