doi: 10.5862/MCE.63.5

Construction management in terms of indicator of the successfully fulfilled production task

Управление строительным производством с учетом показателя успешного выполнения производственного задания

V.G. Burlov,
A.M. Grobitski,
Peter the Great St. Petersburg Polytechnic University, St. Petersburg, Russia

A.M. Grobitskaya
Grodno State Agrarian University, Grodno, Belarus

Д-р техн. наук, профессор В.Г. Бурлов,
аспирант А.М. Гробицкий,
Санкт-Петербургский политехнический университет Петра Великого, Санкт-Петербург, Россия

Канд. филол. наук, доцент А.М. Гробицкая
Гродненский государтсвенный аграрный университет, Гродно, Республика Беларусь

Key words: management; manager's decision; model; feedback; problem; graph

Ключевые слова: управление; решение руководителя; модель; обратная связь; проблема; граф

Abstract. The article considers the model of the administrative decision based on synthesis It allows knowing the results of task implementation in advance. With this model it is possible to create conditions for a guaranteed solution to the task. The authors have built a schematic diagram for obtaining a management decision. The article shows how to form the concept of maintaining the social system based on feedback, following the integrity conservation law. The authors provide the technique that links three basic components (situation, situation monitoring, problem solving) in the process of taking an adequate decision in the construction area. The indicator for the impact of the successfully implemented industrial task on the task implementation has been calculated.

Аннотация. В статье разрабатывается модель управленческого решения на основе синтеза, что позволяет заранее знать результаты выполнения задач. На основе такой модели становится возможным гарантированное выполнение задачи. Построена структурная схема получения управленческого решения. Показано, как с применением закона сохранения целостности формируется концепция поддержания функционирования социальной системы на основе обратной связи. Приведена методика, увязывающая три базовых компонента – обстановка; мониторинг обстановки; работа по устранению проблем – при принятии адекватного решения в строительстве. Выполнен расчет влияния показателя успешного выполнения производственного задания на вероятнось выполнения задания.

Introduction

The formation of management functions is one of the most difficult issues in construction. As U.R. Ashbee notes, "The natural criterion of management efficiency is the degree of correspondence of managing impacts on the states of a management object in every cycle of management. There is a deviation of the state of the management object from the required state in real-life management" [1].

The construction process is managed on the basis of the manager's decision. The literature on the issues of forming an administrative decision suggests only the results that are aimed at the formation of mathematical methods to validate the decision, rather than the mathematical model of the administrative decision [2, 3].

The works [4–7] are devoted to the problem with the definition of the most important indicator, according to which one can determine reliability of a construction company (a contractor). Actually, the researchers concluded that the lowest price is not a central indicator that must be used when selecting a

Бурлов В.Г., Гробицкий А.М., Гробицкая А.М. Управление строительным производством с учетом показателя успешного выполнения производственного задания // Инженерно-строительный журнал. 2016. № 3(63). С. 77–91.

contractor. The main criterion for the reliability of the contractor is to provide the required standard of work within the time limits set and within the approved budget [4]. In [5] the method of multicriteria analysis to select a contractor and evaluate tender bids, based on the utility theory, is considered. The process of analytic hierarchy with many criteria is considered in [6]. Some authors believe that success of the project depends on the price, time, cost and quality of work, while others believe that it is something more complex. In [7] the system for measuring success of construction projects is developed.

Any activity is based on a person's decision and in well-known publications the methods of justification are used [8–12]. In solving management tasks one can use necessary and sufficient conditions. The necessary conditions are the ones under which it is assumed that the process satisfies certain properties. This approach is valid only when the process exists by definition. However, a necessary condition does not guarantee us activity goal achievement. In [8] the authors present the building process in the framework of a Markov process of a "birth and death" type, followed by probability distribution calculation. The process of searching for optimal management decisions is discussed in [9]. We find an algorithm for developing a model of managing a construction company, using logical and analytical methods of the quantitative analysis.

The author of [10] concludes that implementing the concept of sustainable development for socio-economic systems is primarily connected with the strengthening of public administration and the creation of new centers for producing innovations. The authors in [11] offer to present the model construction in the form of two kinds of knowledge: formal and heuristic. In [12] an innovative technology of managing socio-economic systems of different hierarchical levels, based on a synergistic approach, allowing for the use of methods of nonlinear modeling and advanced software for computers, is offered.

There are two approaches to the development of the system: an approach based on analysis and synthesis. The one based on synthesis implies the knowledge of the law, but the other based on analysis does not guarantee the desired result. According to the papers presented in the review there can only be a general analysis without detailed recommendations. However, [13] presented the approach to the development of a mathematical model for a management decision.

Methods

Difficulties of any process are incompliance of the received results with the demanded ones which is grounded in contradictory conclusions. To exclude contradictory conclusions, the axiomatic method is used [13].

The axiomatic method presupposes the existence of the following components:

- basic assumptions and statements that are usually expressed in some basic principles;
- basic notions, key words, axioms, rules of inference, theorems;
- basic principles should characterize the core of the process under work.

There are three components included in the activity: a person (his consciousness), the outside world (the object) and universal connection. Accordingly, these three components are reflected in the following three principles:

- First – this is the principle of three-component knowledge.

Component A. Abstract representation (A condition of the existence of a process. It answers the question "What?").

Component B. Abstract-specific representation (Cause-consequence relationships. (Methods). It answers the question "Why?").

Component C. Specific representation (Technologies. Algorithms. It answers the question "How?").

- Second – this is the principle of the world's integrity. It is realized by the integrity conservation law referring to an object.

This is a stable objective recurring connection of the object properties with the ones of its purposeful functioning. It is manifested in the mutual transformation of the object properties and the properties of its functioning for a fixed purpose [13].

- Third – this is the principle of the world's knowability. It is realized by three methods of scientific knowledge: decomposition, abstraction, aggregation. Knowledge is reduced to the establishment of laws. This is the essence of the aggregate (aggregation). But this is possible only through decomposition and abstraction. The reverse process is carried out while realizing. From the "aggregate" – a law, a specific object is created through abstraction and decomposition.

To solve a task, it is necessary to understand what the model of a correctly built system should be. This model will meet the demands of a particular situation.

To describe the given model, one should understand what is meant by the notion “model”.

A model is a description or representation of an object corresponding to the given object and allowing obtaining necessary characteristics of this object [13]. The model should have the following key features:

- it is in objective accordance with the object (system) being perceived (learnt);
- it substitutes the given object (system) in some particular relation;
- it gives some information about this object, resulting from the research of the model and the corresponding rules of transmission “model – object” (prototype) [14].

The problem of correlation between a model and a modeled process is a topical problem in the course of modeling. The adequacy of a model can be estimated by comparing it with the standard or experiment results.

There exist two approaches to the system engineering – analysis and synthesis [15].

While analyzing (solving the problem of choice) there is a set of physical elements and it is required to predict the possible result of the system functioning (some output characteristics). That is, it is necessary to form one variant of the system, another and so on. Having analyzed the result of functioning each of them, the variant that meets the conditions to the fullest is chosen.

With synthesis there is a set of output characteristics of the projected system and it is required to define the quantitative and qualitative makeup of the system.

That is, with analysis a task is solved “from the beginning” and the result is analyzed, whereas with synthesis a task is solved “from the end”, from the desired result, and the system with the required output characteristics is formed.

The methods of decomposition, abstraction (mathematical interpretation) and aggregation take a central place in system modeling (Fig. 1) [16, 17].

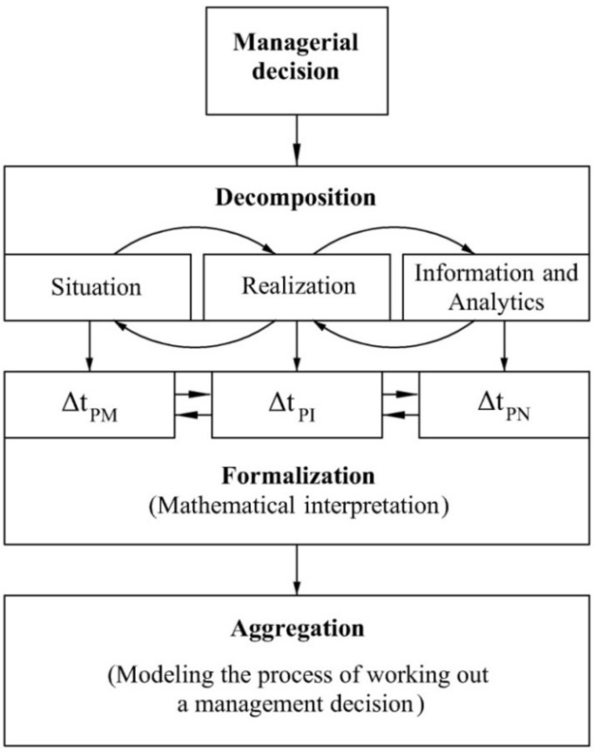

Figure 1. The schematic structure of taking a management decision

Decomposition is a scientific method in which the research of a system (model) is totally replaced with the research of its separate subsystems (sub-models), done allowing for their mutual influence on one another, and, if possible, the full reflection of integral qualities of the system [16, 17].

Aggregation is a scientific method in which the multitude of elements (subsystems) of a model (system) is replaced with the elements called aggregates, which the aggregated model is built upon. This model has a substantially smaller number of dimensions than the original one, but it reflects well enough the qualities of the system in its essence [16, 17].

In the building process a manager encounters external challenges that need to be detected and neutralized. Problems arise with a certain average frequency:

- Problems occur with the frequency equal to Δt_{PM} – the average development time of the problem (Fig 2a).
- To neutralize the problem, the manager must be due to identify it, and the problem should be identified until the next one arises. The problems are identified with the frequency equal to Δt_{PI} – the average identification time of the problem (Fig. 2b).
- After identifying the manager starts neutralizing a problem with the help of resources. Problems are neutralized with the frequency equal to Δt_{PN} – the average neutralization time of the problem (Fig. 2c).

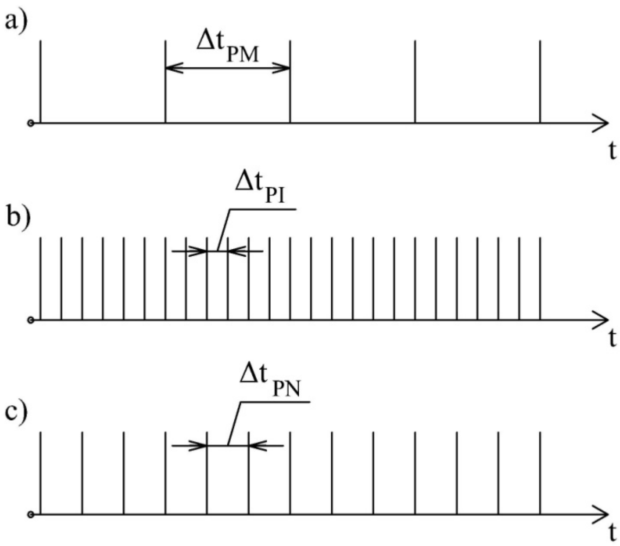

Figure 2. Diagram of problems:
a) the rate of problem occurrence; b) the time of problem identification; c) the time of problem neutralization

At present schemes, based on the analysis approach, are used, i.e. a launched process with input and output (Fig. 3). In the scheme like that, disturbances are not taken into account. Thus, if disturbances affecting the process are not taken into account, the process breaks down. In order to avoid such a course of events, the authors have formed the concept of maintaining a social system based on feedback led by a manager (Fig. 4).

An approach based on the analysis of the model, as mentioned above, does not allow an adequate response to changing situations. Because of this, the deadlines of construction are often not met. An approach based on the synthesis of the model, which the authors suggest, allows forming a process with predetermined properties, hereby this guarantees achievement of the management objective. The model based on synthesis allows a significant reduction of time expenditures due to the fact that the objective feedback has been built [18].

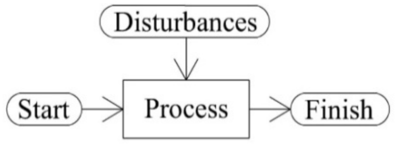

Figure 3. The concept of the social system based on the analysis approach

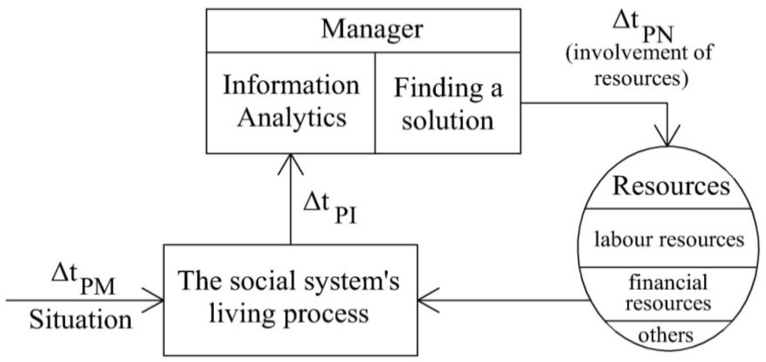

Figure 4. The concepts of maintaining the social system functioning based on feedback

Applying the integrity conservation law, the concept of maintaining the social system functioning based on feedback is formed (Fig. 4) [13, 19].

Figure 5 is a scheme of the gnoseological meaning for the object integrity conservation law. This representation of a substantiated sufficiently objective development of the system's image and modes of application allows considering it as a certain set of ordered elements located "beneath the surface of the cone." The cone generators "are described" by the law of the system's integrity conservation and define directions of specifying the synthesis [20].

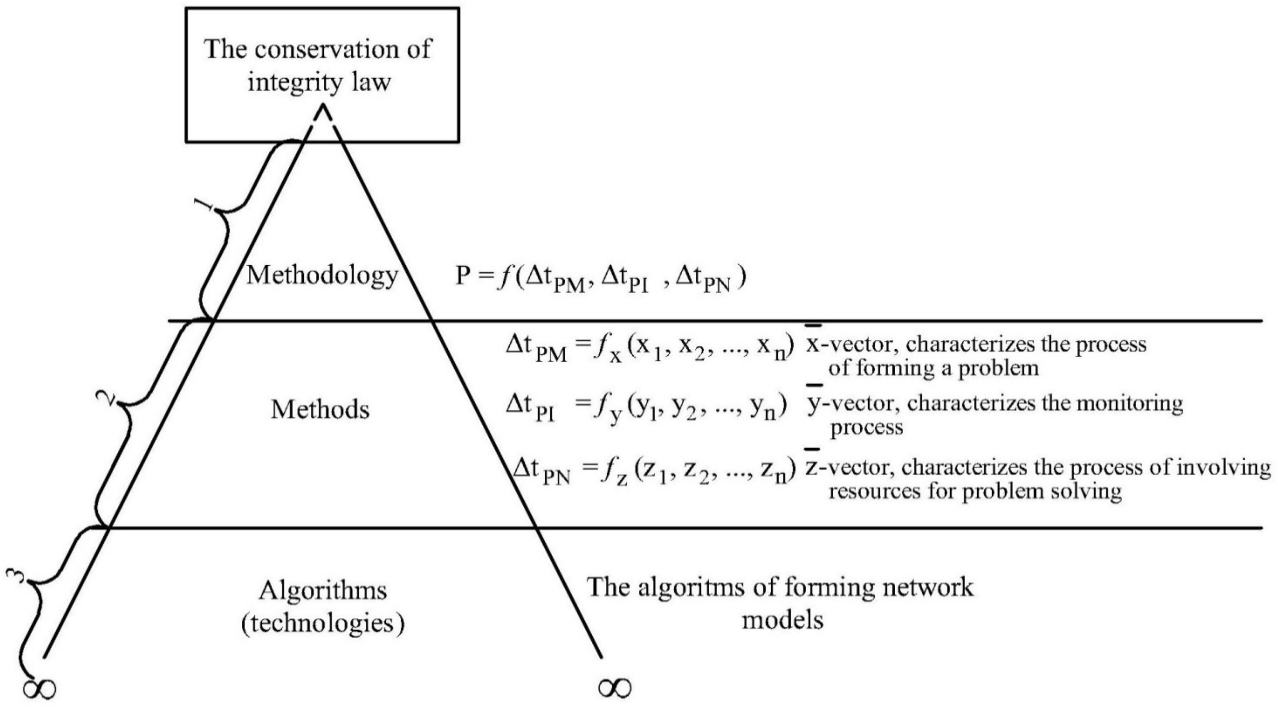

Figure 5. Scheme of the gnoseological meaning for the object integrity conservation law

The first level describes the abstract level of representation of the theory, which includes: basic concepts of the theory; basic dependencies of achieving a result by the system; basic logical rules of deployment of the theory.

The second level characterizes the abstract and specific level of representation of the theory's main concepts, which include (conditions of the required changes of the system's state, or conditions of the transition from one state to another on these sets): methods for validating the system's model; methods for validating the use of the system; methods for estimating the efficiency of the system's use.

The third level characterizes the particular level of representing the basic concepts of the theory, which include (the technology of required changes of the system's states, the conditions for transition implementation); possibilities of the system (economic, social, technical); system's operations (types, methods and forms); mechanisms of balancing the capabilities and system's operations in order to achieve the desired performance.

General Approach

The integrity conservation law allows creating an adequate model of the process control, depending on varying socio-economic conditions, based on establishing a formal analytical dependence $P = f(\Delta t_{PM}, \Delta t_{PI}, \Delta t_{PN})$ between the three basic components where Δt_{PM} is the average time of problem occurrence; Δt_{PI} is the average time of problem identification; Δt_{PN} is the average time of problem neutralization of a; P is an efficiency indicator for implementing administrative decisions [13].

The state referring to achieving a goal by the object of management is the main component in solving practical management problems. In real life conditions the manager can find himself in two situations:

- he is not ready for a particular situation;
- he is not ready to solve a problem in the management process, which will require additional time resources from him.

Taking into account these two basic situations in the model, it is necessary to distinguish four basic states:

The first state is the one when the management object is at the beginning of the process under consideration.

The second state is the one that characterizes the achievement of a management goal by the process (object).

In the management process there can occur standard situations that are characterized by proven schemes, and emergency situations characterized by a problem that arises in management (a situation in which your possibilities are not adequate to the current situation and you have to look for resources to solve a problem). Accordingly, there appears the third basic state of the system (process) characterized by the fact of the problem's manifestation – state 3 [13].

When the object (process) of management is in state 3, there appears the necessity of identifying the given problem. Naturally, the manager spends some time Δt_{PI} on the problem's identification. This stage stipulates readiness for involving additional resources to solve the problem. Consequently, during the solution analysis the managed system moves into state 4 where the manager understands what resources, and how, should be used to achieve the management goal. In this state there appear two variants of the management process development:

- the manager can solve the problem but it takes time, therefore he moves from state 4 into state 2, where the problem is solved.

There are two possible variants of the situation development in state 2:

- while solving the problem, the manager spends unacceptably too much time, which is equal to failing the target task in the management process. This is characterized by moving from state 2 into state 1;
- the time spent on the problem's solution is in acceptable limits, when the manager solves the management target task.

The situation of the system's moving back into the initial state characterizes the manager's talent to tackle a great number of problems. The frequency of transition from state 1 into state 2 (ζ^+) is equal to the value inverse to the average execution time of the target task, where (ζ^-) characterizes the degree of readiness of the organization to solve the target management tasks and the frequency characterizes the average number of the execution plan failure. The authors believe that the status of a construction organization is an indicator of successful implementation of production tasks [13].

The frequency of moving from state 4 into state 2 is the value $\left(\nu_2 = \frac{1}{\Delta t_{PN}}\right)$, Δt_{PN} is the average time of problem neutralization. The level of competence to solve unknown tasks depends on the correlation ν_2.

This logic of reasoning allows constructing the following graph (Fig. 6) [21].

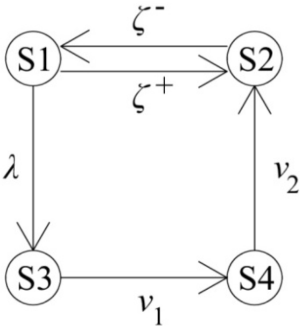

Figure 6. The state graph

The main assumptions and presumptions [13]:

- The information-management system (IMS) – the production management system – is under consideration.
- Time intervals between the moments of detecting the facts of problem manifestation are random values.
- The detected facts form a stream in time that is closely approximated to a Poisson arrival.
- The time for processing the data on a desired feature is a random value.
- The processes within the system data on the features are shared between the allocated forces and means, solving the corresponding target tasks in the production control.
- The instance is considered where the stay period the desired features (facts) in the sphere of production management system is extremely limited and comparable to the time that is necessary for them to be detected, as well as for data processing and adequate action taking according to these features.
- The system under discussion is meant to evaluate the potential opportunities of the production management system, depending on the situation.
- The manager is always prepared to solve this class of problems.
- The foundation of the status of a construction organization is an indicator of the successful implementation of production tasks.

Main Correlations

While developing a management solution, different models are reviewed. Dynamic models are of particular interest. The paper [22] does not reveal the problem of dynamic models to the full,extent, that is why it is necessary to make the Kolmogorov equation.

Against this background, the Kolmogorov differential equation system can be used [23, 24]:

$$\frac{dP_i(t)}{dt} = \sum_{j=1}^{n} \lambda_{ji}(t) \cdot P_j(t) - P_i(t) \cdot \sum_{j=1}^{n} \lambda_{ij} \cdot (t) \,, \tag{1}$$

where $i = 0,1,2,...,n$

To make the Kolmogorov differential equation for the function $P_i(t)$, $i = 1,...,n$, the derivative $\frac{dP_i(t)}{dt}$ of the function $P_i(t) = P(S_i(t))$, $P_i(t)$, must be written in the left part of this equation, while in the right part of the equation there must be the product $-\left(\sum_{j=1}^{n} \lambda_{ij}\right) \cdot P_i(t)$ of the sum $\sum_{j=1}^{n} \lambda_{ij}$ of transition probability densities λ_{ij} with the arrows coming out of the state S_i, by the probability $P_i(t)$ of this state signed "minus", plus the sum $\sum_{j=1}^{n} \lambda_{ji} \cdot P_j(t)$ of the products $\lambda_{ji} \cdot P_j(t)$ of the transition probability densities λ_{ij}, corresponding to the arrows coming into the state S_i, by the probabilities of the states $P_j(t)$, where these arrows come out from. Herein the transition probability densities λ_{ij}, corresponding to the arrows absent on the graph, are equal to zero [23].

Final probabilities of states can be obtained by solving the system of linear algebraic equations that result from the Kolmogorov differential equations if derivatives are equal to zero and the probability functions of the states $P_1(t),...,P_n(t)$ in the right parts of equations are changed correspondingly into the unknown final probabilities $P_1,...,P_n$. To find the exact value $P_1,...,P_n$, the normalizing condition $P_0 + P_1 + ... + P_n = 1$ is added to the equations.

Let us make the system of the Kolmogorov equations for the state graph in figure 6:

$$\begin{cases} \frac{dP_1(t)}{dt} = -(\zeta^+ + \lambda) \cdot P_1(t) + \zeta^- \cdot P_2(t), \\ \frac{dP_2(t)}{dt} = \zeta^+ \cdot P_1(t) - \zeta^- \cdot P_2(t) + \nu_2 \cdot P_4(t), \\ \frac{dP_3(t)}{dt} = \lambda \cdot P_1(t) - \nu_1 \cdot P_3(t), \\ \frac{dP_4(t)}{dt} = \nu_1 \cdot P_3(t) - \nu_2 \cdot P_4(t). \end{cases} \tag{2}$$

Then the final probabilities can be obtained by solving the system of linear algebraic equations:

$$\begin{cases} 0 = -(\zeta^+ + \lambda) \cdot P_1 + \zeta^- \cdot P_2, \\ 0 = \zeta^+ \cdot P_1 - \zeta^- \cdot P_2 + \nu_2 \cdot P_4, \\ 0 = \lambda \cdot P_1 - \nu_1 \cdot P_3, \\ 1 = P_1 + P_2 + P_3 + P_4. \end{cases} \tag{3}$$

The system solution is as follows:

$$P_1 = \frac{\nu_1 \cdot \nu_2 \cdot \zeta^- + \nu_1 \cdot \nu_3 \cdot \zeta^-}{\lambda \cdot \nu_1 \cdot \nu_2 + \lambda \cdot \nu_1 \cdot \zeta^- + \lambda \cdot \nu_2 \cdot \zeta^- + \lambda \cdot \nu_3 \cdot \zeta^- + \nu_1 \cdot \nu_2 \cdot \zeta^+ + \nu_1 \cdot \nu_2 \cdot \zeta^- + \nu_1 \cdot \zeta^- \cdot \nu_3 + \nu_1 \cdot \nu_2 \cdot \zeta^-}.$$

$$P_2 = \frac{\lambda \cdot \nu_1 \cdot \nu_2 + \nu_1 \cdot \nu_2 \cdot \zeta^+ + \nu_1 \cdot \zeta^+ \cdot \nu_3}{\lambda \cdot \nu_1 \cdot \nu_2 + \lambda \cdot \nu_1 \cdot \zeta^- + \lambda \cdot \nu_2 \cdot \zeta^- + \lambda \cdot \nu_3 \cdot \zeta^- + \nu_1 \cdot \nu_2 \cdot \zeta^+ + \nu_1 \cdot \nu_2 \cdot \zeta^- + \nu_1 \cdot \zeta^- \cdot \nu_3 + \nu_1 \cdot \nu_2 \cdot \zeta^-}.$$

$$P_3 = \frac{\lambda \cdot \nu_2 \cdot \zeta^- + \lambda \cdot \nu_3 \cdot \zeta^-}{\lambda \cdot \nu_1 \cdot \nu_2 + \lambda \cdot \nu_1 \cdot \zeta^- + \lambda \cdot \nu_2 \cdot \zeta^- + \lambda \cdot \nu_3 \cdot \zeta^- + \nu_1 \cdot \nu_2 \cdot \zeta^+ + \nu_1 \cdot \nu_2 \cdot \zeta^- + \nu_1 \cdot \zeta^- \cdot \nu_3 + \nu_1 \cdot \nu_2 \cdot \zeta^-}.$$

$$P_4 = \frac{\lambda \cdot \nu_1 \cdot \zeta^-}{\lambda \cdot \nu_1 \cdot \nu_2 + \lambda \cdot \nu_1 \cdot \zeta^- + \lambda \cdot \nu_2 \cdot \zeta^- + \lambda \cdot \nu_3 \cdot \zeta^- + \nu_1 \cdot \nu_2 \cdot \zeta^+ + \nu_1 \cdot \nu_2 \cdot \zeta^- + \nu_1 \cdot \zeta^- \cdot \nu_3 + \nu_1 \cdot \nu_2 \cdot \zeta^-}.$$

(4)

The probability that the problem will be identified and neutralized by the management system is determined by the following correlation:

$$P_2 = \frac{\lambda \cdot \nu_1 \cdot \nu_2 + \nu_1 \cdot \nu_2 \cdot \zeta^+ + \nu_1 \cdot \zeta^+ \cdot \nu_3}{\lambda \cdot \nu_1 \cdot \nu_2 + \lambda \cdot \nu_1 \cdot \zeta^- + \lambda \cdot \nu_2 \cdot \zeta^- + \lambda \cdot \nu_3 \cdot \zeta^- + \nu_1 \cdot \nu_2 \cdot \zeta^+ + \nu_1 \cdot \nu_2 \cdot \zeta^- + \nu_1 \cdot \zeta^- \cdot \nu_3 + \nu_1 \cdot \nu_2 \cdot \zeta^-}.$$

(5)

The concept of maintaining the social system functioning based on feedback suggested by the authors (Fig. 4) and the mathematical model of an administrative decision make it possible to coordinate two processes: 1 - the monitoring process; 2 - the process of solving a problem. As a result of this coordination, the risk of failing a task by a construction organization is reduced. In addition, this technique makes it possible to assess the status of the construction organization. Let us consider an example.

Results and Discussion

Let us consider a single-purpose network graph of constructing a secondary school for 300 students as a process (Fig. 7) [25, 26, 27, 28].

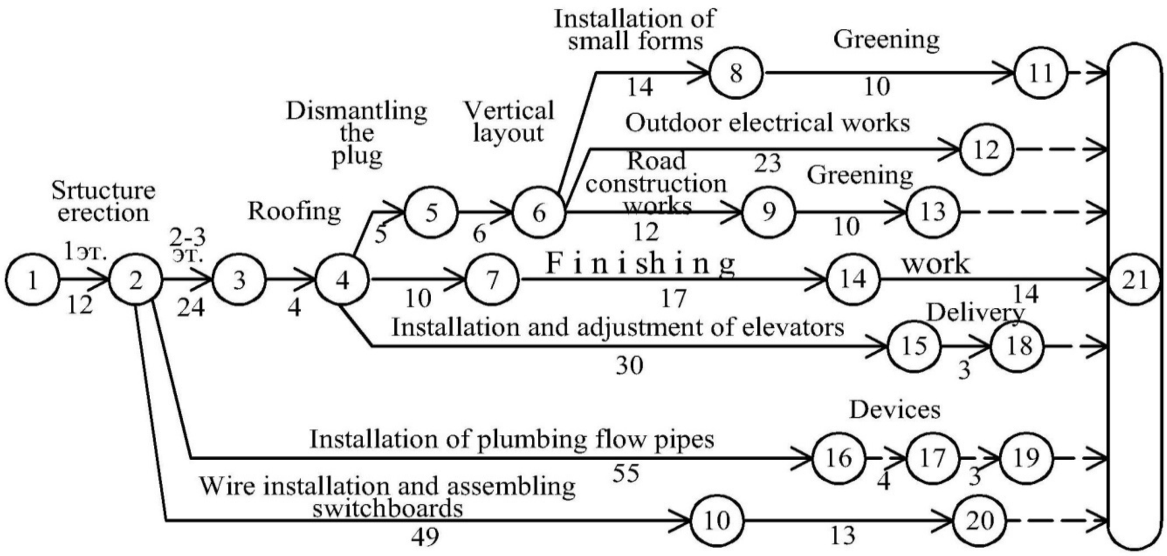

Figure 7. A single-purpose network graph of constructing a secondary school for 300 students

In every working process there appear problems (disturbances) that need to be promptly solved. Let us give the number of problems that may arise in this example:

- Structure erection (event 1-2, 2-3) – 15 problems.
- Roofing (event 3-4) – 4 problems.
- Wire installation and assembling switchboards (event 2-10) – 6 problems.
- Installation of plumbing flow pipes (event 2-16) – 4 problems.
- Finishing work (event 4-7, 7-14, 14-21) – 6 problems.
- Dismantling the plug (event 4-5) – 2 problems.
- Installation and adjustment of elevators (event 4-15) – 8 problems.
- Vertical layout (event 5-6) – 5 problems.
- Installation of small forms (event 6-8) – 3 problems.
- Road construction works (event 6-9) – 10 problems.
- Greening (event 8-11, 9-13) – 5 problems.
- Outdoor electrical works (event 6-12) – 6 problems.
- Devices (event 6-17, 17-19) – 1 problem.

Let us divide the graph into time intervals so that the beginning of an interval - this is the end or the beginning of an event and all events that fall within this interval should be considered as a single period of time with the definite number of problems (Fig. 8).

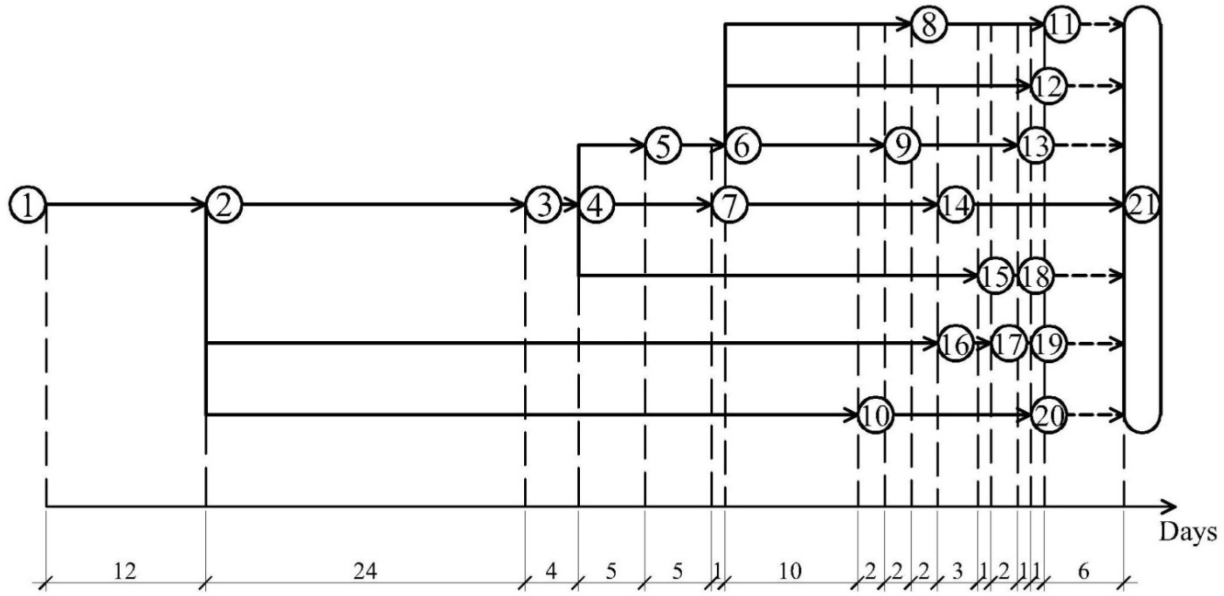

Figure 8. Breakdown of the network graph into intervals

As a result of the breakdown 16 intervals are formed. Each interval has its duration. The total duration of the construction according to a network graph makes up $T = 81$ days. We assume that in every job there appears a maximum number of problems at each interval. One working day is 8 hours (in further calculations let us convert days into hours, i.e $T = 81$ days $= 648$ hours.). Let us summarize in (Table 1) the results of breaking down the network graph.

Table 1. Results of the breakdown of the network graph allowing for the number of problems

Days	12	24	4	5	5	1	10	2	2	2	3	1	2	1	1	6
Hours	96	192	32	40	4	8	80	16	16	16	24	8	16	8	8	48
Number of problems,pcs.	15	25	14	26	29	29	43	37	32	29	26	19	19	18	11	6

In managing the building process three processes are considered regardless of the situation:

- The process of forming problems.
- The process of identifying problems.
- The process of problem solving.

In the construction process network diagrams are used. As a mathematical model of the administrative decision is lacking, network diagrams are impossible to join, they are joined at the verbal

Burlov V.G., Grobitski A.M., Grobitskaya A.M. Construction management in terms of indicator of the successfully fulfilled production task. *Magazine of Civil Engineering*. 2016. No. 3. Pp. 77–91. doi: 10.5862/MCE.63.5

level. This joining leads to the breakdown of a plan, and the "mathematical apparatus" suggested by the authors allowed building a mathematical model of the administrative decision and to link three most important processes in the organization of building on this basis. Due to this mathematical model a guarantee to achieve the implementation of the plan is provided.

Let us draw the network diagram of problem identification (Fig. 9) and the network of problem neutralization (Fig. 10).

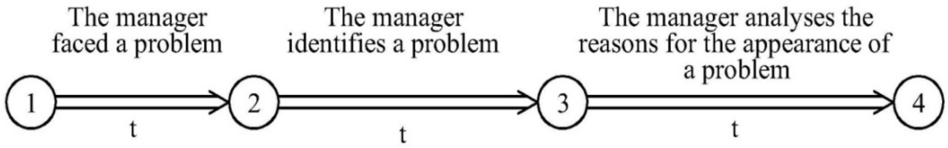

Figure 9. The network diagram of identifying a problem by the construction manager

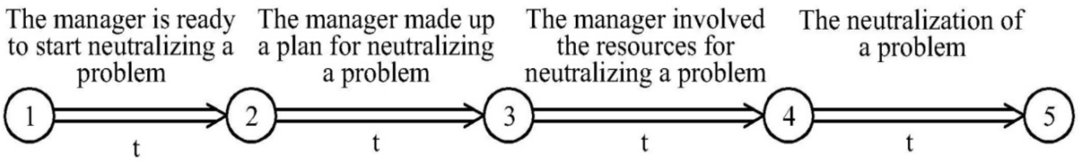

Figure 10. The network diagram of problem neutralization by the construction manager

For the graph in Figure 6 let us make up a system of algebraic equations of Kolmogorov. The system of Kolmogorov equations (2) for the graph of states in Figure 6:

$$\begin{cases} \dfrac{dP_1(t)}{dt} = -(\zeta^+ + \lambda)\cdot P_1(t) + \zeta^- \cdot P_2(t), \\ \dfrac{dP_2(t)}{dt} = \zeta^+ \cdot P_1(t) - \zeta^- \cdot P_2(t) + \nu_2 \cdot P_4(t), \\ \dfrac{dP_3(t)}{dt} = \lambda \cdot P_1(t) - \nu_1 \cdot P_3(t), \\ \dfrac{dP_4(t)}{dt} = \nu_1 \cdot P_3(t) - \nu_2 \cdot P_4(t). \end{cases}$$

where λ is the frequency of problem manifestation;

ν_1 – the frequency of the analysis of factors influencing the neutralization of a problem;

ν_1 – the frequency of activities aimed to neutralize a problem;

ζ^+ – the frequency of performance of the task plan;

ζ^- – the frequency of the average number of the failed plan execution.

The solution of the system with algebraic equations of Kolmogorov (2) is the expression (4).

The probability that the problem will be identified and neutralized by the management system is defined by the correlation (5).

The efficiency indicator of the model of the management process, depending on the varying socio-economic environment, will serve the analytical dependence:

$$P_2 = f(\lambda, \nu_1, \nu_2, \zeta^+, \zeta^-) \,, \quad (6)$$

where λ – is the value $\lambda = \left(\frac{1}{\Delta t_{PM}}\right)$, where Δt_{PM} – is the average development time of a problem;

ν_1 – is the value $\nu_1 = \left(\frac{1}{\Delta t_{PI}}\right)$, where Δt_{PI} – is the average identification time of a problem;

ν_2 – is the value $\nu_2 = \left(\frac{1}{\Delta t_{PN}}\right)$, where Δt_{PN} – is the average neutralization time of a problem;

ζ^+ – is the value $\zeta^+ = \left(\frac{1}{T}\right)$, where T – is the duration of solving a task;

ζ^- – the frequency of failure of the implementation of the plan task;

P_2 is the indicator of efficiency from the implementation of management decisions.

According to the example, we have:

$T = 648$ h.; $N_P = 24$ – the average number of problems;

$$\Delta t_{PM} = 27 \Rightarrow \lambda = \left(\frac{1}{\Delta t_{PM}}\right) = \left(\frac{1}{27}\right) = 0.036.$$

$$\Delta t_{PI} = 3 \Rightarrow \lambda = \left(\frac{1}{\Delta t_{PI}}\right) = \left(\frac{1}{3}\right) = 0.365.$$

$$\Delta t_{PN} = 22 \Rightarrow \lambda = \left(\frac{1}{\Delta t_{PN}}\right) = \left(\frac{1}{22}\right) = 0.046.$$

$$T = 648 \Rightarrow \zeta^+ = \left(\frac{1}{T}\right) = \left(\frac{1}{648}\right) = 1.543 \cdot 10^3.$$

Let us assume the conditions:

$$\Delta t_{PI} = \frac{\Delta t_{PM}}{8}; \quad \frac{\Delta t_{PI} + \Delta t_{PN}}{\Delta t_{PM}} < 1.$$

Let us substitute all the values in expression (5) and find the probability of solving the task P_2 taking into account the frequency (ζ^-), which characterizes the average amount of failure in the plan execution, which underlies the status of a construction organization and shows success of the implementation of production tasks.

If $\zeta^- = \frac{1}{50}$, then $P_2 = 0.5$.

If $\zeta^- = \frac{1}{100}$, then $P_2 = 0.667$.

If $\zeta^- = \frac{1}{150}$, then $P_2 = 0.75$.

If $\zeta^- = \frac{1}{200}$, then $P_2 = 0.8$.

If $\zeta^{-}=\frac{1}{250}$, then $P_2=0.833$.

If $\zeta^{-}=\frac{1}{300}$, then $P_2=0.857$.

Calculations show that with increasing amounts of successfully implemented production tasks, the probability P_2 increases, and consequently the status of the organization increases (Fig. 11).

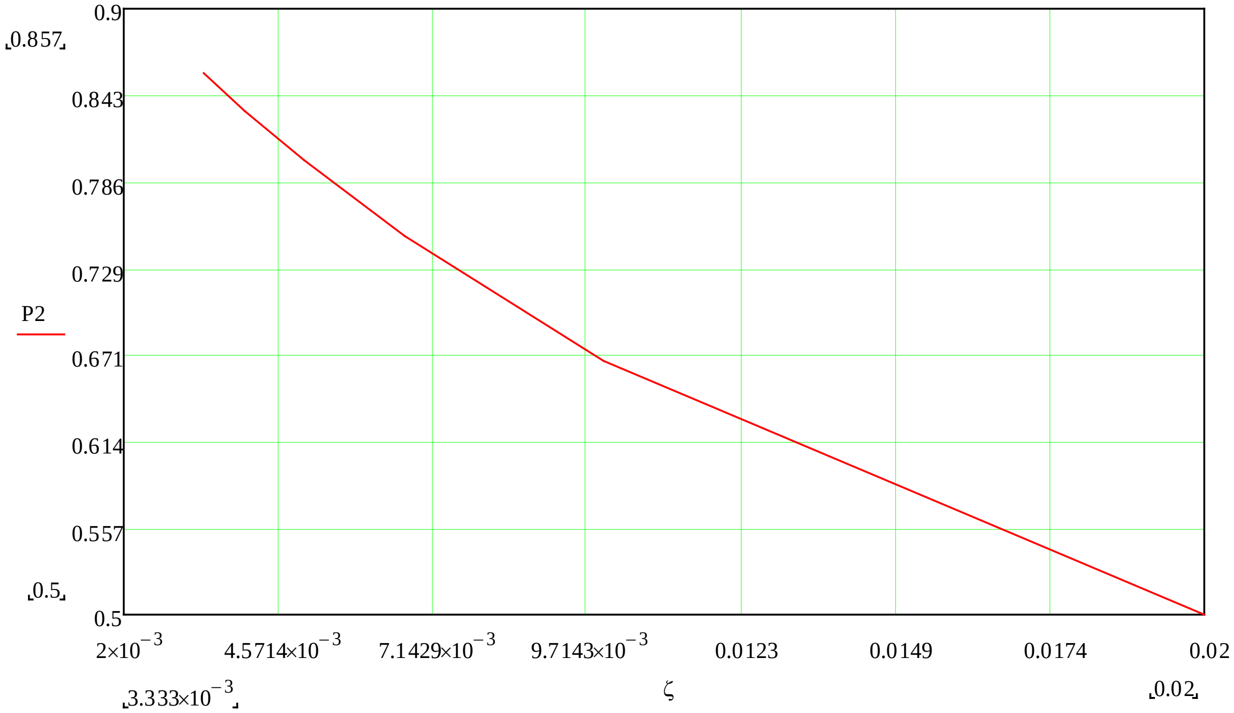

Figure 11. The graph showing the dependence of probability P_2 (probability of task solving) on frequency ζ^{-} (indicator of the status for a construction company)

Conclusions

1. The analysis showed that there are no mathematical models of management solutions in the known publications.

2. In the production process a manager has to deal with three processes: the process of forming a problem (certain inconsistencies), the process of identifying a problem (recognition of the situation) and the process of neutralizing a problem (implementing the solution).

3. Network diagrams of the construction industry are added up and verbally agreed on, because of the lacking mathematical model for a management solution. This methodological approach leads to the breakdown of the plan.

4. The mathematical tool suggested by the authors allowed constructing a mathematical model of the management solution, and hereby linking three most important processes in the construction organization. This mathematical model guarantees the implementation of the plan..

5. The methodological possibilities of the developed approach are confirmed by the numerical experiment. The example showed the dependence of the probability of the manufacturing task implementation – P_2 on the frequency of breaking down the plan of implementing a production task by the organization under consideration ζ^{-}. Therefore, a frequency like that should be viewed as a fundamental indicator of the status for a construction company. This indicator shows reliability and accuracy of performing the obligations by a construction company while constructing an object.

Бурлов В.Г., Гробицкий А.М., Гробицкая А.М. Управление строительным производством с учетом показателя успешного выполнения производственного задания // Инженерно-строительный журнал. 2016. № 3(63). С. 77–91.

References

1. Ashby W.R. *An Introduction to Cybernetics*. Chapman & Hall LTD. London, 1956. 432 p.
2. Harrison E.F, Pelletier M.A. A typology of strategic choice. *Technological Forecasting and Social Change.* 1993. No. 44(3). Pp. 245-263.
3. Harrison E.F. Interdisciplinary Models of Decision Making. *Management Decision.* 1993. No. 31(8). Pp. 27-33.
4. Darvish M., Yasaei M., Saeedi A. Application of the graph theory and matrix methods to contractor ranking. *International Journal of Project Management.* 2009. Vol. 27. No. 6. Pp. 610-619.
5. Hatush Z., Skitmore M. Contractor Selection Using Multicriteria Utility Theory: An Additive Model. *Building and Environment.* 1998. Vol. 33. No. 2. Pp. 105-115.
6. Cheng E. W.L., Li H. Contractor selection using the analytic network process. *Construction Management and Economics.* 2004. Vol. 22. No. 10. Pp. 1021-1032.
7. Chan A.P.C., Chan A.P.L. Key performance indicators for measuring construction success. *Benchmarking.* 2004. Vol. 11. No. 2. Pp. 203-221.
8. Komov V.M., Korotkov A.A. Opredeleniye veroyatnosti sostoyaniy sistemy stroitelnogo proizvodstva [Determining the probability of states of the construction production system]. *Vestnik grazhdanskikh inzhenerov.* 2015. No. 3 (50). Pp. 140-147. (rus)
9. Golovan A.M., Klashanov F.K., Petrova S.N. K teoreticheskim osnovam postroyeniya modeli upravleniya v stroitelstve [To the theoretical basics of building up models of construction management]. *Vestnik grazhdanskikh inzhenerov.* 2013. No. 5 (40). Pp. 208-212. (rus)
10. Gulenko O.I. Razrabotka modeli upravleniya ustoychivym razvitiyem sotsialno-ekonomicheskoy sistemy [Construction of a model of management of sustainable development of a socio-economic system]. *Vestnik Udmurtskogo universiteta. Seriya ekonomika i pravo.* 2015. No. 6. Pp. 14-20. (rus)
11. Klashanov F.K. Sostavleniye logiko-lingvisticheskoy modeli sistemy upravleniya stroitelstvom [Creation of the logical-linguistic model of the system of construction management]. *Nauchnoye obrazovaniye.* 2015. No. 14. Pp. 370-373. (rus)
12. Galeyeva Ye.I. Innovatsionnyye tekhnologii v upravlenii sotsialno-ekonomicheskimi sistemami [Innovative technologies in the management of socio-economic systems]. *Problemy sovremennoy ekonomiki.* 2008. No. 3. Pp. 68-73. (rus)
13. Burlov V.G. *Osnovy modelirovaniya sotsialno-ekonomicheskikh i politicheskikh protsessov (Metodologiya. Metody)* [The fundamentals of modeling socioeconomic and political processes (Methodology. Methods)]. Saint-Petersburg: Fakultet kompleksnoy bezopasnosti SPbGPU, 2006. 270 p. (rus)
14. Kalinin V.N., Reznikov B.A., Varakin Ye.I. *Teoriya sistem i optimalnogo upravleniya. Chast 1. Osnovnyye ponyatiya, matematicheskiye modeli i metody analiza sistem* [Systems theory and optimal management. Part 1. Basic concepts, mathematical models and methods of systems analysis]. Saint-Petersburg: VIKI im. A.F. Mozhayskogo, 1979. 320 p. (rus)
15. Goode H.H., Machol R.E. *System Engineering: An Introduction to the Design of Large-Scale Systems.* McGraw-Hill Book Co. New York, 1957. 551p.
16. Arbib M.A. *Brains, Machines and Mathematics.* McGraw-Hill Book Co. New York, 1964. 494 p.
17. Kalman, R.E. *Topics in mathematical system theory.* McGraw-Hill Book Co. New York, 1974. 358 p.
18. Anokhin P.K. *Ocherki po fiziologii funktsionalnykh sistem* [Essays on Physiology of Functional Systems]. Moscow:

Литература

1. Ashby W.R. An Introduction to Cybernetics. Chapman & Hall LTD. London, 1956. 432 p.
2. Harrison E.F, Pelletier M.A. A typology of strategic choice // Technological Forecasting and Social Change. 1993. No. 44(3). Pp. 245-263.
3. Harrison E.F. Interdisciplinary Models of Decision Making // Management Decision. 1993. No. 31(8). Pp. 27-33.
4. Darvish M., Yasaei M., Saeedi A. Application of the graph theory and matrix methods to contractor ranking // International Journal of Project Management. 2009. Vol. 27. No. 6. Pp. 610-619.
5. Hatush Z., Skitmore M. Contractor Selection Using Multicriteria Utility Theory: An Additive Model // Building and Environment. 1998. Vol. 33. No. 2. Pp. 105-115.
6. Cheng E. W.L., Li H. Contractor selection using the analytic network process // Construction Management and Economics. 2004. Vol. 22. No. 10. Pp. 1021-1032.
7. Chan A.P.C., Chan A.P.L. Key performance indicators for measuring construction success // Benchmarking. 2004. Vol. 11. No. 2. Pp. 203-221.
8. Комов В.М., Коротков А.А. Определение вероятности состояний системы строительного производства // Вестник гражданских инженеров. 2015. №3(50). С. 140-147.
9. Головань А.М., Клашанов Ф.К., Петрова С.Н. К теоретическим основам построения модели управления в строительстве // Вестник гражданских инженеров. 2013. №5(40). С. 208-212.
10. Гуленко О.И. Разработка модели управления устойчивым развитием социально-экономической системы // Вестник Удмуртского университета. Серия экономика и право. 2015. №6. С. 14-20.
11. Клашанов Ф.К. Составление логико-лингвистической модели системы управления строительством // Научное образование. 2015. №14. С. 370-373.
12. Галеева Е.И. Инновационные технологии в управлении социально-экономическими системами // Проблемы современной экономики. 2008. №3. С. 68-73.
13. Бурлов В.Г. Основы моделирования социально-экономических и политических процессов (Методология. Методы). СПб: Факультет комплексной безопасности СПбГПУ, 2006. 270 с.
14. Калинин В.Н., Резников Б.А., Варакин Е.И. Теория систем и оптимального управления. Часть 1. Основные понятия, математические модели и методы анализа систем. СПб: ВИКИ им. А.Ф. Можайского, 1979. 320 с.
15. Goode H.H., Machol R.E. System Engineering: An Introduction to the Design of Large-Scale Systems. McGraw-Hill Book Co. New York, 1957. 551p.
16. Arbib M.A. Brains, Machines and Mathematics. McGraw-Hill Book Co. New York, 1964. 494 p.
17. Kalman, R.E. Topics in mathematical system theory. McGraw-Hill Book Co. New York, 1974. 358 p.
18. Анохин П.К. Очерки по физиологии функциональных систем. М.: Медицина, 1975. 448 с.
19. Burlov V.G., Grobitski A.M. Development of a model for social system management in the construction process taking into account manager's qualification // Humanities&Science Univesity Journal. 2015. No. 15. Pp. 45-57.
20. Бурлов В.Г. О концепции гарантированного управления устойчивым развитием арктической зоны на основе решения обратной задачи // Информационные технологии и системы: управление, экономика, транспорт, право. 2015. №2(16). С. 99-111.
21. Berge C. Théorie des graphes et ses applications. Dunod.

Meditsina, 1975. 448 p. (rus)

19. Burlov V.G., Grobitski A.M. Development of a model for social system management in the construction process taking into account manager's qualification. *Humanities&Science Univerisy Journal.* 2015. No. 15. Pp. 45-57.
20. Burlov V.G. O kontseptsii garantirovannogo upravleniya ustoychivym razvitiyem arkticheskoy zony na osnove resheniya obratnoy zadachi [About guaranteed management concept of sustainable development of the arctic zone on the basis of the inverse problem solution]. *Informatsionnyye tekhnologii i sistemy: upravleniye, ekonomika, transport, pravo.* 2015. No. 2 (16). Pp. 99-111. (rus)
21. Berge S. *Théorie des graphes et ses applications.* Dunod. Paris, 1958. 277 p.
22. Burlov V.G., Volkov V.F. Method of consecutive expert estimates in control problems for the development of large-scale potentially dangerous systems. *Engineering Simulation.* 1994. Vol. 12. No. 1. Pp. 110-115.
23. Kemperman J.H.B. *The Passage Problem for a Stationary Markov Chain.* University of Chicago Press. Chicago, 1961. 127 p.
24. Bellman R.E. *Stability Theory of Differential Equations.* McGraw-Hill Book Co. New York, 1953. 166 p.
25. Crowston W.B.S. *Decision Network Planning Models.* Carnegie-Mellon University. Pittsburgh, 1968. 457 p.
26. Papadakis V.M., Lioukas S., Chambers D. Strategic decision-making processes: The role of management and context. *Strategic Management Journal.* 1998. Vol. 19. No. 2. Pp. 115-147.
27. Lu M., Li H. Resource-activity critical-path method for construction planning. *Journal of Construction Engineering and Management.* 2003. Vol. 129. No. 4. Pp. 412-420.
28. Simpson III W.P., Patterson J.H. A multiple-tree search procedure for the resource-constrained project scheduling problem. *European Journal of Operational Research.* 1996. Vol. 89. No. 3. Pp. 525-542.

Paris, 1958. 277 p.

22. Burlov V.G., Volkov V.F. Method of consecutive expert estimates in control problems for the development of large-scale potentially dangerous systems // Engineering Simulation. 1994. Vol. 12. No. 1. Pp. 110-115.
23. Kemperman J.H.B. The passage problem for a stationary Markov chain. University of Chicago Press. Chicago, 1961. 127 p.
24. Bellman R.E. Stability theory of differential equations. McGraw-Hill Book Co. New York, 1953. 166 p.
25. Crowston W.B.S. Decision network planning models. Carnegie-Mellon University. Pittsburgh, 1968. 457 p.
26. Papadakis V.M., Lioukas S., Chambers D. Strategic decision-making processes: The role of management and context // Strategic Management Journal. 1998. Vol. 19. No. 2. Pp. 115-147.
27. Lu M., Li H. Resource-activity critical-path method for construction planning // Journal of Construction Engineering and Management. 2003. Vol. 129. No. 4. Pp. 412-420.
28. Simpson III W.P., Patterson J.H. A multiple-tree search procedure for the resource-constrained project scheduling problem // European Journal of Operational Research. 1996. Vol. 89. No. 3. Pp. 525-542.

Viacheslav Burlov,
+7(911)1004101; burlovvg@mail.ru

Andrei Grobitski,
+7(964)3318710; afcrf@mail.ru

Anna Grobitskaya,
80298646873; a.grabitskaya@yandex.ru

Вячеслав Георгиевич Бурлов,
+7(911)1004101; эл. почта: burlovvg@mail.ru

Андрей Матвеевич Гробицкий,
+7(964)3318710; эл. почта: afcrf@mail.ru

Анна Матвеевна Гробицкая,
80298646873;
эл. почта: a.grabitskaya@yandex.ru

Бурлов В.Г., Гробицкий А.М., Гробицкая А.М. Управление строительным производством с учетом показателя успешного выполнения производственного задания // Инженерно-строительный журнал. 2016. № 3(63). С. 77–91.