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V.V. Kobzev, A.E. Radaev

INSTRUMENTS FOR MANAGEMENT OF INDUSTRIAL ENTERPRISES' HIGH-TECH MANUFACTURE ON THE BASIS OF SIMULATION MODELING

В.В. Кобзев, А.Е. Радаев

ИНСТРУМЕНТАРИЙ УПРАВЛЕНИЯ ВЫСОКОТЕХНОЛОГИЧНЫМ ПРОИЗВОДСТВОМ ПРОМЫШЛЕННЫХ ПРЕДПРИЯТИЙ НА ОСНОВЕ ИМИТАЦИОННОГО МОДЕЛИРОВАНИЯ

This article covers current issues in the area of design and application of automated or high-tech manufacturing into the structure of domestic industrial enterprises. Instruments for the management of high-tech manufacturing within industrial enterprises on the basis of simulation modeling are created.
HIGH-TECH MANUFACTURING. INDUSTRIAL ENTERPRISE. SIMULATION MODELING. OPTIMIZATION MODEL. SIMULATION MODEL.

Рассматриваются современные проблемы в области проектирования и внедрения автоматизированных производств в структуру отечественных промышленных предприятий. В настоящее время упомянутые производства называют высокотехнологичными. Разработан инструментарий управления высокотехнологичным производством промышленных предприятий на основе имитационного моделирования.
ВЫСОКОТЕХНОЛОГИЧНОЕ ПРОИЗВОДСТВО. ПРОМЫШЛЕННОЕ ПРЕДПРИЯТИЕ. ИМИТАЦИОННОЕ МОДЕЛИРОВАНИЕ. ОПТИМИЗАЦИОННАЯ МОДЕЛЬ. ИМИТАЦИОННАЯ МОДЕЛЬ.

Modern trends of enterprise development in the high-tech sector of industrialized countries in combination with intensive improvement of opportunities provided by computing machinery and increasing importance of information technologies in project works stimulate researches in the area of design and application of high-tech manufacturing into the structure of domestic industrial enterprises [1, 3]. Currently, the most actual elaborations concern the automation of manufacturing and management at the enterprises of domestic industry for increasing the share of science-intensive production, which meets the modern requirements of Russian economy's modernization in order to be competitive in the world markets. One of the ways to increase the adequacy of managerial decisions taken in the area of high-tech manufacturing is connected to the application of simulation software tools to manufacturing management at the different stages of the life-cycle. In spite of the extensive spread of simulation modeling into Russian practice of management of industrial enterprises including high-tech manufacturing, scientific achievements proceedings in the corresponding area do not include concrete methodical groundwork and instrumental tools. The last circumstance determined the need for scientific research, which is focused on the elaboration of instruments for the management of industrial enterprises' high-tech manufacturing on the basis of simulation modeling.

The research is based on the concept of management within industrial enterprises' high-tech manufacturing which involves simulation modeling software. The elaborated concept includes specified terms of «high-tech manufacture

(HTM)», «organizational design» and «organization of functioning»; formulated principles of management (integration, flexibility, adaptability, reliability, economization, automaticity [5]); proposed discrete-event approach in the area of simulation modeling (SM), which supposes the implementation of modeling object as a system of processing similar elements (calls, transacts) using disposable resources; formed composition and sequence of the tasks for HTM management for most important (towards sustainable development of the enterprise) stages of life-cycle: organizational design and organization of functions.

The list of tasks (in the area of management for industrial enterprises' HTM) was used as the basic for classification of the factors of functioning effectiveness. The classification particularly defines the factors for functional areas of production, transportation, control and storage, traditionally assigned in line with conception of lean production, which is an inseparable component of any modern HTM.

This concept of HTM management and the classification of the factors of the object's functioning effectiveness became the basis for the elaboration of an algorithm to solve the tasks in the area of HTM management at the stages of the organizational design and the organization of functioning with the application of SM software tools. The algorithm supposes the creation (in the process of task implementation), optimization and simulation models, their integration within respective procedures, in which an optimization component formalizes the objectives and conditions of subject's functioning, and a simulation component forms alternative variants of this functioning.

The complexity of HTM functioning and the need for the detailed economic analysis determined the reasonability for the elaboration of the system of target and planning-and-control indicators [8], which should be used as output parameters of simulation models (building within the process of task implementation) to obtain the adequate of selection and the accuracy of control over the managerial decision's realization in the area of industrial enterprises' HTM [6]. The structure the of the proposed system of indicator is shown in Fig. 1. The indicators of Net Present Value (NPV) and Return On Investment Capital (ROIC) were proposed as target indicators responsible for selection of managerial decisions made for long- and short-term periods during the research. A system of interconnected planning-and-control indicators was created for the target indicators. The system includes:

– coefficients of cost – shares of different articles of enterprise expenditures in sales proceeds;
– coefficients defining effectiveness of different asset groups of the enterprise;
– indicators describing the structure of the enterprise capital.

To take into account the main principles of HTM management (including the principle of economization) during the process of control over the respective managerial decisions' realization, a hieratical structure of effectiveness indicators was elaborated. Elaborated structure includes:

1. Low level which contains absolute and relative particular indicators of effectiveness which correspond with the proposed planning-and-control indicators. Absolute indicators characterize factual and planned values of economic characteristics; relative indicators characterize the ratio of factual and planned indicators; if the value of a relative indicator is greater or less than a unit indicator, the deviation between factual and planned values of indicator occurs. These deviations must be classified according to the places they appear, causes and responsible persons.

2. Middle level – includes the so-called key indicators of effectiveness, which describe the degree to which the industrial enterprise achieves the goals in a certain area of functioning (production, transportation, control and storage) described by the group of low-level indicators. If key indicator value is not equal to the unit indicator, the deviation between planned and real goals' achievement scenarios occurs within a current area of industrial enterprise functioning. As each key indicator is connected to several relative indicators of effectiveness, the methods of indicator grouping in the order of importance were proposed during the research:

– differential qualimetry method should be used in case indicators are of equal importance and therefore are grouped with the application of a mean arithmetical formula;
– complex qualimetry method should be used in case indicators are of different importance and therefore are grouped according to the weighted average formula including the calculation of weighted coefficients describing indicators' importance.

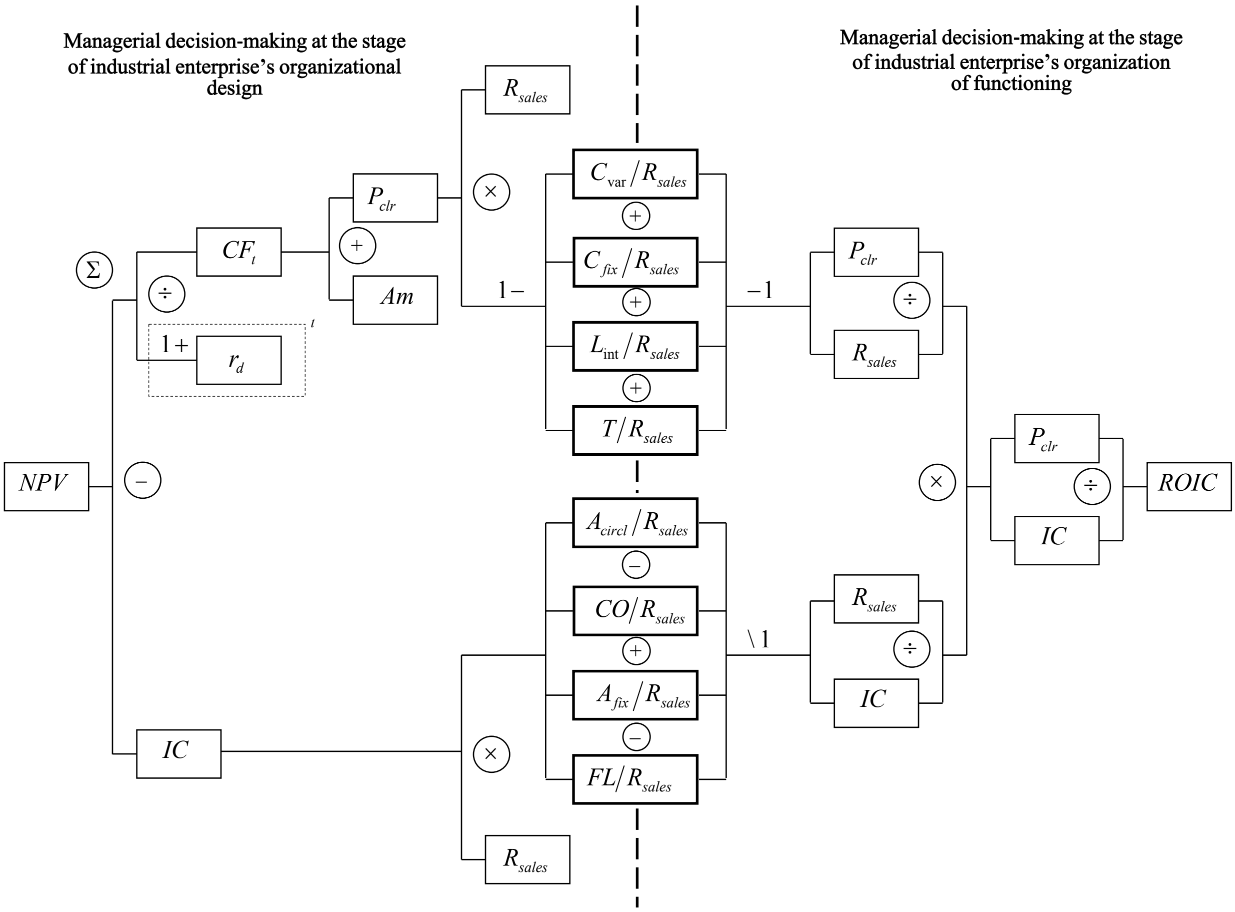

Fig. 1. Structure of the system of target and planning-and-control indicators elaborated during the research

Indicators used:

NPV – net present value; $ROIC$ – return on invested capital; CF_t – current flow for time period; r_d – discounting rate; t – time period sequence number; P_{clr} – clear profit for time period; Am – total depreciation costs for period; R_{sales} – sales proceeds (revenue); C_{var} – variable costs for period; C_{fix} – fixed costs for period; L_{int} – loan interest; T – accrued taxes; IC – invested capital; A_{circl} – circulating assets; CO – current obligations; A_{fix} – fixed assets; FL – fixed liabilities.

– hybrid qualimetry method is based on the combination of the above mentioned methods.

Weighed coefficients describing indicators' importance in complex and hybrid qualimetry methods should be calculated using expert judgments method and relative preferences method.

3. High level is based on the so-called total effectiveness indicator describing the degree of goals achievement for the whole industrial enterprise. If the total indicator value is not equal to the unit indicator, factual and planned states of industrial enterprise are different. High-level indicator calculation is based on the grouping of key indicators of effectiveness according to the same principles and methods as described above.

Managerial decisions must be made concerning deviations calculated during the procedure of relative, key and total effectiveness indicators within a certain factor, area and the whole industrial enterprise respectively.

Thus, the process describing the implementation of the task of management in the area of industrial enterprises HTM with the application of SM software tools includes the following main stages:

1. Preparation of initial data concerning the object of exploration.

2. Economic-and-mathematical definition of the task by building optimization model including the factors of internal and external environment [2, 10, 11].

3. Creation of simulation model on the basis of preliminarily built optimization model with target and planning-and-control indicators as the output parameters of the simulation model.

4. Selection of the optimal combination of simulation model input parameters' values, which are corresponding to the most efficient managerial decision, by minimizing / maximizing the values of the target indicator, which are calculated during the series of simulation experiments with the created model.

5. Formation of absolute (planned) values of indicators to control HTM managerial decisions realization by treating statistical results of simulation experiments for certain combination of output parameters' values corresponding to the most efficient managerial decisions.

The complex of optimization economic-and-mathematical models based on the algorithm for solving management tasks in the area of industrial enterprises HTM with the application of SM software tools and also the system of indicators to control the selection and realization of managerial decisions was elaborated during the research. The complex includes:

– model of throughput optimization of the elements of manufacturing structure in the area of HTM;
– model of throughput optimization of the production sector concerning integrated processing of production items;
– model of optimization if the number of machinery within different technological zones.

The complex of optimization models described above ensures the interdependent managerial decisions in line with manufacturing structure in the area of industrial enterprises with HTM [4].

The elaborated complex of optimization models became the basis for the creation of the complex of respective simulation economic-and-mathematical models built with the application of AnyLogic simulation software. The complex includes:

– simulation model implementing the functioning of the elements of HTM manufacturing structure;
– simulation model of the production sector with fixed processing technology;
– simulation model of the production sector with regulated processing technology;
– simulation model of the distribution center of raw materials and finished products in the area of HTM service.

The elaborated complex of simulation economic-and-mathematical models ensures the accurate predictable data during the process of economic reasoning of managerial decisions made at the consecutive stages of the design and exploitation of industrial enterprises HTM [9].

AnyLogic simulation software used during the research ensures the interaction between the models and external data sources and, consequently, the integration of the models into the enterprise automated management system. In addition, this fact defined reasonability for the elaboration of informations system, ensuring automated calculation of planning-and control indicators (proposed for of the control over the realization of managerial decisions in the area of industrial enterprises HTM) and also the control over the dynamics of indicators values for different time periods. Information system was created with the application of AnyLogic software tool as static simulation model connected with external data source (usually Microsoft Office Excel electronic table is used in line with AnyLogic educational license; Microsoft Office Access database can be used within AnyLogic professional license). The main benefits of using created the information system are:

– minimal time costs for calculation of the effectiveness of indicators due to special algorithms in AnyLogic simulation software and its computational capability;
– accumulation (due to special features of AnyLogic software) of the results of the effectiveness indicators calculation, which ensures high quality of indicators dynamics analysis and, as a consequence, high effectiveness of warehouse system managerial decisions;
– simplicity and user-friendliness of the information system due to the application of standard control elements of the Windows operation system, which most administration personnel within industrial enterprises are familiar with.

The information system includes the following elements:

– calculation block – for the calculation of the effectiveness indicators values;
– main panel – for the demonstration of the indicators' values (Fig. 2);
– additional panel – for the representation of the indicators values dynamics in different time periods (Fig. 3);
– external data source with sectored tables (in Microsoft Excel file columns are connected to time periods) for the calculation and accumulation of effectiveness indicators.

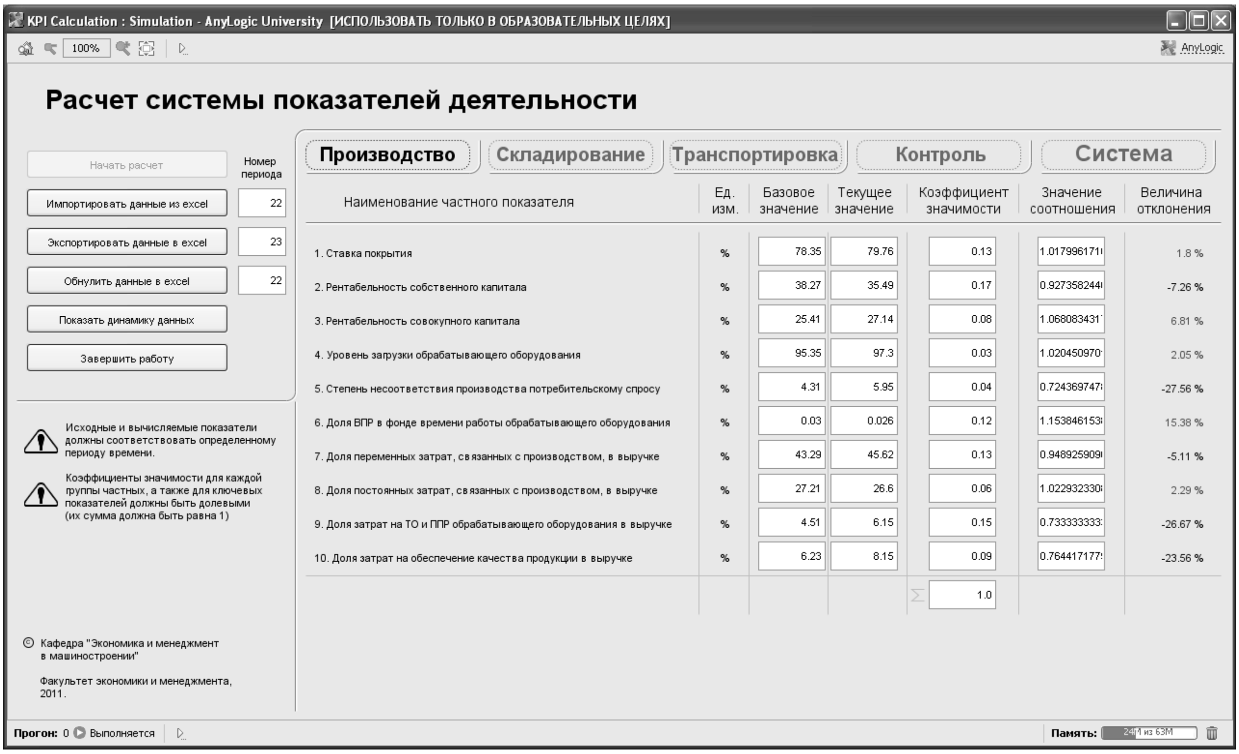

Fig. 2. Main panel of the information system elaborated during the research

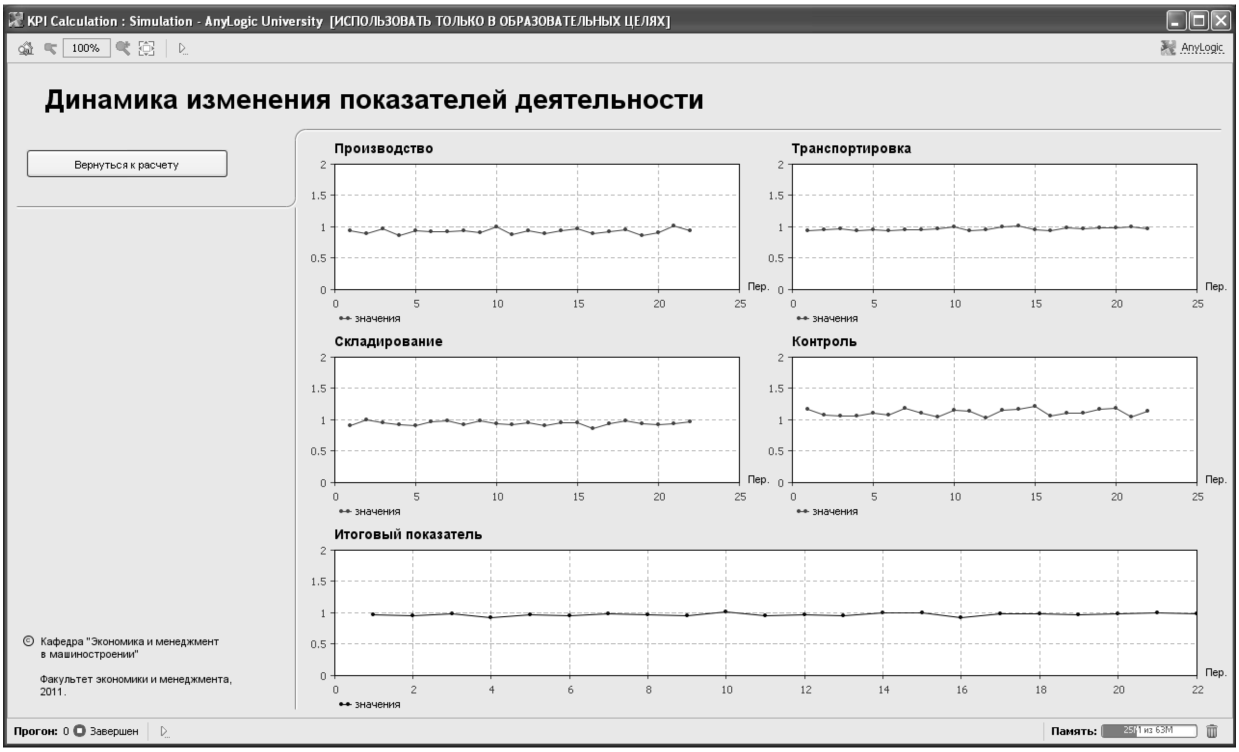

Fig. 3. Additional panel of the information system elaborated during the research

On the basis of scientific results, the method of organization and estimation of economic effectiveness of industrial enterprises HTM using SM [7] was created.

The structure of the method is defined by the sequence of the main phases (modules), where each one is connected to a certain scientific result, generated at the previous stages of the research.

The elaborated method was applied to the real object for the task to determing the optimal number of production machinery. During the procedure, an optimization economic-and-mathematic model was created as the basis of the corresponding simulation model built with AnyLogic simulation software. The simulation experiments provided the optimal number of machinery according to the maximization of ROIC target indicator. Economic reasoning of a corresponding managerial decision was realized. As a result simple simulation experiments, the planned values of the elements of planning-and-control indicators' system were estimated for the further control over the realization of managerial decisions.

REFERENCES

1. **Babkin A.V.**, **Novikov A.O.** Estimation of innovative potential of industrial enterprise and cluster: tutorial. St. Petersburg, Saint-Petersburg State Polytechnic University publisher, 2012. 129 p. (rus)

2. **Gluhov V.V., Mednikov M.D., Korobko S.B.** Mathematical methods and models for management: tutorial. 3rd ed. Moscow; Krasnodar, Lan'. 523 p. (rus)

3. **Ilyin I.V., Lyovina A.I.** Management of activity of enterprise as the object of contract interaction. *St. Petersburg State Polytechnical University Journal. Economics*, 2007, no. 3–1(144), pp. 54–61. (rus)

4. **Kobzev V.V., Krivchenko A.S.** Methods and models for industrial enterprises' supply chain management: monograph. 2nd ed., revised and amplified. St. Petersburg, Saint-Petersburg State Polytechnic University publisher, 2009. 205 p. (rus)

5. **Kozlovsky V.A.**, **Kobzev V.V.** Production and operating management: tutorial. Under the ed. of prof. V.V. Kobzev. St. Petersburg, Saint-Petersburg State Polytechnic University publisher, 2011. 356 p. (Economics and management of enterprise). (rus)

6. **Okorokov V.R. Vetrov A.A. Sokolov Ju. A.** Introduction to the controlling theory. Saint-Petersburg: Saint-Petersburg State Polytechnic University publisher, 2000. 249 p. (rus)

7. **Radaev A.E.**, **Kobzev V.V.** Methods of organization and economic effectiveness's estimation for high-tech manufacture within machine-building enterprise. *St. Petersburg State Polytechnical University Journal. Economics*, 2012, no. 2–1(144), pp. 40–43. (rus)

8. **Radaev A.E.**, **Kobzev V.V.** System of indicators for reasoning and realization of managerial decisions in the area of high-tech manufacture within machine-building enterprise. Theory and instruments for development of innovative economics during the period of global recession: collective monograph. St. Petersburg, Saint-Petersburg State Polytechnic University publisher, 2011, pp. 681–711. (rus)

9. **Radaev A.E., Leventsov V.A.** Systems of phased simulation modeling of manufacturing processes. *Manufacture organizer*, 2011, no. 3(50), pp. 30–33. (rus)

10. **Silkina G.Ju.** Risk theory and modeling of risk situations: tutorial. St. Petersburg, Saint-Petersburg State Polytechnic University publisher, 2012. 109 p. (rus)

11. **Yuriev V.N.**, **Kuzmenkov V.A.** Methods of optimization in economics and management: tutorial. St. Petersburg, Saint-Petersburg State Polytechnic University publisher, 2006. 803 p.

СПИСОК ЛИТЕРАТУРЫ

1. **Бабкин А.В., Новиков А.О.** Оценка инновационного потенциала промышленного предприятия и кластера: учебное пособие. СПб.: Изд-во Политехн. ун-та, 2012. 129 с.

2. **Глухов В.В., Медников М.Д., Коробко С.Б.** Математические методы и модели для менеджмента : учеб. пособие. Изд. 3-е. СПб.; М.; Краснодар: Лань, 2007. 523 с.

3. **Ильин, И.В., Лёвина А.И.** Управление деятельностью предприятия как объекта контрактного взаимодействия // Научно-технические ведомости Санкт-Петербургского государственного политехнического университета. Экономические науки. 2007. № 3–1. С. 54–61.

4. **Кобзев В.В., Кривченко А.С.** Методы и модели управления сетью поставок промышленных предприятий : монография. изд. 2-е. СПб.: Изд-во Политехн. ун-та, 2009. 205 с.

5. **Козловский В.А., Кобзев В.В.** Производственный и операционный менеджмент: учеб. пособие / под общ. ред. проф. В.В. Кобзева. СПб.: Изд-во Политехн. ун-та, 2011. 356 с. (Экономика и управление на предприятии).

6. **Окороков В.Р., Ветров А.А., Соколов Ю.А.** Введение в теорию контроллинга. СПб.: Изд-во Политехн. ун-та, 2000. 249 с.

7. **Радаев А.Е., Кобзев В.В.** Методика организации и оценки экономической эффективности высокотехнологичного производства предприятия машиностроения // Научно-технические ведомости Санкт-Петербургского государственного политехнического университета. Экономические науки. 2012. № 2–1(144). С. 40–43.

8. **Радаев А.Е., Кобзев В.В.** Система показателей для выбора и реализации управленческих решений в высокотехнологичном производстве предприятия машиностроения // Теория и инструментарий развития инновационной экономики в период глобальной рецессии: коллективная монография. СПб.: Изд-во Политехн. ун-та, 2011. С. 681–711.

9. **Радаев, А.Е., Левенцов В.А.** Системы поэтапного имитационного моделирования производственных процессов // Организатор производства. 2011. № 3(50). С. 30–33.

10. **Силкина Г.Ю.** Теория риска и моделирование рисковых ситуаций: учебное пособие. СПб. : Изд-во Политехн. ун-та, 2012. 109 с.

11. **Юрьев В.Н., Кузьменков В.А.** Методы оптимизации в экономике и менеджменте: учеб. пособие. СПб.: Изд-во Политехн. ун-та, 2006. 803 с.

KOBZEV Vladimir V. – St. Petersburg State Polytechnical University.
195251. Politechnicheskaya str. 29. St. Petersburg. Russia. E-mail: kobzev_vv@mail.ru

КОБЗЕВ Владимир Васильевич – заведующий кафедрой «Экономика и менеджмент в машиностроении» Санкт-Петербургского государственного политехнического университета, доктор экономических наук, профессор.
195251, ул. Политехническая, д. 29, Санкт-Петербург, Россия. E-mail: kobzev_vv@mail.ru

RADAEV Anton E. – St. Petersburg State Polytechnical University.
195251. Politechnicheskaya str. 29. St. Petersburg. Russia. E-mail: TW-inc@yandex.ru

РАДАЕВ Антон Евгеньевич – Санкт-Петербургский государственный политехнический университет, ассистент.
195251, ул. Политехническая, д. 29, Санкт-Петербург, Россия. E-mail: TW-inc@yandex.ru