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Formal Methods for the Synthesis of the Organizational Structure of the Management Through the Personnel Recruitment at the Industrial Enterprises

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Abstract: This study proposes an approach to the development of network models of the processes that constitute the basis of the description of the scenario for the interactive business simulation game. The possibility of automatic conversion of formal schemes describe the process in the script multirole business game in the likeness of the use of critical sections based on the blocking variables for synchronizing the movement of a single process. Formulated and solved the problem of determining the structure of the optimal control system constraints as the problem of finding the optimal organization tree on the set of one group of performers with the functional value of the node, where necessary direct computation of information flow and temporal parameters of the decision making process.

Key words: Collaborative learning, business game, corporate learning system, distance learning, formal models and method, petri nets, queuing networks

INTRODUCTION

The organizational and technological level of modern industrial enterprises is largely determined by the creation and application of effective mechanisms for the formation and implementation of strategic plans for the development and effectiveness of the operational management of all production, logistics and organizational processes that aim to achieve high profitability, development and improvement of production. Therefore, the construction of the organizational structure of enterprise management is a complex multi-level problem (Barinov *et al*., 2007a-c, 2009a, b, 2010, 2011a-f, 2012a, b; Barinov and Kartashev, 2011; Barinov and Ostroukh, 2008; Astakhov *et al*., 2005; Malygin *et al*., 2007; Petrova *et al*., 2008; Ostroukh and Nikolaev, 2013a, b). Principles and methods of the construction of organizational management structure are directly dependent on many factors. The most significant of these are the specifics of the particular production process the set of technological processes used, production volume, productive capacities used, tactical, technical and quality parameters of the products, the issues of standardization and certification, the qualification level of technical, administrative and management personnel, the management system utilized, the regulatory and legal framework of the enterprise and the organization of internal and external documents. The task of building the organizational structure in an industrial environment is a high-priority task in relation to other problems of industrial process control. Formulation and solution of this problem at a high scientific and technical level is a prerequisite for the effective organization of production, the output of highly competitive products, the growth of financial and economic indicators, dynamic development and continuous improvement of production.

The relevance of the topic is determined by the need to optimize the organizational structure of the enterprise management as the problem of the “upper level” to be the priority decisions as a basic component of a successful and efficient operation of any industrial enterprise, regardless of the type of products and production capacity.

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GOAL OF CONSTRUCTING A HIERARCHICAL REPRESENTATION OF THE ORGANIZATIONAL STRUCTURE OF MANAGEMENT OF PRODUCTION PROCESSES AT INDUSTRIAL ENTERPRISES

Creating an organizational structure can be formulated as a problem of the add-on to the technological tree graph whose upper-level nodes are control nodes guiding production units at the underlying level and the nodes of the lowest level, or the leaves will be the top of technological graph, where the arcs of the tree are directed from the executor to the head (Fig. 1) (Barinov *et al*., 2007a, b, 2011a, b).

The group at node v of the organization is the union of groups in the nodes under control of node v:

$$g(v) = \bigcup_{v' \in Q(v)} g(v')$$

In the organisational graph node v controls technological workflows only between apexes of its subordinate group g(v). Vector $l_T(g)$ of the total flow between apexes of an arbitrary group g can be defined as:

$$l_T(g) = \sum_{\substack{u,v \in N \\ (u,v) \in E_T}} l_T(u,v)$$

Since the total flow within a group g (v) of the node v is e $l_T(g(v))$ and flows l_T (g (v1)),..., l_T (g(vk)) is controlled by direct subordinates of node v, the node v controls only flow $L_T(v) = l_T(g(v))-l_T(g(v1))-...-l_T(g(vk))$, where g(v1),..., g (vk) are groups within subordinate nodes {v1,..., vk} = Q(v).

The existence of each node in the organizational graph involves certain costs. The costs of node v depends on the flow of $L_T(v)$, controlling the node and is described by the function K(LT (v))≥0.

Then the cost of maintaining the P(G) of an organizational graph G = <V, E> (where V is the set of control nodes of the organizational graph (i.e., apexes, apexes with subordinates) and E is set of arcs that define the mutual subordination of nodes) is equal to the sum of costs of its nodes:

$$P(G) = \sum_{v \in V} K(L_i(v))$$

Thus, the problem of determining the structure of the optimal control system for technological relations is formulated as the problem of finding the optimal organizational tree of one group on the set of performers with the functional of the node cost. Here one needs to calculate the information flows and time parameters for decision-making.

The temporal characteristics of the decision-making are formed on the basis of the results of the business game. In this work we propose a method for solving the problem of estimating the efficiency of redistribution of personnel over the various technological operations. It consists in reducing the network structure of technological process to the model QNW.

We constructed a simulation model for the process "Registration and control of the process of the order for the road repair and construction and materials handling equipment" shown in Fig. 2. This model includes a series-parallel execution of 17 core operations of the process.

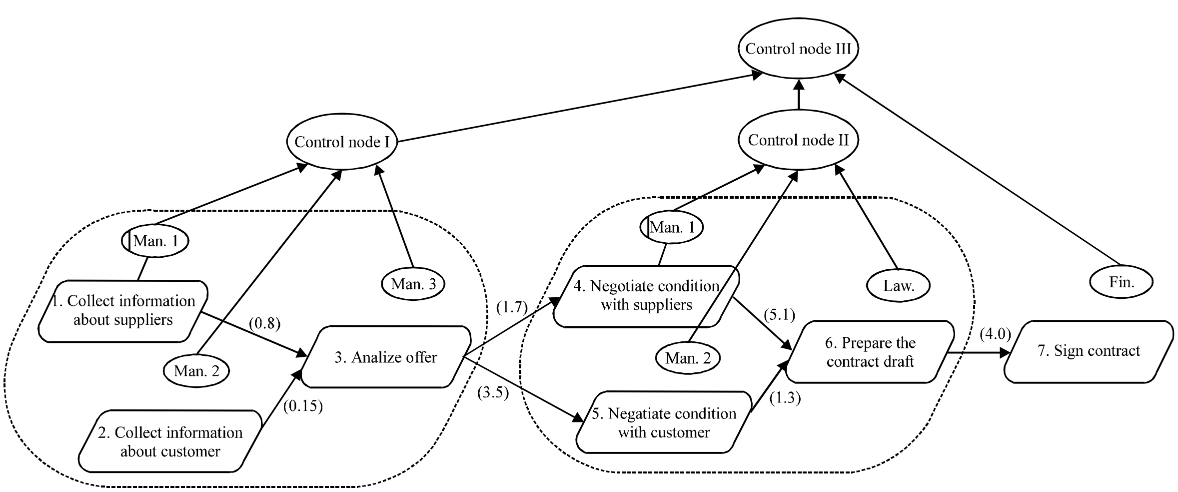

Fig. 1: Structure of the control system for technological connections

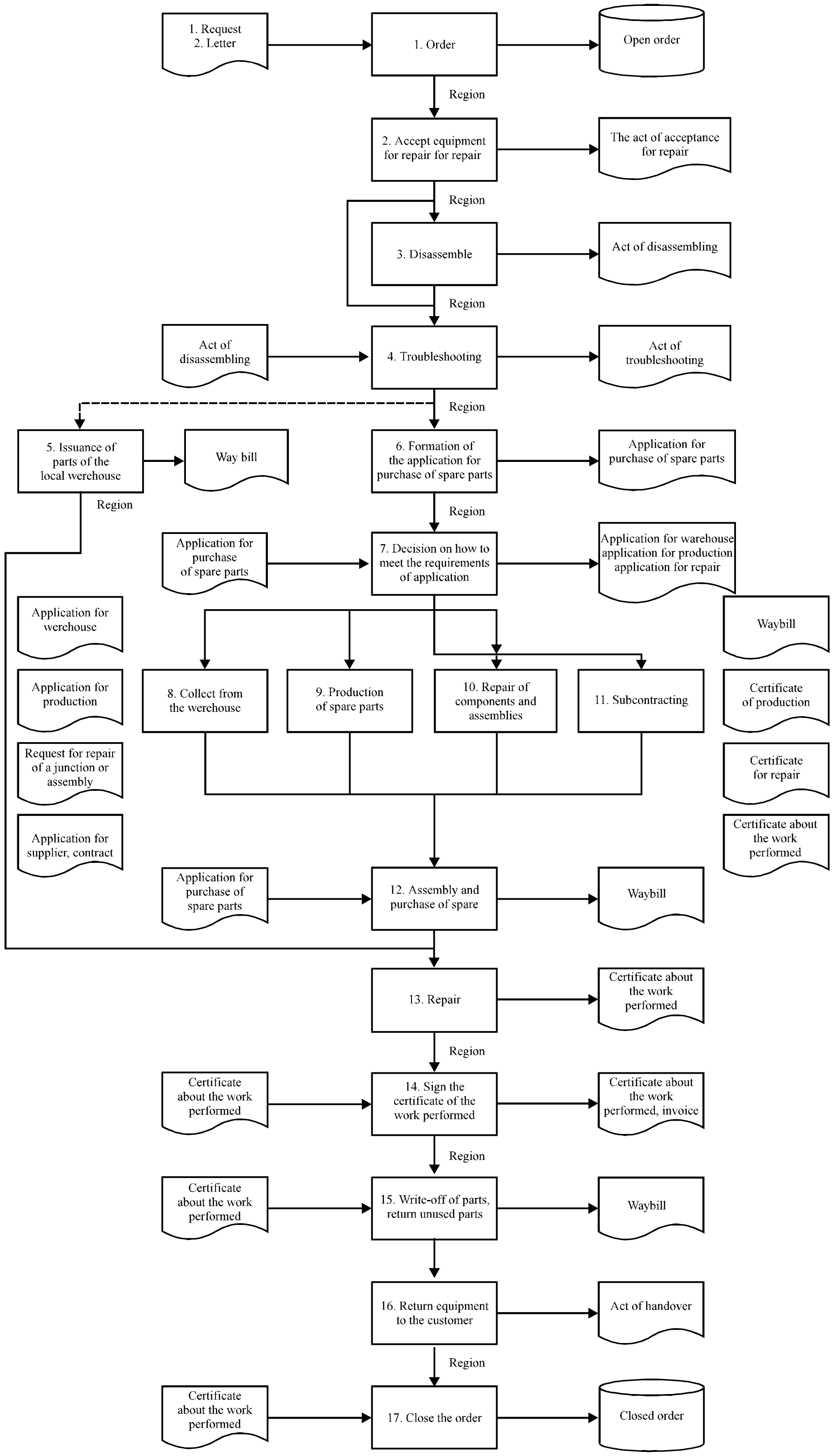

Fig. 2: Schematic of the "Registration and control of the process of the order for the road repair and construction and materials handling equipment" process

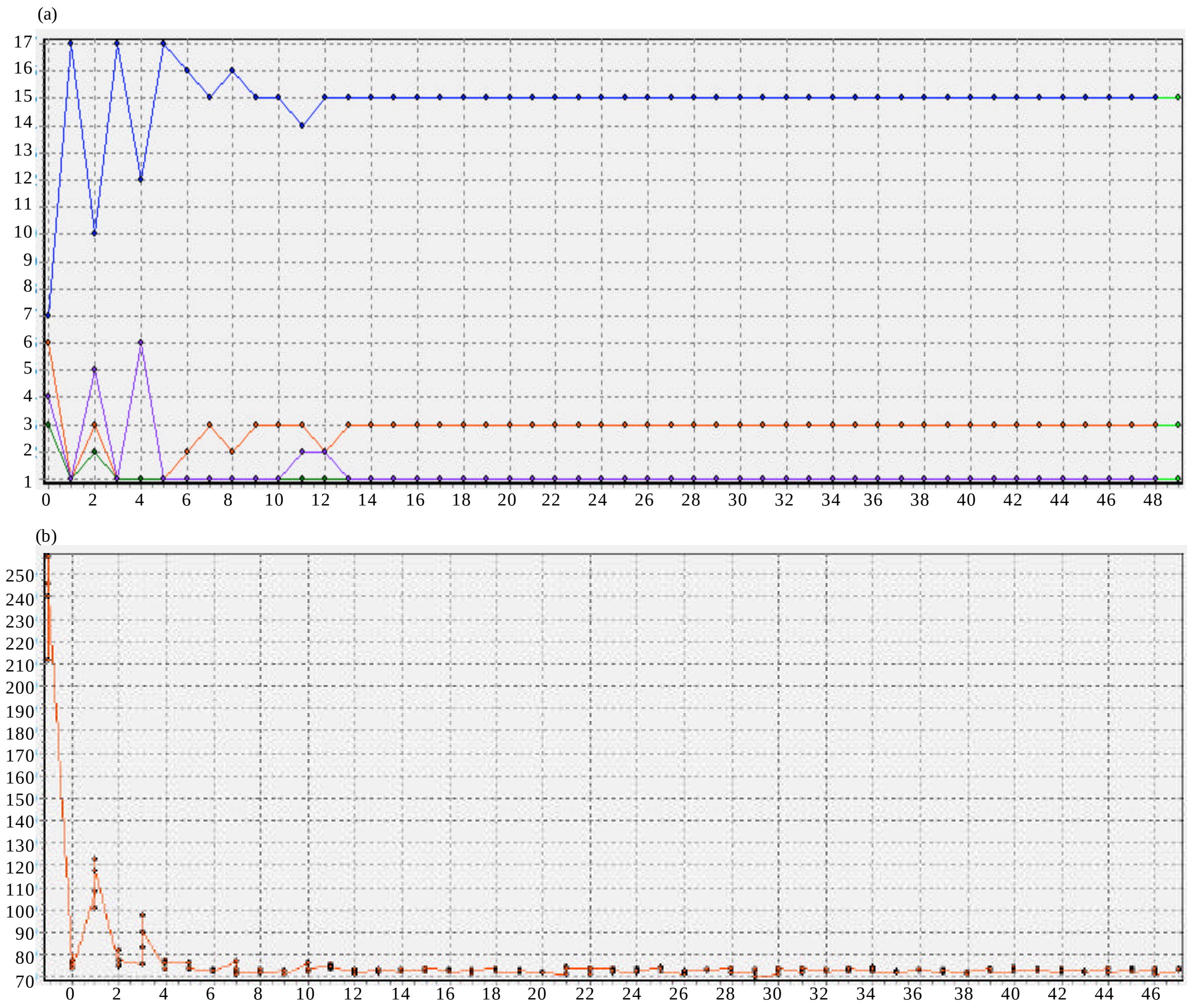

Fig. 3(a-b): (a) Track of the stochastic approximation procedure (top panel) and (b) Corresponding change in the procedure realization time (bottom panel) at each step of the procedure

Table 1: Results of the distribution of the numerical composition of performers over the operations of technological process

	No. of performers	
Operation NN	Before	After
3	6	3
4	3	1
6	4	1
13	7	15
Process realization time (h)	240	72

The main task is to find such a distribution of a fixed number of members of structural unit "Site" on a selected set of operations performed by them which minimizes the average time of a process for given values of the average intensity of the flow of orders and other model parameters. The operations 3, 4, 6 and 13 were chosen as operations for varying the number of the performers in each of the models. The total number of people to be redistributed is 20.

The search for the rational distribution of number of people was based on the stochastic approximation methods that are implemented in the simulation environment developed.

The initial distribution of the numerical composition (Table 1) provided the average time of a process equal to 240 h.

The distribution option which we established provided the average time of the process equal to 72 h. Iteration steps of the stochastic approximation procedure and the corresponding change of the time variable of the process are presented in Fig. 3.

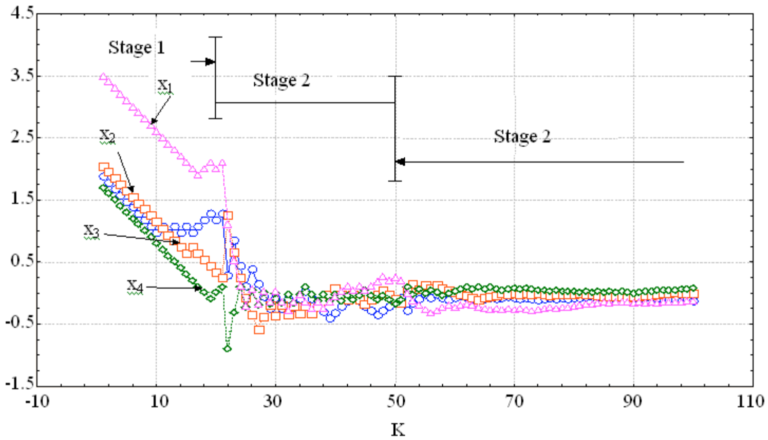

Fig. 4: Trends of the controlled parameter in the three-stage algorithm

Based on the models developed for a number of technological processes it has been shown that the reallocation of personnel to perform the necessary processing steps in the overall process results in a significant reduction in processing time.

PROCEDURE FOR OPTIMIZING THE PERSONNEL DISTRIBUTION

Usage of algorithms of stochastic approximation on the selected trajectories of the time characteristics of technological processes is suggested.

As a result of our research we propose to use of the algorithm with the two-fold change. At the initial stage a random walk with the constant step-size is performed. Then one runs the algorithm of stochastic approximation with sufficiently large values of the parameters a_0 and c_0. Finally, the algorithm with the smaller values of the same parameters is executed. Table 2 shows the parameters of the algorithm with the two-fold change for one of the experiments. The spatial dimension of the controlled parameters was 4, the number of steps was 200 and the number of repetitions of implementations was 200.

The first stage corresponds to an algorithm with a constant step size while the second and third to the converging algorithms. The following annotation was used in the Table 2: $\|A\|$ is norm of the matrix A; σ_y is variance of the functional; σ_{x0} is dispersion of the initial choice of the control parameter; K is the number of steps of algorithms; $a^{<0>}$, $c^{<0>}$ is the values of the coefficients a and c in the algorithm with a constant step; a_0, c_0 is initial values of the coefficients a and c in convergent algorithms.

Trajectories of the process for each of the controlled parameters for the 4 dimensional case are shown in Fig. 4.

Table 2: Algorithm parameter values

Stage	$\|A\|$	σ_y	σ_{x0}	K	$a^{<0>}$	a_0	ap	$c^{<0>}$	c_0	cp
1	9	1	3	20	0.1			0.3		
2	9	1		30		1.0	0.8		1.0	0.3
3	9	1		50		0.2	0.8		0,5	0.25

Comparison of the convergence of one-step and multistep algorithms shows a considerable advantage of the latter ones. For example, in our experiment with the classical stochastical approximation we obtained the same final values of the controlled parameter after 1000 steps as with the three-stage algorithm after only 200 steps (Fig. 5).

As a result convergence rates of the optimization algorithms in the problem of the choice of parameters describing the nodes of queuing networks were obtained.

METHOD OF FORMATION OF THE MANAGEMENT ORGANIZATIONAL STRUCTURE BASED ON THE QNW MODELLING

The problem of finding the optimal graph of the organizational structure is a computationally difficult problem. In practice, it is often sufficient to find a good structure and the personnel distribution within this structure to where the expenses for this structure do not exceed some minimal value too much. In this thesis we suggest to use the following heuristic algorithm (Barinov *et al*., 2010, 2011c, 2012a; Barinov and Kartashev, 2011; Ostroukh and Nikolaev, 2013a, b).

- Calculate the approximate number of nodes in the structural tree:

$$n^* = \arg\min_{n=1..|N|-1} nK'(L_i / n)$$

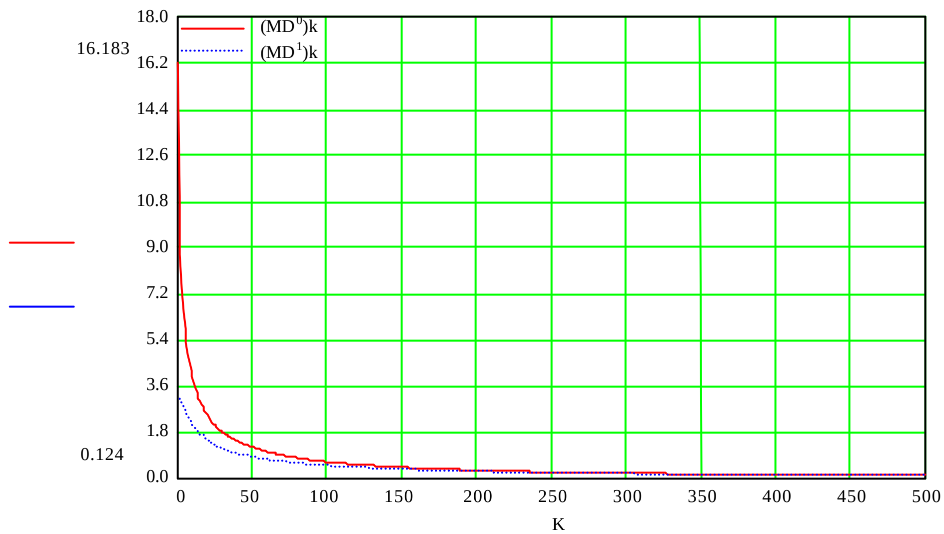

Fig. 5: Graph mean and standard deviation (Mean = 0.126, Standard deviation = 0.124)

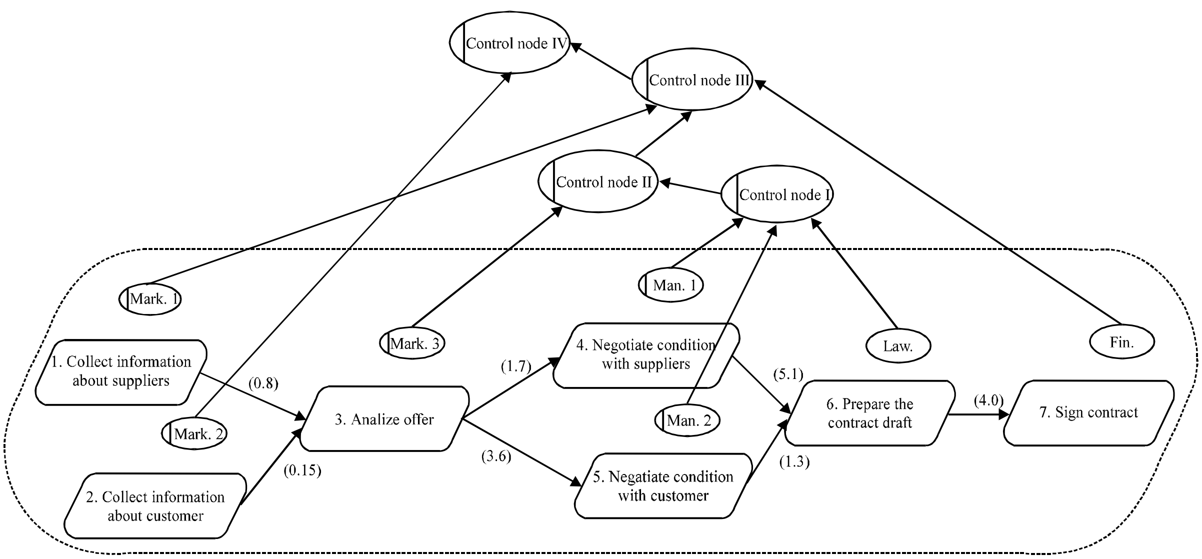

Fig. 6: Rational structure of the control system for the tecnological connections

Assuming the equal distribution of flows over the n nodes of the structure graph the minimum cost of maintaining the organizational structure is achieved when the number of nodes is equal to n*.

- Determine the, reference' flow L: = L_T/n^* per one node
- So long as each relation of the technological graph is not controlled by one of the nodes of the graph of the organizational structure, add nodes to the tree of the structure such that the flow controlled by these nodes approaches the reference flow L

Suppose that the process graph (Fig. 3) is represented by the function K (L) = $300+(L_1+L_2)^2$. Then n* = 4, L = 16, P*(n*): = n*K(LT/n*) = 2224. An example embodiment of the organizational structure constructed using this algorithm is shown in Fig. 6.

Congestion of the control nodes I-IV: L_I = 16, L_{II} = 15, L_{III} = 13, L_{IV} = 20, cost of the organization is P(G) = 2250 which is compatible with the minimum cost of the structure with four control nodes P*(4) = 2224.

CONCLUSION

The network models of the processes describing the interactive business simulation game developed here allow to check correctness and to identify the presence the blocks in its description. It also allows identifying possible options for the further development of the modelled technological process at an early stage.

It is possible to apply automatic transformation of the formal description of technological processes to the multipart business game scenario the similar to using the critical sections based on the blocking variables when syncing the flows of the single process.

The problem of determining the structure of the optimal control system for the technological connections was formulated as a problem of finding the optimal organizational tree of a single group over a set of performers with the node functional, where the direct calculation of the informational flows and time variables of the decision making process must be performed.

To determine the efficiency of the personnel redistribution over the various operations we suggested a scheme of reducing the network structure of the technological process to the QNW model with the subsequent optimization based on the stochastic approximation algorithm.

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