# *Innodiversification model of the digital economy of the agricultural sector*

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*Abstract* – **The paper discusses the most important trends and concepts of the modern stage of digitalization and end-to-end technologies offered by the program "Digital economy". The necessity of creating a digital sub-platform for regulation of agriculture as an important component of the modern digital economy is substantiated. The aim of the research is to develop a sub-platform model for regulating the digital economy of agriculture. According to the definition of the digital economy proposed in the work, it should be built as an innovation-diversifying, self-developing system. The concept of a sub-platform for regulating the digital economy of agriculture should be formed on the basis of a system approach and have a hierarchical 5-level network structure. The possibility of realizing the structure using the mathematical apparatus of the Petri net theory is substantiated. It is established that the model design of the subplatform is the best way to improve the structure of production systems and technological processes, as well as to manage its structures.**

***Keywords: agriculture, digital economy, digitalization, digital platform, subplatform, model, modeling.***

## I. INTRODUCTION

Digitalization of production and communications has become the most significant consequence of the transition to a post-industrial society. This has led to the emergence and development of a digital economy with global reach. It is worth noting that the targeted actions of the major world powers largely prepared the ground for its formation.

The order of the President of the Russian Federation V.Putin on the development and adoption in Russia of the concept of the development of the digital economy, given in the annual message to the Federal Assembly of the Russian Federation on December 1, 2016, seems to be an extremely timely and necessary step in the conditions of the ongoing transformation of world economic relations [1].

"The Government of the Russian Federation has developed and approved a program to create conditions for the country's transition to a digital economy. Autonomous non-profit organization Digital Economy, created by successful Russian high-tech companies, coordinates the participation of expert and business communities in planning implementation, development and evaluation of program effectiveness "[2].

The preliminary analysis of the program "Digital Economy of the Russian Federation" [1], which was presented on July 5, 2017, allowed to formulate a conclusion about its relevance, timeliness, detailed study, taking into account the opinions of all interested parties and potential effectiveness for the goals and objectives set by the knowledge-based industry. It should be noted the need for additional analysis of the program and related documents, taking into account the opinions of industry experts and multifactor analysis. The «digital agenda» set at the highest state and strategic level is very important for the Russian Federation, and the measures presented will stimulate the growth of the digital economy and the Russian economy as a whole.

The Ministry of agriculture of the Russian Federation, the ministries of regions, scientific and business communities developed an explanatory note to the proposal to implement the new direction of the program "Digital economy of the Russian Federation" in the direction of "Digital agriculture" [3].

The current level of digitalization of domestic agriculture is a matter of serious concern. The lack of scientific and practical knowledge on innovative modern agricultural technologies and methodology, the lack of a global forecast for agricultural products prices, as well as the underdevelopment of the logistics, storage and delivery system lead to high production costs.

Some agricultural commodity producers do not have the financial capacity to purchase new equipment, use IT equipment and platforms. The amount of costs for information and computer technologies under "Agriculture, hunting and forestry", according to Rosstat in 2015 amounted to 4 billion rubles.This is 0.34 percent of all Information and Communication Technologies investments in all sectors of the economy, in 2017, 0.85 billion rubles. (0.2 percent). This is the lowest figure for the sectors, which indicates a low level of digitalization of the domestic agricultural economy. However, this figure highlights that the industry has the greatest potential for investment in information and computer

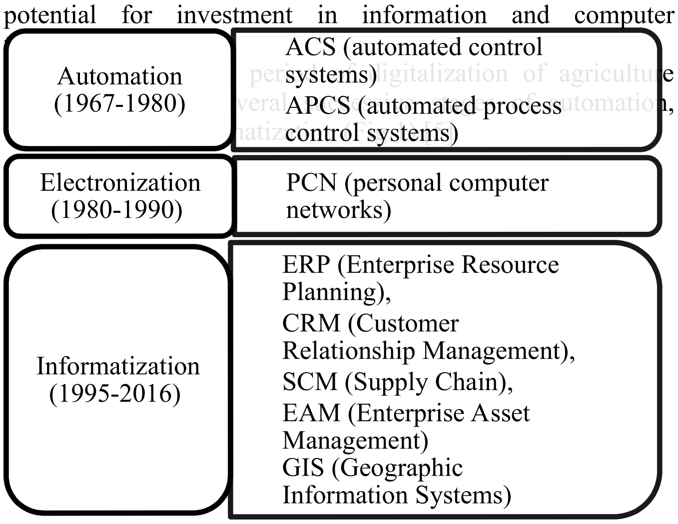


Fig. 1. The stages prior to the period of digitalization

The power of computing systems is growing rapidly, communication networks and computer technology of information processing are improving, but the quality of management of economic processes not only does not improve at a comparable pace with the technical capabilities, but remains at a very low level.

One of the most important reasons for the relative failures of previous periods is their focus on the automation of existing and often very imperfect management processes, rather than on the creation of new economic models corresponding to new information technologies.

The creation of new models of economic behavior of market participants is the main direction of digitalization. It works for their benefit, not for the benefit of Supervisory public services, like most previous systems from ACS to GIS. This gives hope for the success of the digital economy of agriculture.

The concept of "digital economy" does not yet have an unambiguous, clear definition due to the large number of its various interpretations. It is possible to formulate a generalized definition of the term "Digital economy" based on the definitions and concepts given in various sources.

We propose the following definition: digital economy is an environment that includes a set of digital infrastructure and information and communication technologies for doing business.

Intensive digitalization and the Internet of things penetrating the agricultural sector are able to transform this sphere. This is due to the accelerated increase in productivity and the reduction of unproductive expenditures that are characteristic of agricultural activities.

## II. LITERATURE REVIEW

Reasons for slow implementation of innovations in agriculture is revealed in the works of V. E. Afonina [6], Medennikov V. I., Muratova L. G., Salnikov S. G. [7], Ognivtsev S. B. [5]. The possibilities of ICT application in agricultural production are considered, the principles of digitalization application in the agricultural sector of economy are investigated and the variants of platforms for digital economy of agriculture are offered.

The article [6] reveals the reasons for the slow introduction of innovations in agriculture, considers the possibility of using IT in agricultural production, and investigates the principles of digitalization in the agricultural sector of the economy. The purpose of the article [7] is to identify opportunities for the development of the agricultural sector of the economy based on the application of the principles of the digital economy. The disadvantages of the work [5-7] include the lack of specific recommendations for the regulation and promotion of innovation and digitalization of agriculture.

The article [5] describes the most important trends and concepts of the modern stage of digitalization and end-to-end technologies offered by the program "Digital economy" [1]. The business model "Platform-as-a-Service", which can be represented in the form of a digital platform ("state as a platform"), is proposed. In this case, the API will be software modules that perform various functions and services of the state. The platform will allow the user to solve their life problems by selecting a set of APIs that the platform will provide to support a specific life situation. In the article [4] we consider three enlarged sub-platforms of the digital agribusiness platform:

1. Land and provision.
2. Agriculture.
3. Processing and trade.

The absence of a sub-platform with a control function should be attributed to the disadvantages of this digital platform.

The purpose of this work is to develop a model of the sub-platform for regulating the digital economy of agriculture. According to the definition of the digital economy that we proposed, it must be built as an innovation-diversifying and self-developing system. Using the term we proposed in [8], innovation diversification most fully characterizes the process of transformation of agriculture into the digital economy.

## III. RESEARCH METHODOLOGY

Systematic and institutional approaches to the formation of a digital platform for the effective development of agriculture are the main methodological research. Methods of comparison and analogy, analysis and synthesis were applied in the design of the system, which is specified in the goal [9, p. 19]. Normative legal documents in the field of organization of the digital economy of agriculture in the Russian Federation were used as a methodological base. Modern information and communication technologies that improve the efficiency of production processes in agriculture, [10, p.60] were used in the same way. The program "Digital economy" provides for the use of several innovative digital technologies, called in the Program [1] end-to-end technologies at all levels.

## IV. THEORY

In our opinion, the concept of a sub-platform for regulating the digital economy of agriculture should be formed on the basis of a systematic approach and have a hierarchical multi-level network structure:

1. Modules in the form of automated workplaces of agricultural producers should be at the lowest level.
2. Farms consisting of one or several modules (personal part-time farms, peasant farms, small enterprises, sectors of medium and large organizations) may be located at the lower level.
3. Associations (cooperatives, medium-sized enterprises), consisting of one or more farms, may be at an average level.
4. Unions (large organizations at the regional level), consisting of one or more associations, should be located at a higher level.
5. Organizations of the state level, consisting of one or more unions, should be located at the highest level.

The mathematical apparatus for network structure systems is well developed and can be implemented in the form of IT. In our opinion, such structure can be realized on the basis of the Petri net theory [11-16].

Modern agriculture is an industrial and technological system. It has a complex structural and functional organization. A specific technological process (or a combination of them), which can be described by a set of sets of transitions, conditions and relationships, act as a control object in such systems.

Any production is divided into stages (steps). A complex of certain actions with the transformation of material flows and energy transformations is carried out at each of the steps. The order of steps can be described in the form of technological schemes in which each element corresponds to a certain technological process. The interconnections of the elements of the technological scheme are reflected both by the material and energy flows that flow in the system. The algorithm of functioning aimed at achieving objective functions characterizes the system itself.

The system approach to the technological process is characterized by a complex dynamic system. It consists of various units that are in continuous motion, interaction and change, these are: materials, equipment, means of control and management, auxiliary and transport devices, processing tools [17, p.124]. The system also consists of production facilities, operators (people, robots, manipulators) carrying out processes and managing them. Analysis of complex technological processes involves decomposition of the production system into subsystems of different depth levels. The hierarchy of the production system structure, which will allow to consider it at different levels of detail, can be built as a result of decomposition.

It is advisable to use digital technologies in view of the high complexity and laboriousness of the processes of designing agricultural technological processes and systems.

Forecasting of the results of designing technological processes and systems using IT is most expedient to carry out with the help of simulation methods.

The objective function of the concept of simulation modeling of processes and systems in agriculture is to calculate the productivity and the main indicators of economic efficiency, taking into account the consideration of different variants of the structure, the degree of risk [17, p.124], as well as the impact of disturbing factors of the environment and internal spheres. It is necessary to solve the following problems of model design to achieve this goal:

- forecasting of the main characteristics of production systems and technological processes,
- obtaining statistical indicators and other characteristics of technical and economic efficiency,
- using the results of model design to find the best option for production systems or processes,
- research of optimal variants of the technological process structure using tools of the model of digital economy.

It is possible to describe the work of an automated workplace of an agricultural producer, a farm, an agricultural holding, or the industry as a whole, using model design tools. Modeling design of production systems or technological processes will allow to reproduce a parallel, sequential or parallel-sequential scheme of functioning, to take into account stochastic events and their influence on the process [17, p.125]. Model design will allow to carry out a detailed analysis of the designed variants of the operations structure and the impact of various parameters on performance, load factor and other economic indicators that are necessary for making management decisions taking into account unforeseen risks[17, p. 125].

The questions of cost modeling based on the apparatus of Petri nets are considered in the sources of scientific information on modeling. The result of this modeling is the identification of inconsistency and duplication of the operations that make up the processes, as well as the identification of a rational sequence of their implementation, in order to reduce the total cost. Therefore, the use of the Petri nets apparatus makes it possible to determine the optimal sequence of operations of the simulated process, as well as the time and costs for its implementation [18].

Simulation of a particular structure process is performed at the stage of choosing the optimal operation. The production system can contain one, two or more work items. Work can also be done simultaneously (in parallel) at all positions. The model is considered as a process of complex production functioning and economic systems.

Highly complex production systems and technological processes of agriculture operate under the influence of random disturbances that lead to disruption of the normal course of work. Perturbing effects include environmental factors, as well as a number of deviations occurring within the agricultural system [18] in the performance of planned tasks.

Reproduction of the occurring events at full preservation of their logical structures and arrangements in time takes place at model design of production systems (or technological processes). Inodiversification model will allow to extract the most accurate characteristics of technological processes in agriculture [18] (time of processing or Assembly, utilization or loading factors, technical productivity, delays in operations, etc.).

The structure of operations, which clearly defines the order of execution of the transitions, is the basis of the inodiversification model (Table I).

The production process is a discrete stochastic process by nature. Its discreteness is characterized by the fact that elementary acts (transitions, changeovers, measures to restore efficiency, etc.) are not implemented instantly, but are characterized by a certain duration (delay), and the next act is performed only after the complete end of the previous one.

A large number of elements (for example, weather, tools, equipment) are involved in the operation of the production system. These elements can disrupt the process at random times, creating delays. As a result, there are various violations of the normal course of process operations in the simulated production system. The values that estimate the occurrence of failures and the time spent on the restoration work are random [17, p.126]. In addition, the life cycle of tools before their failure, the cycles of the uninterrupted operation of individual subsystems between successive failures, the duration of operability recovery are also referred to random variables.

## V. RESULTS

Processes and systems can be implemented by computer technology using modern IT and mathematical apparatus of Petri nets theory. In particular, the package of applications "Simulator" is applicable not only in agriculture, but also in other sectors of the economy: in trade, in the production of goods or services. It allows to model economic processes when implementing them on the systems of a concrete structure: individual modules, farms, cooperatives, departments, sections, lines and shops [19].

TABLE I. GRAPHIC STRUCTURE OF SYSTEMS AND TECHNOLOGIES IN MODELING

| | Name | Nota-tion | Presentation | Remarks |
|---|---|---|---|---|
| T | Event | ▌ | Finite set of transitions: T=(T1,T2,...Ti), where i is a number of transitions | Sowing, collection, processing, loading, unloading |
| P | Condition | ○ | Finite set of positions: P=(P1,P2,...Pj), where j is a number of positions | Units, operators, accumulators, equipment |
| A | Relations | ↗ | Finite set of relations: A=(A1,A2,..Ak) where k is a number of relations | Sequence of implementing a manufacturing process |
| M | Tags (tokens) | • | Tag (token) in the condition means its execution | Marking of a set positions |
| I | Input function | P(A)→T | Finite set of inputs: I(j,k) | How many times the position P(j) is an input of the transition T(k) |
| O | Output function | T→P(A) | Finite set of outputs: O(j,k) | How many times the position P(j) is an output of the transition T(k) |
| Z | Actuation of transitions | | T(k)→P(j)*M(i)→A | Transition is allowed when there are places for tags and if the number of tags is larger or equal to the number of relations |

Production systems or technological processes may consist of any number of loading devices at the input, unloading devices at the output and any number of consecutive modules connected with each other by drives of a given capacity. The module can consist of one or more pieces of equipment and operator workstations (robots, manipulators or people). The operator can service any number of equipment. [19]. The mathematical representation of the simulation model in the software package is fully consistent with its graphical image, its symbols are shown in table I.

The software package "simulator" was developed on the basis of the simulation theory, it is a model of event sequences (T) under the necessary conditions (P) in accordance with the established relationships (A) [19]. The correctness of the model design logic was proved by analyzing the software package with the help of Petri nets theory. Simulation modeling allows to optimize the content of events, to exclude duplicate relations of events and states. The design of production and economic systems and technological processes is represented by a Petri net and contains four main parameters (table I):

$$C = (P,T,I,O).$$

Modeling to form the network structure requires the initial data to specify these parameters in the following sequence: the number of positions (P), the number of transitions (T), all inputs (I) and outputs (O) in all transitions (Table II). The "Simulator" demonstrates the network formed according to the initial data and requires its approval. After that, the user sets the operating mode. The order of transitions starts is carried out under other equal conditions for those with the highest priority, the value of which must always be integer and greater than 0. First of all, the possible transition that has a higher priority value (Pr) is performed. The best option is chosen by changing the priority values.

Possible failures of devices and organizational features of production are taken into account with the help of a random number sensor in the software package. The device duration and operators before failure and recovery time are described by random numbers (expectation (AO[I]) and standard deviation (ZO[I]) of delays in positions and transitions).

TABLE II. MENU OF THE APPLICATION SOFTWARE PACKAGE "SIMULATOR"

| | **Simulator** |
|---|---|
| 1 | The Petri net structure input |
| 2 | Transition priorities input |
| 3 | Delay arrow input |
| 4 | Position delays input |
| 5 | Transition delay input |
| 6 | Position marking input |
| 7 | Modeling time input |
| 8 | General entry input |
| 9 | Printing of results |
| 10 | Operating mode continuation |
| 11 | Operating mode |
| 12 | End |

Storage capacity (or other positions) can be limited by means of holding arrows, they come out of position and rests on the transition. The transition is delayed by specifying the limit. The position and value of the limit (maximum number of marks in the position) are specified when entering the delay arrows, the execution of this transition is delayed above this value and another possible transition is performed. The position and limit are separated by a comma. If there are no restrictions in the transition - enter 0.

Every position is marked with labels (chips). Labeling is a function that translates a set of positions into a set of non-negative integers. The state of the economic system is characterized by its marking at any time. All possible markings of any system are described by the formula: P = (C,M). Entering the marking is an indication of the number of chips (goods, blanks, semi-finished products, equipment, robots, etc.) on the positions of the network. Marking is a positive integer: 0, 1, 2, 3, etc. Then while working in the system and the number of parallel operations is introduced. Deadlocks can be detected in case of incorrect organization of systems and processes [19]. Summary table of results appears at the right end of the simulation.

## VI. DISCUSSION OF THE RESULTS

Graphical model of modules, mathematical models in the form of a graph represented by a matrix of binary relations (table.III) and sets of two-component maps are created in the first design step (Fig.II):

$$M_1 = \begin{pmatrix} \langle P_1, T_1\rangle, \langle P_2, T_1\rangle, \langle P_3, T_1\rangle, \langle T_1, P_4\rangle, \\ \langle P_4, T_2\rangle, \langle T_2, P_2\rangle, \langle T_2, P_3\rangle, \langle T_2, P_5\rangle \end{pmatrix}.$$

Table for input of initial data (table.III) is formed on the basis of a graphical model (Fig.(II). Initial data are processed using the "Simulator" application package [19].

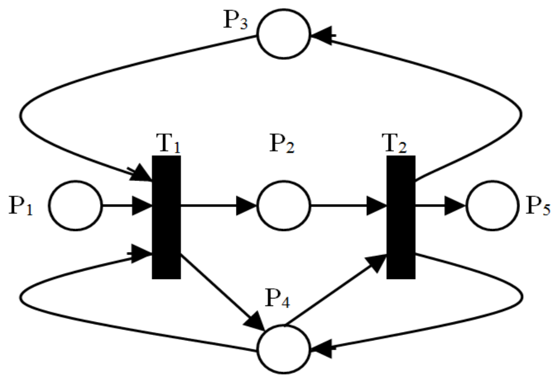


Fig. 2. Graphic model of modules

TABLE III. BINARY RELATION MATRIX

| | | $T_1$ | $T_2$ | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ |
|---|---|---|---|---|---|---|---|---|
| G= | $T_1$ | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| | $T_2$ | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| | $P_1$ | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | $P_2$ | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | $P_3$ | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | $P_4$ | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| | $P_5$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Calculation of the simulation model is required at least five points for qualitative analysis of the design. The results of the calculations are presented in a summary table and a graph is constructed (Fig.III).

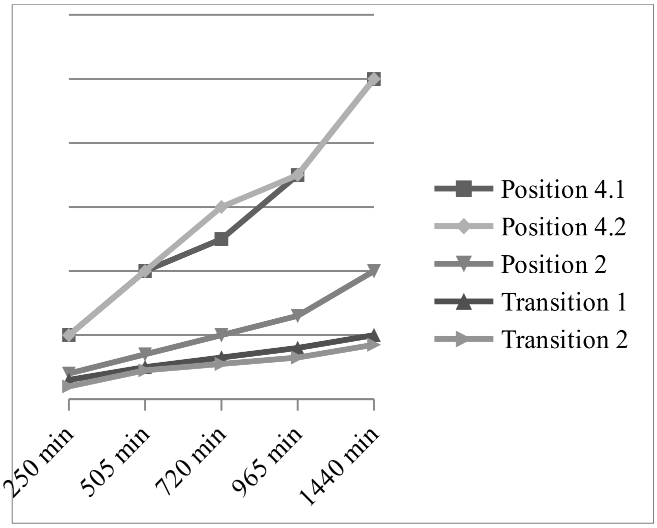


Fig. 3. Efficiency of equipment and operations loading

Optimization of the module structure and management decisions on modernization of the production system or technological processes are made after the analysis of the calculation results: reduction or increase units or operators number, changing their techno-economic characteristics, for example, a change in the length of delays in the working position and in the transitions, the capacity changing (check shooter), etc.

## VII. CONCLUSION

The calculation of the optimal embodiment is performed after upgrading the module. The conclusion on the evaluation of its effectiveness is formulated in comparison with the basic (which is reflected by the customer in the technical assignment).

Then the work of all farms is optimized (consisting of one, two or more modules), then cooperatives, associations (consisting of one, two or more farms), and in conclusion the work of the union (consisting of one, two or more cooperatives, associations).

In conclusion, the work of all modules, farms, cooperatives, associations, and the industry as a whole is analyzed and final conclusions on the effective operation of the upgraded version are given.

It is established that model design is the optimal way to improve the structure of production systems and technological processes in agriculture, as well as to manage these structures [17]. The proposed design technology allows to reduce risks, reduce time, improve quality, strengthen control over observance of technical and technological discipline, reduce the degree of influence of uncertainty, multifactoriness, inconsistency, distribution, diversity, multicriteria, and many other factors, which ultimately contributes more accurately and the effectiveness of obtaining targeted results.

## *References*

[1] The program Digital economy of the Russian Federation, (2017) № 1632-р [Electronic source]: Retrieved from http://static.government.ru/ media/files/9gFM4FHj4Ps B79I5v7yLVuPgu4bvR7M0.pdf

[2] ANO Digital economy [Electronic source]: Retrieved from https://data-economy.ru.

[3] Digital agriculture. Explanatory note to the proposal on the implementation of the new direction of the program Digital economy of the Russian Federation [Electronic source]: Retrieved from https://iotas.ru/files/documents/Пояснит.записка%20eAGRO%20fin %20000.pdf.

[4] Chernyakov M. K. (2018) *Directions and tasks of the digital economy of Russia*, Modern trends in education and science: state and prospects, Karaganda: KEUK, Vol. 4, pp. 200-206.

[5] Ognivtsev S. B. (2018) *The concept of the digital platform of the agro-industrial complex*, International agricultural journal, No. 2 (362), pp. 16-22.

[6] Afonina V. E. (2018) *The impact of digitalization on the development of the agricultural sector*, International agricultural journal, No. 3 (363), pp. 15-17.

[7] Medennikov V. I. (2017) *Digital platform for agriculture*, Bulletin of rural development and social policy [Electronic source]: Retrieved from https://cyberleninka.ru/article/n/tsifrovaya-platforma-dlya-selskogo-hozyaystva.ernational Journal of Professional Science, No. 3, pp. 11-20.

[8] Chernyakov M. K. (2016) *Innodiversification*, Competitiveness in the global world: economy, science, technology, No. 6, pp. 283-287.

[9] Babeshko V. N. (2018) *Evaluation of heuristic methods of system analysis*, International Journal of Advanced Studies, Vol. 8, No. 1-2, pp. 15-20.

[10] Chernyakov. M.K (2018) *Efficiency of processing of a large amount of data of rural families of the region*, International Journal of Advanced Studies, Vol. 8, No. 2-2, pp. 52-61.

[11] Peterson J. (1984) *Petri nets Theory and systems modeling*. M: Mir, 1984. - 264 p.

[12] Konyukh V., and Davidenko V. (1999) *Petri Nets as a Tool for Mine Simulation*, Mineral Resources Engineering, Vol. 8, No. 4, pp. 361-371.

[13] Obzherin Yu.E., Boyko E.G., Semi-Markov (2015) *Models. Control of Res-torable Systems with Latent Failures*, USA, Elsevier, Academic Press,p. 214.

[14] Peschansky A.I. (2013) *Semi-Markov Models of One-Server Loss Queues with Recurrent Input*, Germany: LAP LAMPERT Academic Publishing, p. 138.

[15] Mqqte J., Bhkcni I. *Alpha/Sim Simulation Software Tutorial*, Proc. Of the 1999 Winter Simulation Conference, USA: Phoenix, pp. 621–625.

[16] Jqnkh V., Ccxkfenkq V. (1999) Petri Nets as a Tool for Mine Simulation, Mineral Resources Engineering, Vol. 8, No. 4, pp. 361–371.

[17] Chernyakov M.K., Chernyakova M.M., Akberov K.Ch. *Simulation Design of Manufacturing Processes and Production Systems*, Advances in Engineering Research (AER), Vol. 157, International Conference "Actual Issues of Mechanical Engineering" (AIME 2018), pp. 124-128.

[18] Poleshchuk N. A. *Modelirovanie zatrat v ekonomicheskikh sistemakh s pomoshch'yu setei Petri* [Cost Modelling in Economic Systems Using Petri Nets]. [Electronic source]: Retrieved from http://www.marketing-mba.ru/article/v4_11/Paliashchuk.pdf.

[19] Chernyakov M. K., Chernyakov V. M. *Software Package "Simulator"* [Electronic source]: Retrieved from https://refdb.ru/look/1968832.html.