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DEVELOPMENT OF A MARKOV MODEL OF THE INFORMATION ENVIRONMENT AS A COMMUNICATION SYSTEM IN THE SCIENTIFIC SPHERE

Abstract: The paper presents the theoretical foundations of creating the educational environment of an educational institution using the project approach at the stage of building models and displaying communications in the information environment following

GOST R 54869 – 2011. The article considers the Markov process with discrete states, discrete-time, and homogeneous characteristics of transition probabilities. The latter means that the transition probabilities for the series do not change over time. The set of specific values of transition probabilities characterizes the level of organizational maturity of the project. A unified method of transformation of iconographic models of states of complex systems in the Markov chain is developed. The method has sufficient simplicity of the mathematical apparatus and high reliability of the mapping of the phenomenological properties of stochastic systems. The developed model allows us to study the features of communication processes incompetently oriented information training systems in the educational environment of educational institutions and to obtain a quantitative assessment of the effectiveness of such systems. The management of educational activities of an educational institution should be considered as a continuous process of improving its activities in the conditions of modern competition in the market of educational services. The proposed model, based on the project approach, will allow the efficient use of material resources, as well as flexibly respond to any changes both within the educational institution and in the external environment.

Key words: Markov chain, communication system, modelling of complex system, probability matrix, unified model, stochastic systems, educational institutions

Introduction

The objectives of the innovative development of educational institutions are related to the introduction of competently-oriented models and methods of forming the information environment, as well as modern approaches to the transformation of models, methods and mechanisms of organizing activities for the provision of educational services and scientific research. The importance of creating a scientifically based concept of filling and using a single educational space for various educational systems becomes apparent [1].

The learning process is implemented in a complex, weakly structured system that includes many heterogeneous subsystems. The development of an adequate deterministic formal description for such systems, in the general case, does not have its own solution since it is practically impossible to establish causal relationships between results, resources, and methods of organizational and technical interaction [2, 3].

The learning process can be analyzed from the standpoint of the theory of self-organization of complex ordered systems, based on the properties of the synergetic approach [4]. Training systems can be attributed to the class of nonlinear systems, because, for example, an increase in the control action in the form of an increase in the volume of educational material does not lead to a definite result in the form of improved quality. It is also known that it is impossible to apply «hard» control methods to complexly organized systems. It is necessary to understand how, supporting their own development trends, to bring such systems into a state of self-organization when external goals are associated with the needs of these systems. The determining postulate of the synergetic approach is that managed development takes the form of self-government [5, 6]. In addition, the widespread dissemination of various kinds of educational information in electronic forms, on the one hand, leads to the pluralistic nature of ways to achieve the learning goal, and on the other hand, objectively leads to the chaos of educational information [7-10].

Literature review

Today, numerous publications consider the idea of university education through the prism of the mission, compilation, and organization of the educational process and scientific activity [11-15]. In the article [11] with reference to the work [12], it is stated that «It can be argued that in the modern world certain trends in the development of the digital education platform have been identified. These trends led to the formation of her promising portrait – education 4.0, as education of the XXI century.»

Articles [13, 14] present a theoretical understanding of the university as a centuries-old civilization project in the form of a conceptual model that combines the categories, semantic structure, and functions of the university. The author proposed four formats of the university model, which were formed at different times, at different historical stages. Format 1.0 «Corporate University» – the first European universities organized as corporations of students and teachers, whose external referent was culture. Format 2.0 «research university» – various forms of organization of university life, such as the «intellectual university» of J. Newman, the «research university» of W. Humboldt and later the «university of culture» H. Ortega-i-Gasset, united by the idea of «pure science» and «universal knowledge». Truth acted as their external referent. Format 3.0 «Technocratic (Innovative) University» is a complex of education, science, and business, which is K. Kerr's «Multi-University» with management mechanisms similar to manufacturing factories. Quality is the external reviewer for format 3.0, and the university is increasingly immersed in bureaucracy and accountability. Format 4.0 «Bio-Digital University» is a promising model of universities that combine physical and virtual spaces, developing on digital platforms. Creativity is the external referent in this case. The educational process is based on meta-personality and smart technologies.

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The modern stage of modernization of domestic education is characterized by fundamental and qualitative changes in the systematic approach to its further development. This is a special period when high demands are made on education at any level, designed to form the general cultural, intellectual, spiritual, and professional capabilities of the individual. The higher education system of Ukraine today is at a turning point in its development, and the choice of further ways and directions of this development largely determines the prospects not only for domestic education but also for the country as a whole [15].

An important condition for the modernization of the education system is to improve the quality and ensure a high level of training. The emphasis in vocational training is shifted from traditional training within the triad of «knowledge – attainments – skills» to the formation of competencies.

The implementation of competency-based models and methods involves the systemic modernization of all components of the educational process. Particularly relevant are applied developments, for example, the development and implementation of modern models of education and science management, the formation of the educational environment of educational institutions, the organization of a network model of methodological interaction in order to increase the competence of managerial and scientific-pedagogical personnel, the formation of a new generation of specialists in the context of the implementation of the latest standards and labor market requirements, the implementation of the Lifelong Learning concept, the development of tools for diagnosing the level of formation of students' competencies and the qualifications of teachers, etc. [16-21].

Main part

Transformation of the functional structure of communications management in the scientific community into a Markov chain. Many factors in a poorly structured information environment form a complex web of connections between states that change over time depending on the structure of the system and factors of the internal and external environment. The development of the information environment in such a multifactor system can often be presented only in the form of qualitative models. At the same time, the use of Markov chains allows us to pass to quantitative estimates of the functioning of systems [22]. When modeling the information environment as a system of functional communications, the key is to display the structure of the interaction of environmental processes using an oriented weighted graph, in which: the vertices correspond to the basic factors (states) of the environment; relations between states reflect causal chains along which one factor affects another.

The possibility of using Markov chains for describing educational and scientific projects is confirmed by the fact that in projects of this kind and in Markov chains, there are transitions between system states, there are transition probabilities between individual states, the sum of transition probabilities for a certain state is equal to «1», the sum of the probabilities of all states is also equal to «1», there is a similarity of the topological structure of transitions.

Let compare the properties of educational projects and the resulting model in order to prove that the system can be described using the mathematical apparatus of Markov chains. The properties of educational projects include:

- operational activities in projects: a) random process; b) for the community of consumers of services there is a certain set of conditions; c) it is not possible to take into account the background of the transition of a system from one state to another; d) educational and/or scientific activities carried out at some point in time t_k, transfer the system into a new state;
- educational/scientific activities, actions of the project team (management or faculty) at time t_k correspond to steps k of the project;

- the result of the work of educational projects forms the distribution of the probabilities of the states of consumers of services, while you can specify the possible transitions of the system from each state to some other in one step;
- the probability of transitions to other states depends on the properties of the system in which random processes act;
- since the state of the system of consumers of educational services constitute a complete group of events, the sum of the probabilities is equal to one;
- transitions from one state of the system to any other state constitute a complete group of events, one of which should be realized;
- the state of the system can be displayed in a graph, indicating the possible transitions from one state to another in one step.

An analysis of the properties of the object and model allows us to conclude that the use of the apparatus of Markov chains for the modeling of educational projects is justified.

It is taken for the basic functional structure of the system (Fig.1) the interaction scheme of typical functional communications in the scientific environment. The original (an educational project) is displayed in the model through a set of typical functional communications between the entities (states) of the educational project (Fig. 1). These conditions are defined in GOST R 54869-2011 [23]. Characteristics of transitions between project states are determined by estimating the time spent on communication between certain states of the system.

Markov chains reflect a random process that satisfies the Markov property and takes a finite or countable number of values (states) [24]. There are Markov chains with discrete and continuous time. The following is a discrete case. The interaction scheme of typical functional communications for system states is adapted to display a communications system in the scientific environment and can be transformed into a Markov chain (Fig.1).

Denote by S_i {*i*=1, 2,..., 7} the possible states of the system that exist in the project: S_1 = A; S_2 = B; S_3 = C; S_4 = D; S_5 = E; S_6 = F; S_7 = G (Fig.1 and Fig. 2).

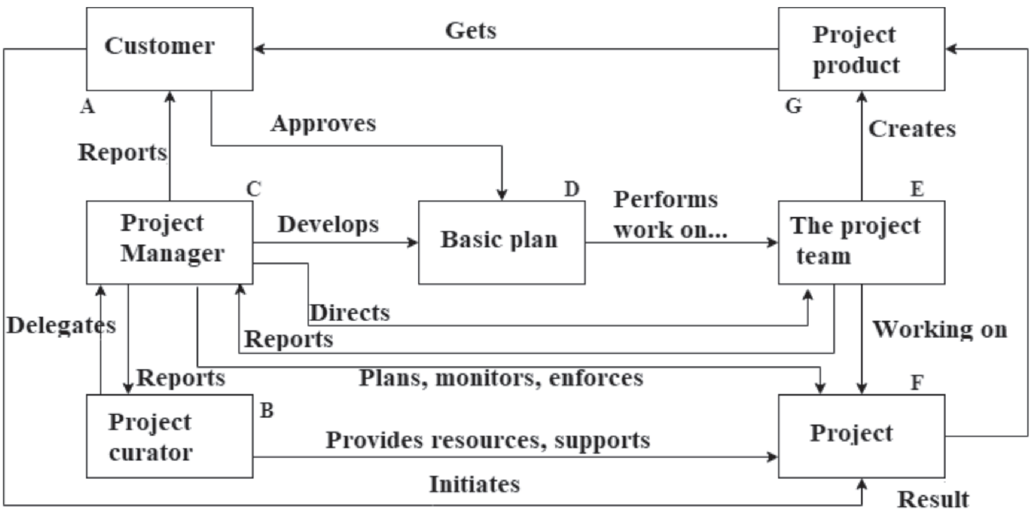

Fig. 1. Scheme of the interaction of typical functional communications for system states [23]: A, B,... G – state identifiers

A sequence of discrete random variables $\{S_k\}_k$ is a Markov chain with discrete-time if

$$P(S_{k+1}=i_{k+1}|\ S_k=i_k;\ S_{k-1}=i_{k-1};\ ...,\ S_0=i_0) = P(S_{k+1}=i_{k+1}|\ S_k=i_k).$$

The following states of the Markov chain depend only on the current state and are independent of all previous states [24]. The range of random variables {Sk} is the state space of the circuit, and the number k is the step number.

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The tops of the transition graph correspond to the states of the Markov chain, and the oriented edges pass from the top i $\{i = 1, 2, ..., m\}$ to the top j $\{j = 1,2,...,m\}$ only if the transition probability is equal to $\pi_{i.j}$ between the corresponding states $i \rightarrow j$ is not equal to zero. These transition probabilities on the marked graph are indicated at the corresponding edge (Fig. 2).

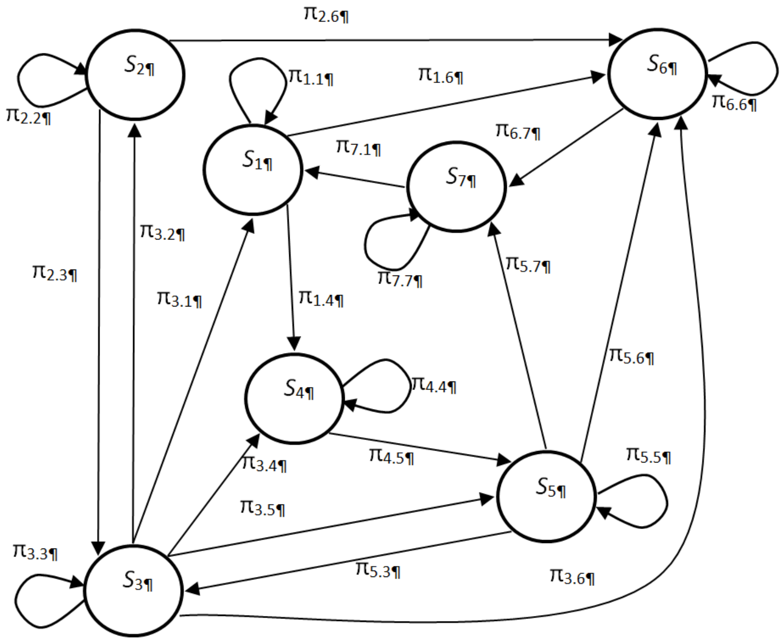

Fig. 2. Marked state graph of the Markov chain

After constructing the structural model of the project in the form of a Markov chain, the parametric identification of the model should be performed. The identification of the Markov chain to describe a specific project is carried out on the basis of determining the set of transition probabilities matrix $\|\pi_{ij}\|$, which is unique for each project. The specificity of the description of various objects by homogeneous Markov chains with discrete states and discrete-time is determined by the methods for estimating transition probabilities. Matrix definition $\|\pi_{ij}\|$ allows to «configure» the Markov chain to reflect the properties of a particular project.

The topology of a directed graph can be represented using the adjacency matrix:

$$\left\| c_{i.j} \right\| = \left\| \begin{matrix} c_{1.1} & 0 & 0 & c_{1.4} & 0 & c_{1.6} & 0 \\ 0 & c_{2.2} & c_{2.3} & 0 & 0 & c_{2.6} & 0 \\ c_{3.1} & c_{3.2} & c_{3.3} & c_{3.4} & c_{3.5} & c_{3.6} & 0 \\ 0 & 0 & 0 & c_{4.4} & c_{4.5} & 0 & 0 \\ 0 & 0 & c_{5.3} & 0 & c_{5.5} & c_{5.6} & c_{5.7} \\ 0 & 0 & 0 & 0 & 0 & c_{6.6} & c_{6.7} \\ c_{7.1} & 0 & 0 & 0 & 0 & 0 & c_{7.7} \end{matrix} \right\| = \left\| \begin{matrix} 1 & 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 & 1 \end{matrix} \right\| \qquad (1)$$

Each element $ci.j$ of the adjacency matrix, nonzero and equal to 1, indicates the presence of a direct connection between the states $i \rightarrow j$. The values of the elements of the main diagonal $ci.i=1$ indicate the presence of a transition loop. This means that the system remains for some time in the same state.

As is known, all possible transitions from one state to another constitute a complete group of events – one of the transitions must be realized [24, 25]. This allows you to enter a norm for each row of the matrix $||ci.j||$ with the replacement of values $ci.j=1$ on transition probabilities $\pi i.j > 0$ with the fulfillment of the condition valid for the full group of events:

$$\sum_{j=1}^{m} \pi_{ij} = 1, \quad \{i = 1, 2, \cdots, m\}, \tag{2}$$

where $m = 7$ is the number of possible states of the system.

The transition probability matrix is written as follows:

$$\left\| \pi_{i.j} \right\| = \left\| \begin{matrix} \pi_{1.1} & 0 & 0 & \pi_{1.4} & 0 & \pi_{1.6} & 0 \\ 0 & \pi_{2.2} & \pi_{2.3} & 0 & 0 & \pi_{2.6} & 0 \\ \pi_{3.1} & \pi_{3.2} & \pi_{3.3} & \pi_{3.4} & \pi_{3.5} & \pi_{3.6} & 0 \\ 0 & 0 & 0 & \pi_{4.4} & \pi_{4.5} & 0 & 0 \\ 0 & 0 & \pi_{5.3} & 0 & \pi_{5.5} & \pi_{5.6} & \pi_{5.7} \\ 0 & 0 & 0 & 0 & 0 & \pi_{6.6} & \pi_{6.7} \\ \pi_{7.1} & 0 & 0 & 0 & 0 & 0 & \pi_{7.7} \end{matrix} \right\|. \tag{3}$$

Elements of this stochastic matrix are the probabilities of transitions between states $i \to j$ in one step, wherein $\forall \pi_{ij} \geq 0$.

The sum of the probabilities of all states $pi(k)$ at each step k:

$$\sum_{i=1}^{m} p_i(k) = 1, \tag{4}$$

where pi(k) is the probability of the i-th state at stage k.

The solution of the Markov chain system of equations. In the Markov chain with time (step k) the probability distribution of the states $\{p1(k), p2(k), \ldots pm(k)\}$ changes. Moreover, the calculation of the probability distribution at each next step is performed according to the well-known full probability formula [26]:

$$\left\| \begin{matrix} p_1(k+1) \\ p_2(k+1) \\ p_3(k+1) \\ p_4(k+1) \\ p_5(k+1) \\ p_6(k+1) \\ p_7(k+1) \end{matrix} \right\|^{\mathrm{T}} = \left\| \begin{matrix} p_1(k) \\ p_2(k) \\ p_3(k) \\ p_4(k) \\ p_5(k) \\ p_6(k) \\ p_7(k) \end{matrix} \right\|^{\mathrm{T}} \cdot \left\| \begin{matrix} \pi_{1.1} & 0 & 0 & \pi_{1.4} & 0 & \pi_{1.6} & 0 \\ 0 & \pi_{2.2} & \pi_{2.3} & 0 & 0 & \pi_{2.6} & 0 \\ \pi_{3.1} & \pi_{3.2} & \pi_{3.3} & \pi_{3.4} & \pi_{3.5} & \pi_{3.6} & 0 \\ 0 & 0 & 0 & \pi_{4.4} & \pi_{4.5} & 0 & 0 \\ 0 & 0 & \pi_{5.3} & 0 & \pi_{5.5} & \pi_{5.6} & \pi_{5.7} \\ 0 & 0 & 0 & 0 & 0 & \pi_{6.6} & \pi_{6.7} \\ \pi_{7.1} & 0 & 0 & 0 & 0 & 0 & \pi_{7.7} \end{matrix} \right\|. \tag{5}$$

So, if a certain transition probability matrix ||πi.j|| and it known the initial probability distribution of states $\{p1(k), p2(k), \ldots pm(k)\}$ at step k, then the new probability distribution of states $||pi(k+1); i = 1, 2, \ldots, m||$ can be found from (5). In most publications on the use of Markov chains, researchers stop at this stage, since an algorithm has already been obtained for practical calculation [27]. At the same time, the presented solution can be transformed. To do this, we use the induction method in the analysis of expressions to calculate the probability distribution of states at steps 1 and 2.

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At step 1:

$$\begin{Vmatrix} p_1(1) \\ p_2(1) \\ p_3(1) \\ p_4(1) \\ p_5(1) \\ p_6(1) \\ p_7(1) \end{Vmatrix}^T = \begin{Vmatrix} p_1(0) \\ p_2(0) \\ p_3(0) \\ p_4(0) \\ p_5(0) \\ p_6(0) \\ p_7(0) \end{Vmatrix}^T \cdot \begin{Vmatrix} \pi_{1.1} & 0 & 0 & \pi_{1.4} & 0 & \pi_{1.6} & 0 \\ 0 & \pi_{2.2} & \pi_{2.3} & 0 & 0 & \pi_{2.6} & 0 \\ \pi_{3.1} & \pi_{3.2} & \pi_{3.3} & \pi_{3.4} & \pi_{3.5} & \pi_{3.6} & 0 \\ 0 & 0 & 0 & \pi_{4.4} & \pi_{4.5} & 0 & 0 \\ 0 & 0 & \pi_{5.3} & 0 & \pi_{5.5} & \pi_{5.6} & \pi_{5.7} \\ 0 & 0 & 0 & 0 & 0 & \pi_{6.6} & \pi_{6.7} \\ \pi_{7.1} & 0 & 0 & 0 & 0 & 0 & \pi_{7.7} \end{Vmatrix}. \qquad (6)$$

At step 2:

$$\begin{Vmatrix} p_1(2) \\ p_2(2) \\ p_3(2) \\ p_4(2) \\ p_5(2) \\ p_6(2) \\ p_7(2) \end{Vmatrix}^T = \begin{Vmatrix} p_1(1) \\ p_2(1) \\ p_3(1) \\ p_4(1) \\ p_5(1) \\ p_6(1) \\ p_7(1) \end{Vmatrix}^T \cdot \begin{Vmatrix} \pi_{1.1} & 0 & 0 & \pi_{1.4} & 0 & \pi_{1.6} & 0 \\ 0 & \pi_{2.2} & \pi_{2.3} & 0 & 0 & \pi_{2.6} & 0 \\ \pi_{3.1} & \pi_{3.2} & \pi_{3.3} & \pi_{3.4} & \pi_{3.5} & \pi_{3.6} & 0 \\ 0 & 0 & 0 & \pi_{4.4} & \pi_{4.5} & 0 & 0 \\ 0 & 0 & \pi_{5.3} & 0 & \pi_{5.5} & \pi_{5.6} & \pi_{5.7} \\ 0 & 0 & 0 & 0 & 0 & \pi_{6.6} & \pi_{6.7} \\ \pi_{7.1} & 0 & 0 & 0 & 0 & 0 & \pi_{7.7} \end{Vmatrix}. \qquad (7)$$

where $||\pi ij||$ transition probability matrix; T – transpose index of columns $||pi(k);\ i = 1, 2,\ldots, 7||;\ ||pi(k+1);\ i = 1, 2,\ldots, 7||$ and $||pi(k+2);\ i = 1, 2,\ldots, 7||$.

The probability distribution of states $\{p1(k), p2(k), \ldots pm(k)\}$ of a homogeneous Markov chain with discrete-time characterizes the phenomenological map of the system, i.e. demonstrates how the investigated object manifests itself.

After substituting (6) in (7), it was obtained:

$$\begin{Vmatrix} p_1(2) \\ p_2(2) \\ p_3(2) \\ p_4(2) \\ p_5(2) \\ p_6(2) \\ p_7(2) \end{Vmatrix}^T = \begin{Vmatrix} p_1(0) \\ p_2(0) \\ p_3(0) \\ p_4(0) \\ p_5(0) \\ p_6(0) \\ p_7(0) \end{Vmatrix}^T \cdot \begin{Vmatrix} \pi_{1.1} & 0 & 0 & \pi_{1.4} & 0 & \pi_{1.6} & 0 \\ 0 & \pi_{2.2} & \pi_{2.3} & 0 & 0 & \pi_{2.6} & 0 \\ \pi_{3.1} & \pi_{3.2} & \pi_{3.3} & \pi_{3.4} & \pi_{3.5} & \pi_{3.6} & 0 \\ 0 & 0 & 0 & \pi_{4.4} & \pi_{4.5} & 0 & 0 \\ 0 & 0 & \pi_{5.3} & 0 & \pi_{5.5} & \pi_{5.6} & \pi_{5.7} \\ 0 & 0 & 0 & 0 & 0 & \pi_{6.6} & \pi_{6.7} \\ \pi_{7.1} & 0 & 0 & 0 & 0 & 0 & \pi_{7.7} \end{Vmatrix} \cdot \begin{Vmatrix} \pi_{1.1} & 0 & 0 & \pi_{1.4} & 0 & \pi_{1.6} & 0 \\ 0 & \pi_{2.2} & \pi_{2.3} & 0 & 0 & \pi_{2.6} & 0 \\ \pi_{3.1} & \pi_{3.2} & \pi_{3.3} & \pi_{3.4} & \pi_{3.5} & \pi_{3.6} & 0 \\ 0 & 0 & 0 & \pi_{4.4} & \pi_{4.5} & 0 & 0 \\ 0 & 0 & \pi_{5.3} & 0 & \pi_{5.5} & \pi_{5.6} & \pi_{5.7} \\ 0 & 0 & 0 & 0 & 0 & \pi_{6.6} & \pi_{6.7} \\ \pi_{7.1} & 0 & 0 & 0 & 0 & 0 & \pi_{7.7} \end{Vmatrix}. \qquad (8)$$

$$\begin{Vmatrix} p_1(2) \\ p_2(2) \\ p_3(2) \\ p_4(2) \\ p_5(2) \\ p_6(2) \\ p_7(2) \end{Vmatrix}^T = \begin{Vmatrix} p_1(0) \\ p_2(0) \\ p_3(0) \\ p_4(0) \\ p_5(0) \\ p_6(0) \\ p_7(0) \end{Vmatrix}^T \cdot \begin{Vmatrix} \pi_{1.1} & 0 & 0 & \pi_{1.4} & 0 & \pi_{1.6} & 0 \\ 0 & \pi_{2.2} & \pi_{2.3} & 0 & 0 & \pi_{2.6} & 0 \\ \pi_{3.1} & \pi_{3.2} & \pi_{3.3} & \pi_{3.4} & \pi_{3.5} & \pi_{3.6} & 0 \\ 0 & 0 & 0 & \pi_{4.4} & \pi_{4.5} & 0 & 0 \\ 0 & 0 & \pi_{5.3} & 0 & \pi_{5.5} & \pi_{5.6} & \pi_{5.7} \\ 0 & 0 & 0 & 0 & 0 & \pi_{6.6} & \pi_{6.7} \\ \pi_{7.1} & 0 & 0 & 0 & 0 & 0 & \pi_{7.7} \end{Vmatrix}^2. \qquad (9)$$

Therefore, it can write in a general for any step k:

$$\begin{Vmatrix} p_1(k) \\ p_2(k) \\ p_3(k) \\ p_4(k) \\ p_5(k) \\ p_6(k) \\ p_7(k) \end{Vmatrix}^T = \begin{Vmatrix} p_1(0) \\ p_2(0) \\ p_3(0) \\ p_4(0) \\ p_5(0) \\ p_6(0) \\ p_7(0) \end{Vmatrix}^T \cdot \begin{Vmatrix} \pi_{1.1} & 0 & 0 & \pi_{1.4} & 0 & \pi_{1.6} & 0 \\ 0 & \pi_{2.2} & \pi_{2.3} & 0 & 0 & \pi_{2.6} & 0 \\ \pi_{3.1} & \pi_{3.2} & \pi_{3.3} & \pi_{3.4} & \pi_{3.5} & \pi_{3.6} & 0 \\ 0 & 0 & 0 & \pi_{4.4} & \pi_{4.5} & 0 & 0 \\ 0 & 0 & \pi_{5.3} & 0 & \pi_{5.5} & \pi_{5.6} & \pi_{5.7} \\ 0 & 0 & 0 & 0 & 0 & \pi_{6.6} & \pi_{6.7} \\ \pi_{7.1} & 0 & 0 & 0 & 0 & 0 & \pi_{7.7} \end{Vmatrix}^k . \quad (10)$$

It follows from (10) that the probability distribution of the states $\{p1(k), p2(k), \ldots pm(k)\}$ at step k depends on the initial distribution at $k = 0$ and the transition probability matrix to the kth degree $||\pi i.j||k$. Therefore, a Markov chain is defined as given when these system parameters are determined.

Various approaches can be used to determine the values πij. An effective way to find the transition probabilities is the method of directly measuring the time spent on certain operations of a certain state based on the "photograph" of the operations, it is assumed that the transition probabilities are calculated as the ratio of the time allotted for each transition to the total operation time. This method can be used in the construction of Markov chains for production operations and processes, which, as a rule, are normalized, and the time of their execution is regulated by the relevant regulatory documents (instructions, rules, regulations, etc.). Transient probabilities can be determined using statistical data, for example, the conditions of patients receiving medical services are clearly recorded in medical records. In fact, such a method is identical to the direct measurement of the number of patients in certain groups (conditions). There is another approach for obtaining transition probabilities expert judgment. Based on a survey of project participants, the probabilities of system states are determined, and then, by solving the inverse problem using the Monte Carlo method, πij values can be founded.

In this case, transition probabilities were determined by estimating the time spent on communication between certain states of the system (tab. 1):

Table 1 – Determination of values of transition probabilities

The nature of the communication $s \to j$ in accordance with the time resource costs	The value of transition probabilities $\pi_{s \to j}$
Most time resource is spent	0,8 – 1,0
Average waste of time resource	0,3 – 0,7
Lower threshold for time consumption	0,1 – 0,2
Slight time resource expenditure	0,01
No time costs	0

Investigation of the dependence of the influence on the effectiveness of the interaction of typical functional communications on the state of the system on the competence of doer. The results of changing the probabilities of the system states in steps for the basic version of the set of transition probabilities are shown in Fig. 3:

$$\pi 5.3=0,5;\ \pi 5.5=0,33;\ \pi 5.6=0,15;\ \pi 5.7=0,02.$$

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The graphs in the following figures are a visualization of the trend (for discrete values, at each step), and not a continuous function. The graph shows how changes in the probabilities of system states at each step occur.

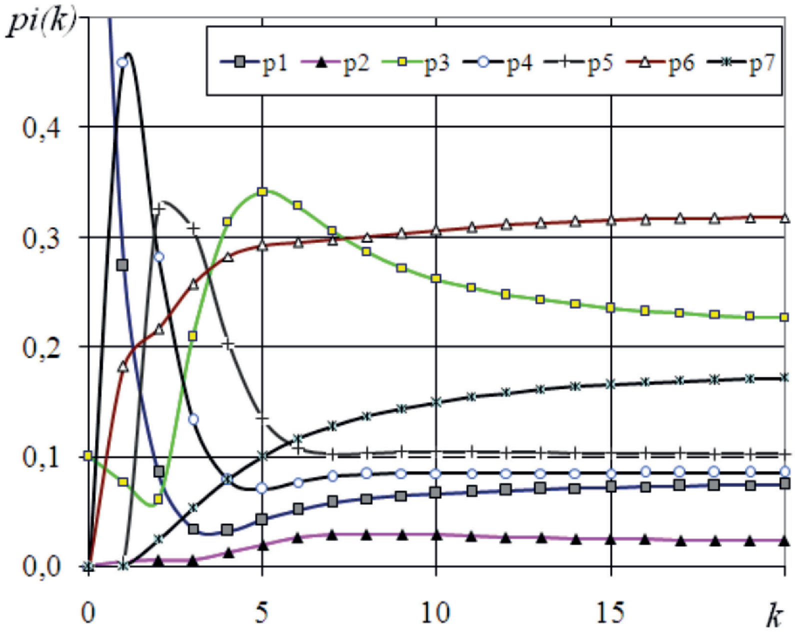

Fig 3. Change in the system state probabilities for a basic data set: *pi(k)* – state probabilities; *k* – steps

The matrix of transition probabilities of the basic version of the system (Fig. 3):

$$\pi_{i,j} = \begin{array}{|c|c|c|c|c|c|c|} \hline 0,3 & 0 & 0 & 0,5 & 0 & 0,2 & 0 \\ \hline 0 & 0,6 & 0,1 & 0 & 0 & 0,3 & 0 \\ \hline 0,04 & 0,04 & 0,76 & 0,1 & 0,04 & 0,02 & 0 \\ \hline 0 & 0 & 0 & 0,30 & 0,70 & 0 & 0 \\ \hline 0 & 0 & 0,50 & 0 & 0,33 & 0,15 & 0,02 \\ \hline 0 & 0 & 0 & 0 & 0 & 0,87 & 0,13 \\ \hline 0,25 & 0 & 0 & 0 & 0 & 0 & 0,75 \\ \hline \end{array} \qquad (11)$$

The basic project in a quasistationary state at stage $k = 20$ is characterized by the following probability distribution of states: *p1(20)=0,07; p2(20)=0,03; p3(20)=0,23; p4(20)=0,08; p5(20)=0,10; p6(20)=0,32; p7(20)=0,17*. This means that at step 20: 32% of the time resource is allocated for the system to work, the manager spends 23% of the same resource, and only 10% of the total resource remains for other performers. The results obtained for the basic version show that with such an organization of interaction of doers, there is a certain contradiction between the implementers of individual processes and the manager. Obviously, the leader himself seeks to perform all the work and does not trust his doers.

To eliminate this contradiction, it is necessary to change the parameters of the performers. This should affect the value of the corresponding transition probabilities for the manager and doers. A new matrix of transition probabilities of the modified version of the system:

$\pi_{ij} =$

0,3	0	0	0,5	0	0,2	0
0	0,6	0,1	0	0	0,3	0
0,04	0,04	0,76	0,1	0,04	0,02	0
0	0	0	0,30	0,70	0	0
0	0	**0,10**	0	0,68	**0,20**	0,02
0	0	0	0	0	0,87	0,13
0,25	0	0	0	0	0	0,75

The results obtained for the new characteristics of the performers show that if only the conditions for the interaction of the performers change, the course and effectiveness of the processes will become different from the base case (Fig. 4).

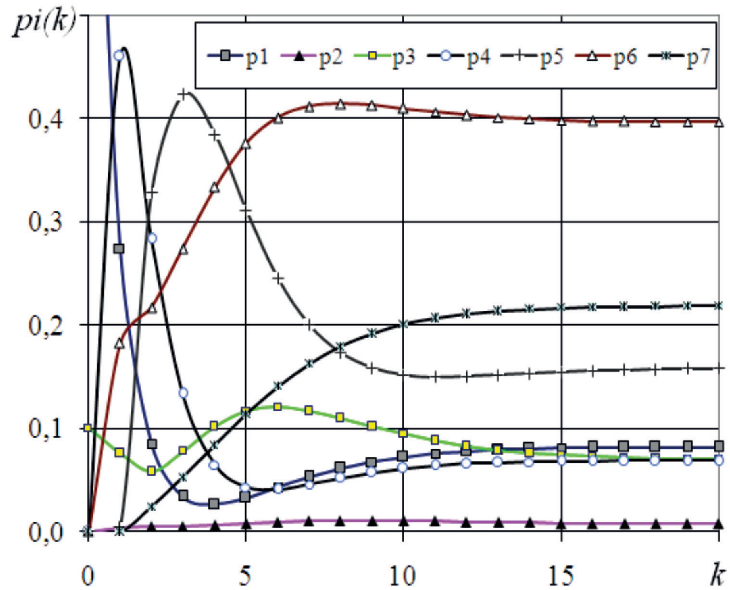

Fig. 4. Change in the probabilities of system states after changes of the data set: *pi(k)* – state probabilities; *k* – steps

Under the same conditions in a quasistationary state at stage $k = 20$ the new system is characterized by the following probability distribution of states: *p1(20)=0,08; p2(20)=0,01; p3(20)=0,07; p4(20)=0,07; p5(20)=0,16; p6(20)=0,40; p7(20)=0,22*. This means that at step 20, 40% of the time resource is already allocated for the work in the system, the manager uses only 7% of the total resource, and the performers increase their share of the work to 16%. The estimates obtained show that the characteristics of the work of performers significantly affect the course of processes. This made it possible to eliminate the contradiction between the executors and the manager identified in the basic version.

In some cases, despite the randomness of the processes under consideration, there is some opportunity to control the laws of distribution or the parameters of transition probabilities [28]. Obviously, the use of Markov chains is especially effective for managing decision making.

Discussion of the results on the development of applied aspects of the application of Markov chains

The generalization and development of applied aspects of the use of Markov chains for describing control systems expand the possibilities of proactive control of functional communications between the states of the systems under study, depending on the competence of the performers of individual processes. A new unified Markov model is proposed, which

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reflects the structure of the system and can be used to describe the features of functional communications. This model allows to represent the probabilities of system states as a complete group of incompatible events, one of which is realized. The advantages of using Markov chains are constrained by the need to «tune» the model to a specific design system by experimentally determining the elements of the transition probability matrix. In the absence of an object – the original system, the elements of the transition probability matrix can be specified taking into account the time taken [26].

Conclusion

The management of educational activities of an educational institution should be considered as a continuous process of improving its activities in the conditions of modern competition in the market of educational services. The proposed model, based on the project approach, will allow the efficient use of material resources, as well as flexibly respond to any changes both within the educational institution and in the external environment.

The paper presents the theoretical foundations of creating the educational environment of an educational institution using the project approach at the stage of building models and displaying communications in the information environment following GOST R 54869-2011.

The article considers the Markov process with discrete states, discrete-time, and homogeneous characteristics of transition probabilities. The latter means that the transition probabilities for the series do not change over time. The set of specific values of transition probabilities characterizes the level of organizational maturity of the project.

The mathematical description of a unified model of Markov chain projects allows us to model the parameters of quantitative goals of functional communications between the states of the systems understudy in the form of the probability distribution of individual states of the system depending on the number of steps. The application of the Markov model allows us to identify the necessary number of steps to achieve the specific goal of the system and eliminate the inconsistencies and conflicts between the process executors. The developed model can also be used to model more complex objects of the educational environment, for example, programs and portfolios of projects of innovative development of educational institutions.

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