Ekonomicko-manazerske spektrum
2018, Volume 12, Issue 2, pp. 37-45

MANAGEMENT SPECIFICITY OF THE LABOUR RESOURCES FOR EXAMPLE DESIGN-CENTER PROJECTS

Tatyana P. Novikova[1,a,*] and Arthur I. Novikov[2,b]

[1]Voronezh State University of Forestry and Technologies named after G.F. Morozov, Russian Federation
[2]Voronezh State University of Forestry and Technologies named after G.F. Morozov, Russian Federation
[a]novikova_tp.vglta@mail.ru, [b]arthur.novikov@vglta.vrn.ru
*Corresponding author

Cite as: *Novikova, T., Novikov, A. (2018). Management specificity of the labour resources for example design-center projects. Ekonomicko-manazerske spektrum, 12(2), 37-45.*

Available at*: dx.doi.org/10.26552/ems.2018.2.37-45*

Abstract: Modern science-intensive projects, such as the design and production of chip, are characterized by a rapid change of technical and technological bases, time constraints in the development and market launch of the product. In such conditions, there is a need for optimal planning and work distribution management. The author had previously proposed a mathematical model aimed at finding the distribution of works by performers, which fit in a given time and minimizes the total costs of the work of performers. However, a number of questions arose: "What if it is necessary to involve third-party performers? What if in the context of globalization, it is more cost-effective to give part of the work to other companies? How to determine what is more cost effective – to give to third-party companies or to perform the work on their own?" The answers to these questions will help to give the proposed mathematical model of the distribution of work, taking into account the possibility of attracting third-party performers. This problem belongs to the class of NP-complete algorithms for which there are no exact efficient (non-exhaustive) algorithms. To solve this problem, the author developed a heuristic algorithm based on splitting works on the fronts. The information management subsystem of works distribution on performers is developed. For example, the project design-center microelectronics were carried out testing of the system.

Keywords: labour management; knowledge-based system; electronic system; design centre project; heuristic algorithm

JEL Classification: M12, M59, L63

1. Introduction

At the global level, the production of complex (Conforti et al., 2015; Gupta et al., 2010; Hernandez, 2012; Klein & Hirschheim, 1985; Salles, 2015) is paramount to strengthening the well-being of any national economics. As an example of the implementation of knowledge-based systems, consider the process of design and production of electronic components. The design process bears a high price responsibility (Puri & Kung, 2010), 70-80 % of the total cost of creating an electronic component base (ECB) for each subsequent stage of the product life cycle, although the design costs themselves are only about 10% of the total cost of ECB development. Puri & Kung (2010) claim: «*Due to ever increasing cost of doing design, design* *productivity and more specifically, cost of design has become a major bottleneck in large scale design projects*».

Thus, an error in the design is an expensive error, this fact aims to obtain a fully functioning system in the first iteration (Novikova, 2014; Achkasov et al., 2012). The process has the following features (Lenning et al., 1997):

1. Complex technologies of ECB manufacturing, including film deposition, optical lithography, etching, etc.
2. Application in the production of semiconductor materials: silicon, metals (Nickel, gold, copper, aluminum), ceramics (Al_2O_3, AlN), etc.
3. Reduction of costs per unit of production in the production of a large number of unified complex functional units.
4. The use of expensive software in the design of ECB (company Cadence Design Systems, Mentor Graphics, Synopsys, etc.).
5. The need for testing ECB to external factors: mechanical, climatic, sinusoidal vibration, resource, structural, electrical.
6. Availability of the test center equipped with modern equipment on the basis of the design center.
7. High cost of silicon factories.
8. The need for high-precision equipment in the production of ECB.
9. The reduction of design rules for electronic components while providing durability and reliability to the external impact factors.
10. A large amount of time for the production of a prototype (can be up to six months, a year).
11. The high cost of the prototype leads to the use of simulation tools to reliably predict the operation of the system at an earlier stage.

The development of complex knowledge-intensive enterprises takes place in the conditions of significant changes in economic constraints, adjustments to the goals and objectives of managers. The dynamics of these processes, along with the continuous improvement of the characteristics of technical systems, design, testing and production technologies that underlie the development of programs and development projects, necessitates a rethinking of theoretical and methodological approaches to assessing the technical and economic efficiency of measures to create and improve high-tech products. In such circumstances, the tasks of analysis and choice of methods of managerial decision-making become more urgent than ever.

Suppose you want to implement some project (for example, product development, production of pilot batch, test and run in a series) within the microelectronics design center (Achkasov et al., 2012; Fujii, 1997; Novikova, 2014). For its implementation it is necessary to perform *n* works distributed by *m* performers, that is, to solve the problem of work distriburion (Barbosa & Souza, 2017; Burkov & Burkova, 2014; Chentsov, 2011; Conforti et al., 2015; Huang et al., 2010; Kamoche, 1996; Lupin et al., 2015, A; Lupin et al., 2015, B; Maritan & Lee, 2017; Novikov, 2018; Novikova et al., 2013; Novikova & Novikov, 2015; Tripathy & Eppinger, 2013; Varthanan et al., 2013; Zhang & Wong, 2016). The person making the decision, in accordance with the provisions of the decision support systems (Barbosa & Souza, 2017; Borges et al., 2014; Gupta et al., 2010), you need to answer the questions: "What if you need to attract third-party human resources (Lepak & Snell, 2002; Shastry, 2012; Brymer et al., 2013; Conti, 2013; Starr et al., 2018)? How to determine what is more profitable-to give to third-party companies or to do the work yourself?"

2. Methodology

Research methods are based on the theory of control systems, optimization; apparatus of computational mathematics; theory of software development; methods of modular, structural and object-oriented programming; structural and parametric modeling. The main method of research is mathematical modeling, based on the use of the apparatus of modern management theory, in particular – system analysis, game theory, the theory of collective choice and the theory of management of organizational systems.

3. Results

Management of the formation and implementation of design center projects was given sufficient attention in the work (Novikova, 2014) the algorithm of decision-making in the formation and implementation of ECB projects was developed (Fig. 1). The development was based on the approach of control theory "top-down", which was not fully considered the private responsibility of the individual processes. Consider the problem of distribution of work between the performers in more detail. The task belongs to the class of NP-complete problems; its solution does not exist efficient algorithms to determine the optimal decision different from complete enumeration. To solve this problem, we proposed an approximate algorithm called the "front-end" bounded search algorithm (Novikova, 2014). This algorithm is based on the ideology of "greedy" algorithms, that is, algorithms in which the work included in the solution under construction cannot be excluded from it in the next steps of construction. For each step of planning a lot of work is formed-the scope of work. On a set of works from the front of works the strict linear order is set. Under the front is understood a set of works for which at a given iteration of the algorithm can be calculated intervals of start and end of the work (in the front of the work includes all the work for which the previous work has already been distributed to the performers). When constructing the work front, we are guided by the fact that work *i*, for which the start and end intervals are not yet defined, falls into the work front, if all the works from the set K (p) have already been performed.

3.1 Baseline data

$K(p)$ – set of works, immediately preceding the work *i*; $K(p) \subset I, \quad i \in I, p \in I, p < i$;

$t_{ij}^{\min}$ и $t_{ij}^{\max}$ – minimum and maximum duration of work *i* by the contractor *j*;

h_i – the starting time, before which work *i* can't start;

d_i – the directive time (moments of completion of works).

3.2 Limitations

1) the *j-th* performer may start work *i* not earlier than any work prior to work *i* will be performed,

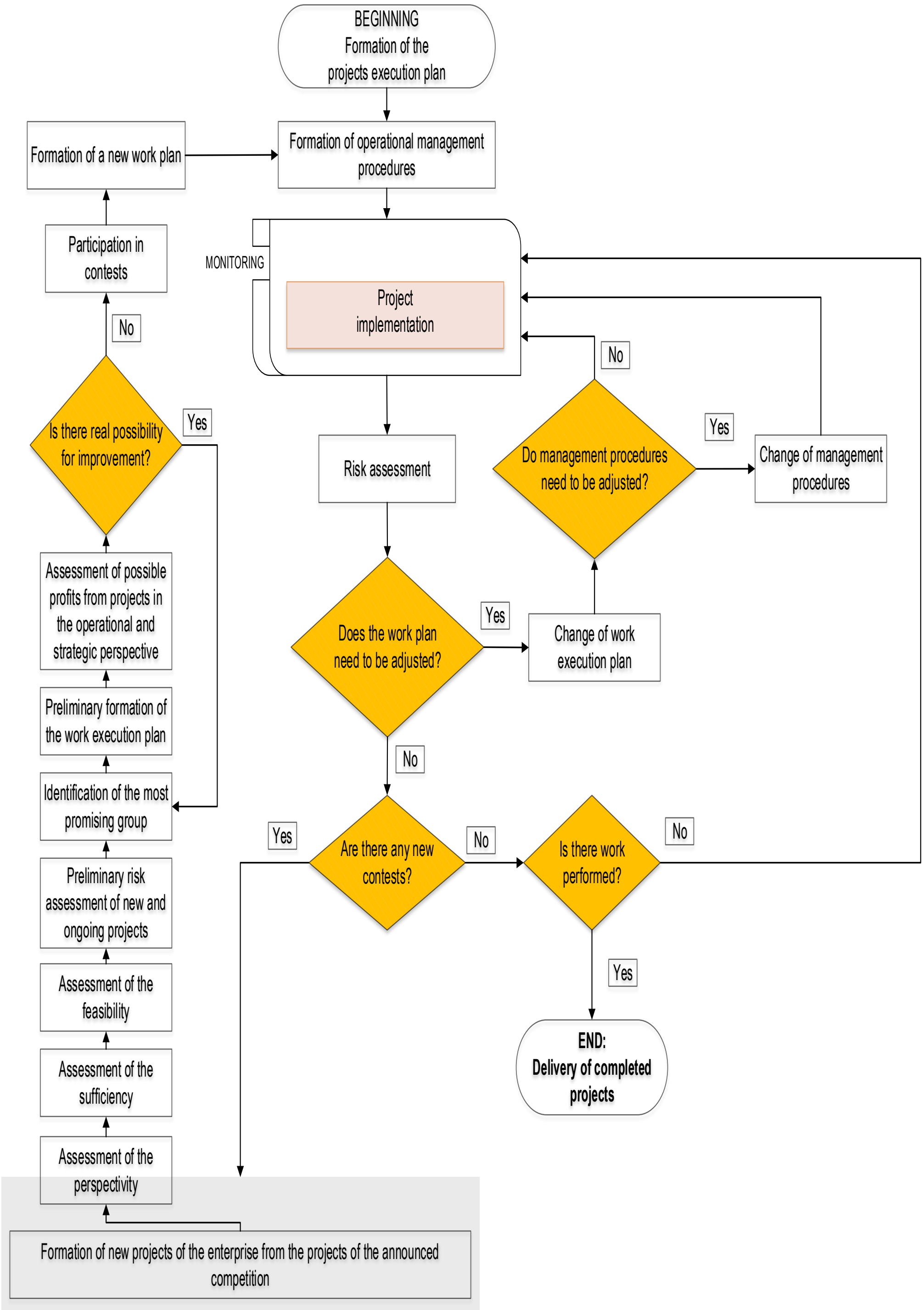
$$\min_{j \in J_{st}} x_{ij} \geq \max_{(i-1) \in Jst} \max_{k \in K(p)} y_{(i-1)k}, \quad i \in I; \tag{1}$$

2) the duration of the works

$$t_{ij}^{\min} \leq (y_{ij} - x_{ij}) \leq t_{ij}^{\max}, \ i \in I, \ j \in I_{st}; \tag{2}$$

3) order of works execution

Figure 1: Block diagram of decision-making on the formation and implementation of projects



Source: Authors based on the data from own research

$$x_{ij} \geq y_{ik},\ \text{либо}\ x_{ik} \geq y_{ij},\ \ i \in I,\ \ j \in I_{st},\ \ k \in I_{st}; \tag{3}$$

4) fulfillment of the specified initial time

$$\min_{j \in J} x_{ij} \geq h_i,\ \ i \in I^H, \tag{4}$$

5) implementation of policy deadlines

$$\max_{j \in J} y_{ij} \geq d_i, \quad i \in I^D, \tag{5}$$

6) the number of assignees (each work *i* is performed by one of *R(i)*:

$$\sum_{j \in R(i)} e_{ij} = 1; \tag{6}$$

$$x_{ij}, y_{ij} \in T. \tag{7}$$

Any solution that satisfies (1) to (6) is valid, hence we obtain a distribution of performers to work.

3.3 Objective function

Let's set an optimization task. Let's translate (5) from constraints to the target function. We will introduce a penalty for violation of deadlines:

$$f = \sum_{i \in I} \sum_{j \in Jst} \lambda_i (d_i - y_{ij}) e_{ij}. \tag{8}$$

We obtain the task of minimization function ($f \to \min$) under restrictions (1)-(4), (6), (7).

If the optimal value of the objective function $f_{\min} \geq f_{\lim}$ is obtained as a result of the solution of equation (8), it is not advisable to involve third-party contractors. Otherwise, part of the work should be given to third-party contractors.

The criterion for the selection of works for third-party contractors is the total cost – *S*, which includes:

– the cost of remuneration of regular employees S_1;

– the cost of contracts for the performance of individual works on the project, concluded with third-party contractors S_2.

The value of S_1 depends on the time of execution of the entire project and is determined by the salaries of staff members.

$$S_1 = \sum_{j'' \in J_{st}} d_{\text{end}} \cdot c_{j''}, \tag{9}$$

where d_{end} – is the total project execution time (the end time of the last work minus the start time of the first work);

$c_{j''}$ – remuneration of the j''-th full-time contractor.

The value of S_2 is the money that is paid to third parties for the performance of a certain amount of work:

$$S_2 = \sum_{i' \in I_{\text{CT}}} \sum_{j' \in J_{\text{CT}}} z_{i'j'} \cdot c_{i'j'}, \tag{10}$$

where $c_{i'j'}$ – cost of the i'-th work performed by the j'-th third-party contractor.

Objective function

$$S = \sum_{j'' \in J_{\text{st}}} d_{\text{end}} \cdot c_{j''} + \sum_{i' \in I_{\text{CT}}} \sum_{j' \in J_{\text{CT}}} z_{i'j'} \cdot c_{i'j'} \to \min \tag{11}$$

Restrictions (1)-(7) hold for all $i'j'$, such that $i' \in I, z_{i'j'} = 0 \; \forall \; j' \in J_{\text{CT}}$.

The task of works distribution by performers belongs to the class of NP-complete, for which there are no exact effective (other than full search) algorithms (Novikov, 2018; Novikova, 2014).

To solve this problem, we propose a heuristic algorithm based on the division of works by fronts. The block diagram of the algorithm is shown in fig. 2. Let us explain the determination of the algorithm. Manufacturing technology of each product is represented by a set of interrelated actions – works. Each work is performed by exactly one contractor and the following restrictions: on the sequence of work; on the duration of work; on the implementation of policy deadlines. The policy period is some time later than which this work could not be completed. As a rule, the policy deadlines are set for the works that are final for a particular project, that is, the completion of this work means the completion of the entire project.

Step 1. Suppose there is a set of works, for each work the intervals of the beginning and the end of works are set. Suppose there are many interchangeable staff performers, for whom it is known from the experience of previously implemented projects the time of execution of individual works on the project.

Step 2. Building the front of F1. Under the front of work, we understand a lot of work for which at this iteration of the algorithm can be calculated intervals of start and end of work (in the front of work includes all the work for which the previous work has already been distributed to the performers). When building the front of work will be guided by the fact that the work for which the intervals of the beginning and end have not yet been defined, falls into the front of work, if all the work of the set has already been completed). When you first build the scope of work F1 it will get the job, without having preceding and following the front of the work of the previous front.

Step 3. In the work of the front F1 of the produced task assignment. To do this, complete enumeration (since the amount of work and number of performers for each job is usually small, an exhaustive search is possible) defined by all possible options for assignment work. That is, we determine the moments of the beginning and end of the work. Choose a job assignment for which the end time of the last work from the front of the work will be the smallest.

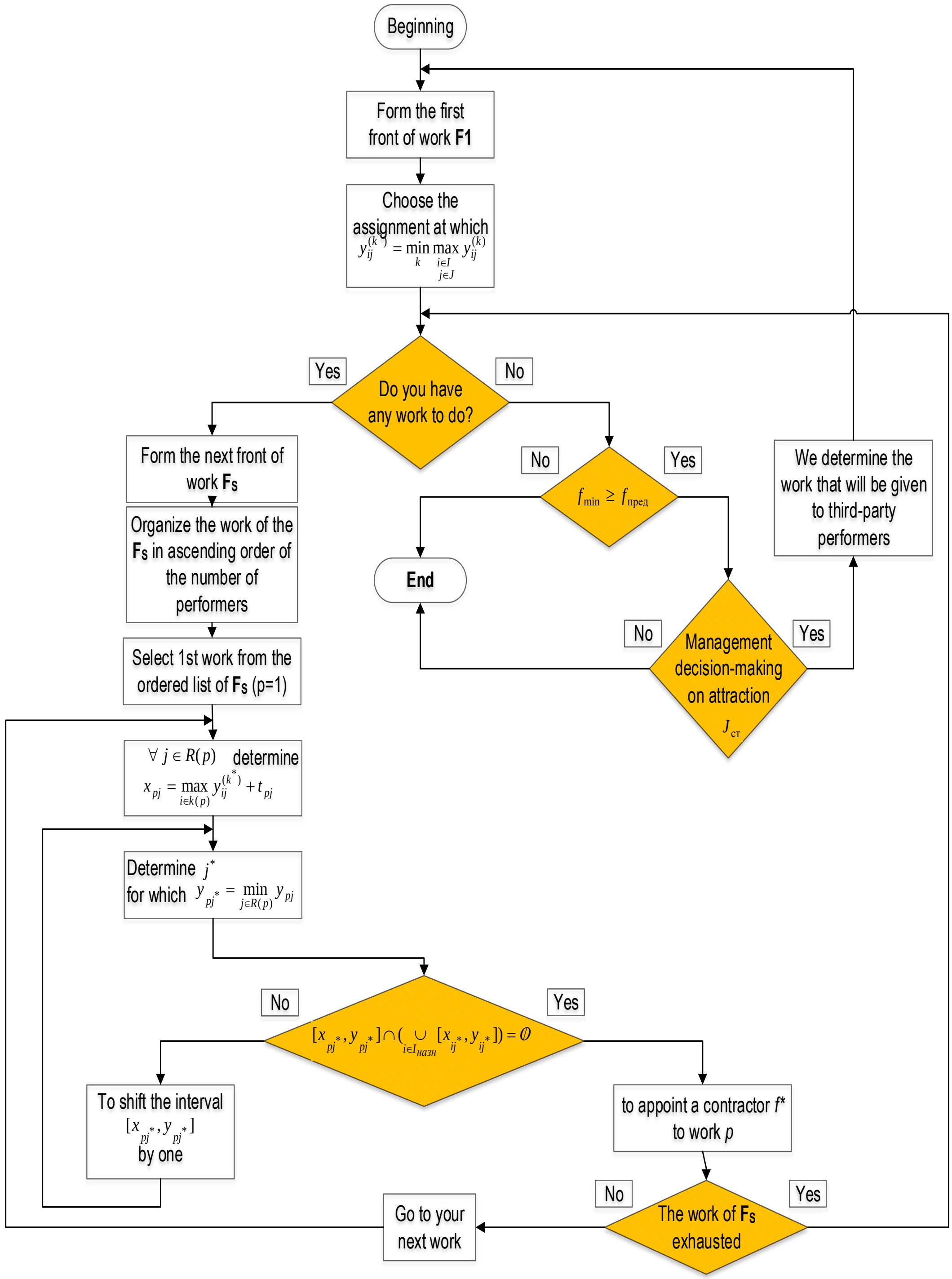
Step 4. Build the following scope of work f s. In front of the FS fall all the work that must be done immediately after the work of the current front. If all works are finished – go to step 8.

Step 5. Determine the order of assignment of works from the front F_S. The first in order should be those works that can be performed by the smallest number of performers.

Step 6. Choose a job from the front of the F_S. For each work the previous works are known, therefore, the moment of the beginning of this work should be not less than the greatest of the moments of the end of the previous works. For each possible performer of work, the intervals of his employment at the already assigned works are known. As a performer of work is selected the performer, which is the least time after finishing the work.

Step 7. If the list of works from the FS front is not exhausted, proceed to the next work and step 6, otherwise to step 4.

Figure 2: Block diagram of the algorithm of work distribution by performers within the project



Source: Authors based on the data from own research

Step 8. Check the value of the target function. If the optimal value of the objective function is obtained, it is not advisable to involve third-party executors and the algorithm ends at step 12.

Step 9. If the value of the target function exceeds the limit, it is advisable to involve third-party performers to reduce the project execution time. However, the person making the decision, guided by other considerations, may waive outsourcing and the algorithm terminates.

Step 10. We determine the works that will be given to third-party performers. The selection criterion is the total cost of remuneration of regular employees and the cost of contracts for the performance of individual works on the project concluded with third-party contractors.

Step 11. Proceed to step 1, given the reduction in the number of works performed by staff performers (new matrix of works).

Step 12. The end of the algorithm.

4. Discussion

The solution of the task of works distribution at the global level by classical methods (network planning, branches and borders, Gantt) is not possible, since the time of execution of the work depends on the contractor, the appointment of the contractor for a specific work occurs only after the optimal distribution of previous works and depends on the time of execution of previous works, there is also almost always the possibility of execution of works by other performers. The problem belongs to the class of NP-complete problems, i.e. there are no effective algorithms for determining the optimal solution other than the full search. To solve this problem, we propose a "frontal" bounded search algorithm. This algorithm is based on the ideology of "greedy" algorithms, that is, algorithms in which the work included in the solution under construction cannot be excluded from it in the next steps of construction. For each cycle of planning a lot of work is formed – the front of work. On the set of works from the work front, a strict linear order is given. The front refers to a set of works for which the start and end time intervals can be calculated at a given iteration of the algorithm (all works for which the previous works are already distributed among the performers are included in the front of work). When building the front of work, we should not forget that work *i*, for which the start and end intervals are not yet defined, falls into the front of work, if $K(i)=0 \vee K(i)\neq 0$ (all work from the set $K(i)$ has already been performed).

5. Conclusion

The solution of the problem of the distribution of works by classical methods (network planning, branches and boundaries, Gantt) is not possible, since the execution time of the work depends on the contractor, the appointment of the contractor for a specific work occurs only after the optimal distribution of previous work and depends on the time of the previous work, there is also almost always the possibility of performing work by other performers.

The developed mathematical model is aimed at finding the distribution of work by the performers, which fits in a given time and minimizes the total cost of the performers by reducing the time of their work. The developed mathematical model provides the decision-maker with objective information about the timing of the project and the possibility of reducing them.

References

Achkasov, V.N., Zolnikov, V.K. & Belyaeva, T.P. (2012). *Controlling Means of Development Electronic Component Basis*. Lorman, MS, USA: Science Book Publishing House LLC.

Barbosa, G.E. & Souza, G.F. (2016). A Risk-Based Framework with Design Structure Matrix to Select Alternatives of Product Modernisation. *Journal of Engineering Design*, 28(1), 23-46.

Borges, J.G., Nordstrom, E.M., Garcia-Gonzalo, J., Hujala, T. & Trasobares, A. (2014). *Computer-Based Tools for Supporting Forest Management the Experience and the Expertise World-Wide*. Umea, Sweden: Institutionen for Skoglig Resurshushallning, Sveriges Lantbruksuniversitet.

Brymer, R.A., Molloy, J.C. & Gilbert, B.A. (2013). Human Capital Pipelines. *Journal of Management,* 40(2), 483-508.

Burkov, V.N. & Burkova, I.V. (2014). The Network Programming Method in Control Over Target Programs. *Automation and Remote Control*, 75(3), 470-480.

Chentsov, P.A. (2011). Distribution of Assignments Among Participants Under Conditions of Constraints. *Automation and Remote Control*, 7*2*(8), 1690-1704.

Conforti, R., Leoni, M.D., Rosa, M.L., Aalst, W.M., & Hofstede, A.H. (2015). A Recommendation System for Predicting Risks Across Multiple Business Process Instances. *Decision Support Systems,* 69, 1-19.

Conti, R. (2013). Do Non-Competition Agreements Lead Firms to Pursue Risky R&D Projects? *Strategic Management Journal,* 35(8), 1230-1248.

Fujii, R.H. (1997). Microelectronic Systems Design Educational Challenge. *1997 IEEE International Conference on Microelectronic Systems Education - MSE'97, Proceedings: Doing More with Less in a Rapidly Changing Environment.* Los Alamitos, CA, 91-92.

Gupta, J.N., Forgionne, G.A. & Mora, M. (2010). *Intelligent Decision-Making Support Systems: Foundations, Applications and Challenges*. Berlin: Springer.

Hernandez, J.E. (2012). *Decision Support Systems – Collaborative Models and Approaches in Real Environments*. Berlin, Heidelberg: Springer.

Huang, Z., Aalst, W.V., Lu, X. & Duan, H. (2010). An Adaptive Work Distribution Mechanism Based on Reinforcement Learning. *Expert Systems with Applications,* 37(12), 7533-7541.

Kamoche, K. (1996). Strategic Human Resource Management Within a Resource-Capability View of the Firm. *Journal of Management Studies,* 33(2), 213-233.

Klein, H. & Hirschheim, R. (1985). Fundamental Issues of Decision Support Systems: A Consequentialist Perspective. *Decision Support Systems,* 1(1), 5-23.

Lenning, L., Shah, A., Ozguner, U. & Bibyk, S. (1997). Integration of VLSI Circuits and Mechanics for Vibration Control of Flexible Structures. *IEEE/ASME Transactions on Mechatronics,* 2(1), 30-40.

Lepak, D.P. & Snell, S.A. (2002). Examining the Human Resource Architecture: The Relationships Among Human Capital, Employment, and Human Resource Configurations. *Journal of Management,* 28(4), 517-543.

Lupin, S., Davydova, A., Maw, S.W., Aung, S.M. & Chakirov, R. (2015A). Evaluating the Effect Iveness of Hierarchical Management Systems. *2015 IEEE NW Russia Young Researchers in Electrical and Electronic Engineering Conference (EIConRusNW).* St. Petersburg, Russia, 89-92.

Lupin, S., Maw, S.W., Thike, A.M., Kovalenko, D. & Worden, J. (2015B). Job Distribution in Hierarchic Systems. *2015 Internet Technologies and Applications (ITA).* Wrexham, UK, 104-108.

Maritan, C. A. & Lee, G. K. (2017). Resource Allocation and Strategy. *Journal of Management,* 43(8), 2411-2420.

Novikov, D.A. (2018). Analytical Complexity and Errors of Solving Control Problems for Organizational and Technical Systems. *Automation and Remote Control,* 79(5), 860-869.

Novikova, T.P. (2014). *Microelectronics Design Center Project Management System*. Voronezh, Russian Federation: Voronezh State University of Forestry and Technologies named after G.F. Morozov.

Novikova, T.P., Avseeva, O.V. & Novikov, A.I. (2013). The Mathematical Model of Optimal Distribution Works in Network Canonical Structures. *Fundamental and Applied Problems of Technics and Technology,* 5(301), 48-52.

Novikova, T.P. & Novikov, A.I. (2015). Algorithms for Solving Problems of Optimum Distribution Work in Network Canonical Structures. *Forestry Engineering Journal,* 4(4), 309-317.

Puri, R. & Kung, D.S. (2010). The Dawn of 22nm Era: Design and CAD Challenges. *2010 23rd International Conference on VLSI Design,* 429-433.

Salles, M. (2015). *Decision-making and the information system*. London, UK: ISTE.

Shastry, G.K. (2012). Human Capital Response to Globalization Education and Information Technology in India. *Journal of Human Resources,* 47(2), 287-330.

Starr, E., Ganco, M. & Campbell, B.A. (2018). Strategic Human Capital Management in the Context of Cross-Industry and Within-Industry Mobility Frictions. *Strategic Management Journal,* 39(8), 2226-2254.

Tripathy, A. & Eppinger, S.D. (2013). Structuring Work Distribution for Global Product Development Organizations. *Production and Operations Management,* 22(6), 1557-1575.

Varthanan, P.A., Murugan, N. & Kumar, G.M. (2013). An AHP Based Heuristic DPSO Algorithm for Generating Multi Criteria Production–Distribution Plan. *Journal of Manufacturing Systems,* 32(4), 632-647.

Zhang, L. & Wong, T. (2016). Solving Integrated Process Planning and Scheduling Problem with Constructive Meta-Heuristics. *Information Sciences,* 340-341, 1-16.