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MANAGEMENT OF INDUSTRIAL STABILITY AND DEVELOPMENT IN THE CONTEXT OF SYNERGETIC PARADIGM

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УПРАВЛЕНИЕ УСТОЙЧИВОСТЬЮ И РАЗВИТИЕМ ИНДУСТРИИ В КОНТЕКСТЕ СИНЕРГЕТИЧЕСКОЙ ПАРАДИГМЫ

Solution to the problem of maintaining the efficiency and stability of the developing industry is subject to quick and sudden changes in the globalizing business environment has recently been of priority in the economic research. In the dynamic background of the institutional and innovative transformation in Russia activities of industrial enterprises are subject to risks of resource deterioration, competitive advantage loss and sliding towards bankruptcy. On this account it is an important challenge to develop and improve control technologies for stability of enterprises. For this purpose, we suggest theoretical, methodological and applied support of the design technology, including the involvement of both familiar tools of systems analysis, management, cybernetics, etc. and of innovative knowledge of nonlinear dynamics and self-organization theory which form the foundation for the interdisciplinary synergetic paradigm. Within the framework of its ideas, a logical explanation is given to the evolution of industrial enterprises from unstable equilibrium to stable non-equilibrium, as well as to qualitative modifications in their activities, in particular, those connected with the transition from a stable and less effective state to a more effective one. Along with this, from the perspective of the entropy approach and information theory, it becomes possible to give reasons for the nonlinear (exponential) dependence of the industrial enterprise performance on the amount of the accumulated information and to substantiate conditions for maintaining the stability of this effect, as well as the multi-factor analysis of dependence of financial and economic indicators of the enterprise performance on the knowledge achieved by the enterprise. In order to apply the concept and technology of managing the industrial enterprise stability, including the use of the heuristic algorithm (based on fuzzy sets), there has been developed and certified the software to monitor their stability which fulfills functions of the operational processing, visualization and understanding of change trends with regard to indicators observed.

KNOWLEDGE; INFORMATION; MONITORING; FUZZY SETS; EQUILIBRIUM; STABILITY; EVOLUTION; ENTROPY; EFFICIENCY.

Приоритетное значение в экономических исследованиях последнего времени приобретает решение проблемы поддержания эффективности и устойчивости развивающейся индустрии, подверженной воздействию быстрых и резких перемен в глобализирующейся деловой среде. На динамичном фоне проводимых в России институциональных и инновационных преобразований деятельность промышленных предприятий испытывает риски деградации ресурсов, потери конкурентоспособности и сползания к банкротству, ввиду чего актуализируется задача разработки и совершенствования технологии управления устойчивостью предприятий. С этой целью предлагается теоретическое, методологическое и прикладное оснащение проектируемой технологии с привлечением как известных инструментов системного анализа, менеджмента, кибернетики и др., так и новейших представлений нелинейной динамики и теории самоорганизации, образующих основания междисциплинарной синергетической парадигмы. В рамках ее воззрений находят логичное объяснение эволюция промышленных предприятий от неустойчивого равновесия к устойчивому неравновесию и качественные перестройки в их деятельности, в частности связанные с переходом от устойчивого менее эффективного состояния к более эффективному. Наряду с этим с позиций энтропийного подхода и теории информации становится возможной аргументация нелинейной (экспоненциальной) зависимости эффекта деятельности промышленного предприятия от количества накопленной информации и обоснование условия поддержания устойчивости этого эффекта, а

также многофакторный анализ зависимости финансово-экономических показателей работы предприятия от достигнутого им уровня знаний. Для прикладного обеспечения концепции и технологии управления устойчивостью промышленных предприятий с применением эвристического алгоритма (на базе нечетких множеств) разработана и апробирована компьютерная программа мониторинга их устойчивости, выполняющая функции оперативной обработки, визуализации и осмысления тенденций изменения наблюдаемых показателей.

ЗНАНИЕ; ИНФОРМАЦИЯ; МОНИТОРИНГ; НЕЧЕТКИЕ МНОЖЕСТВА; РАВНОВЕСИЕ; УСТОЙЧИВОСТЬ; ЭВОЛЮЦИЯ; ЭНТРОПИЯ; ЭФФЕКТИВНОСТЬ.

Introduction. Drastic alterations in the Russian economy against the acceleration of the innovation flow place priority in the research on the theoretical, methodological and practical issues of forming the modern mechanism of increasing competitive capacity of industrial enterprises. High dynamism of transient processes and mastering tools of innovative modernization in the globalizing world focus the attention of experts on the concept and means of managing stability and development of production systems within the framework of natural-scientific and economic ideas.

It is known that today in terms of manufacturing innovative products Russian enterprises prove to lag behind not only the leading countries but also behind a number of fast developing ones, and regions are unable to compete in the world market in terms of innovative activity and advancement of large innovative projects. So far, there have been only few industrial enterprises in Russia which carried out innovations in 2010–2014: in terms of technological innovations it accounted for from 9.3 % to 9.9 %. Moreover, the volume of innovative goods, processing works and services in the total amount of shipped goods and executed works in those years was meagre and accounted for between 4.5 % and 13.7 % [1]. As a result, Russian enterprises are not only outperformed by their foreign partners in the innovative development, but they are also significantly different from each other both in terms of the financial-economic and scientific-innovative level, which generates difficulties in the choice of directions and projects of enterprises' innovative modernization.

The importance of understanding these problems becomes even higher if taking into account the fact that issues of planning and analyzing the development of production systems with the nonlinear nature of their behavior and synergetic ideas have not been worked out deeply, theoretically and methodologically yet. All the more important are the results obtained by the colleagues both in the conceptual and applied aspects to manage stability and development of industrial enterprises under conditions of modernization of transnational and national industrial complexes and establishment of knowledge economy.

1. Objectives and methodology of the research

The objective of this article is to delineate the contours of the theoretical, methodological and applied approaches to the analysis of stability and development of industrial enterprises from the perspective of transformational processes and scientific paradigms.

The concepts of the theory of systems, system analysis, cybernetics and synergetics have become the basis for the research methodology. Theoretical fundamentals of these sciences allow exposing and realizing behavior and development of complex dynamical systems, their evolution and restructuring in the conditions of the changeable economic environment. In the view of classic and modern concepts about the systems, the author generalized the results obtained earlier in regard to the systems complexity, their chaotic and ordered behavior.

2. Evolution and nonlinear processes in the operation of production systems

A rapid flow of institutional and innovative changes in the business environment force Russian enterprises to test external and internal threats, and, therefore, they undergo a continuous change of their state and behavior. In the epoch of globalizing world economic relations and aggravating the competitive struggle the ability of enterprises to divert the risk of irreversible degradation and maintain their stability is of crucial importance. In this connection the information aspect assumes an active and dominant role, filling up the production system environment with knowledge – implementation of innovations into technologies and products.

With the intensification of the environment information saturation the impressive growth of generated and consumed knowledge implies the

accelerated innovative development of enterprises and shapes the face of the country's future economy. However, taking into account the unusual progress in the area of human labor informatization and computerization, we may consider that the natural-scientific and economic methods have not been implemented to their full extent with regard to planning and analyzing the production systems behavior.

It is clear that the primary attention is paid to the analysis of conditions of equilibrium acquisition and loss and stability of industrial enterprises in the transformational environment of the Russian economy. The conducted research has shown the following: the forced and radical reformation of the country's national economy caused destabilizing processes which prevent industrial enterprises from achieving stable equilibrium. The system and cybernetic principles confirm that such a macro-economic scenario under the conditions of Russia could result only into the disturbance of resource flows among enterprises and weakening their stability in a strongly disturbed environment during the transition period. In addition, applying the Lyapunov [2] criterion allows us to prove that, with proper control of enterprises' performance and resource opportunities, their adaptation mechanism can provide the asymptotic stability for one of the key indicators of their financial stability – autonomy indicator. In other words, whatever the share of proprietary funds in enterprise's liabilities, they will squeeze the borrowed funds over time. A similar feature is also inherent in the indicator of income from selling enterprise's products: regardless of the initial value of the income, its actual value reaches the planned value if there is a required resource potential, as well as the competent management of resource production processes, sales and consumption.

However, problems of the economic stability analysis do not imply only studying the influence of transformational factors. Therefore, there regularities of the production system evolution have been studied, and synergetic interpretation of their modifications and transition from unstable equilibrium to stable non-equilibrium has been formulated. Thus, if the dynamical system features stability, acceptable disturbances do not have the impact which could change the system behavior fundamentally. On the other hand, if the system is unstable, the influence of disturbance becomes significant and even minor fluctuations may cause drastic changes in the dynamical system behavior. In such a nonequilibrium situation, the insignificant external factor effect at the appropriate moment may radically change the nonlinear behavior of the system, located at the bifurcation of possible system motion trajectories. A specific direction of the trajectory will be selected from their bundle based on the nature of the process and effect of random (not necessarily powerful) factors in the system bifurcation point. The identified regularity of transformations and evolution of production systems indicates cause and effect relationships between the historically established factors of labor activity, structure, information and stability of the system's behavior.

3. Synergetic paradigm in the system of natural-scientific and economic ideas on the development of industrial enterprises

In a number of the system research, synergetics is among the integrating fields of the scientific knowledge; it synthesizes ideas of theoretical physics, chemical kinetics, etc. Due to its self-organization, the system has the repression of chaos, it becomes ordered and identifies new properties which are absent in its subsystems. As a result, synergetics has become able not only to embody the cooperation of scientific disciplines but also to express regularities of cooperating parts of the nonlinear system through its ideas.

As we know, the nonlinear system is rich in qualitatively different states, the sequence of which forms the hierarchy of instabilities. Unlike physicochemical systems, the manifestation of regularities of nonlinearity, self-organization and synergetic effects still remains a poorly studied subject, except for a number of informative publications [3–5].

Meanwhile, the complex game of randomness and determinacy, slow and fast processes in nonlinear systems leaves broadens the manifestation of instability that becomes an attribute of such systems. It seems that such processes can also be observed in nonlinear production systems under the influence of the innovation flow, which initiates the decay and oscillation of processes involving stable and unstable states. The effect of innovations can agitate the dimensional flow of a process and generate fluctuations accompanied by irregular resource expenses and loss of stability of the system behavior equilibrium mode. This leads to the formation of states

diverting the trajectory of the production system motion from the equilibrium one and, in addition, having different information contents, this or that level of organization (randomness) and governed by synergetic regularities.

Accordingly, it should be noted that along with the acceleration of the social progress the conditions become mature to modernize production systems and enrich their information potential, which favors the increase of their stability in the face of institutional and innovative disturbances in the economy. By revealing the regularity of unstable behavior in complex systems and its manifestation in modern production systems from the point of synergetics and catastrophe theory, it becomes possible to establish causes and peculiarities of the process of losing stability, as well as to explain soft (initial stage of enterprise crisis) and hard (slow crisis or more unstable performance of enterprise) loss of equilibrium stability depending on enterprises crisis dynamics.

Within the framework of the ideas on nonlinear dynamics and catastrophe theory, we would like to pay attention to the regular change in the development of industrial enterprises when they transmit from one stable state to another, the first of them being characterized by lower, and the second one – by higher efficiency. For this purpose, we use the qualitative findings of the surgery theory which are described by Arnold [6]. It appears that a lowly developed economic system with fewer losses turns into the improved stable state if to compare with a more advanced system, the stability of which runs into additional difficulties to obtain a stable effective state. If it becomes possible to have an intermittent rather than a continuous transition of the system into the improved stable state, when approaching such a state it will evolve (will be attracted) towards this state on its own.

Without covering all applications of scientific disciplines to solve the problem discussed, it is apparent that by invoking the ideas of synergetics, system theory, information theory and catastrophe theory, it is possible to lay preconditions to solve the problem of forming the theoretical, methodological and applied tools for research and providing the stability and development of industrial enterprises [7]. In particular, entropy, nonlinear and synergetic approaches allow explaining the evolution and bifurcation in the behavior of production systems [8– 10], Bohr's complementarity principle [11] – complementarity of probabilistic and determinate information description, Zadeh's principle of incompatibility [12, 13] – invoking the theory of fuzzy sets to handle heuristic information in search models for management solutions and their intellectualization.

4. Knowledge resource as a precondition for maintaining the stable effect of industrial enterprises

Based on the knowledge of statistical physics [14–16] and the fact that useful information, entered in the production system, reduces randomness and entropy in it but increases the effect of its operation, a mathematical condition for stability of this effect has been obtained. The nonlinear form of statistical relation between the accumulated information resource and the effect of the system performance reveals a notable regularity of resources provision with a stable effect within the range of its small and large values. Along with the relative increase of costs due to the growth of the effect, the consequence of this regularity is a priority to materialize scientific knowledge and to launch high technologies in order to maintain the stability of the growing effect of the production system operation.

In respect of the informational aspect the indicator of the knowledge accumulated by the society and built into the economic system (design of machines, combination of units, etc.), and indicator of the management perfection process in Trapeznikov's concept are generalized by the indicator of the knowledge level and skills used or simply by the level of knowledge [17]. It is an indicator that is determined by the amount and usefulness of the input management information and used knowledge when establishing an enterprise. Formally, the level of knowledge is proportional to the product of indicators of labor performance measured with respect to the net product, and the capital productivity. According to Trapeznikov, both the level of knowledge and labor performance reflect the effect of labor (qualifications, skills, etc.), social-psychological (ambition, persistence, discipline, etc.) and other factors.

The importance of our research with regard to the level of knowledge and its relation with financial and economic indicators of the enterprise performance is as follows. Firstly, there is formalized the dependence of the knowledge

level on indicators of economic efficiency (labor performance and efficiency of circulating assets) of the enterprise activity and on the structure of its balance sheet (financial proportions) in the context of assets, liabilities and between them. Therefore, we can state that the level of knowledge generalizes both economic and financial interactions in the enterprise performance. The latter evaluates the balance sheet structure in both of these perspectives: vertically and horizontally.

Secondly, the level of knowledge is in direct proportion both to the current liquidity ratio that is «positive» to reduce enterprises' bankruptcy probability and the related financial strain ratio that is «negative» in this context, which indicates the nontrivial interaction of factors.

Such inconsistency emphasizes a dual role of the loan capital: it plagues enterprise liabilities with debts, degrading its financial stability and increasing the probability of bankruptcy, but, on the other hand, it enables using raised funds to increase enterprise's economic activity, which is reflected in the growth of its performance efficiency indicators. In such an encouraging case revenues grow from sales of products, enterprise payment opportunities are improved, values of labor performance and circulation assets efficiency increase and, as a result, the level of knowledge becomes higher.

5. Information and efficiency of the developing system of industrial enterprise stability management

It is also relevant to consider an issue on the efficiency of the very developing system of management for industrial enterprise stability. The design and implementation of this system require the involvement of information and computer equipment, algorithm and software program elaboration, which is due to additional costs covered by the stream of steadily maintained income. We consider that the system efficiency depends on its structure and cost, returns and payback, bearing in mind that the enterprise income stability is provided by the whole aggregate of the management system components.

According to Trapeznikov's concept [17], the maximum values of the enterprise economic effect are implemented only in the case of a rapidly growing cost of the system, and within the framework of knowledge of the statistical physics and entropy approach there is a correlation between the initial and accumulated information and the effect of the enterprise operation. Therefore, the effect in the area of small values requires less increment of management information, unlike the field of large values, and with the approximation of the effect to the marginal level the amount of the required additional management information at the enterprise grows rapidly.

Let us pay attention to the effect level of the enterprise activity that will remain stable despite the effect of emerging fractions. By the nature of the obtained dependence, we may state that, with comparatively small values of the effect, maintaining its stability is less resource-intensive than for the value of the effect close to the maximum limit.

It is relevant to advance a hypothesis that the trends of change in ordering and efficiency of the production system behavior follow definite cyclic regularities which reflect the nature of its innovative development. Modernization of the system may involve not only the renewal of its elements but also the restructuring of the established internal relations and operating procedure, which may involve degradation of the ordering system operation in the first instance. Furthermore, re-equipment of technical software and other tools is well grounded on the investment pool which assumes the investment of financial resources and local reduction of management efficiency indicators. Only in the course of time, in the process of mastering innovations and with the growing input of coordinating information, conditions appear to compensate the lost order and, due to the improved organization of the system behavior, to advance its activity to a higher level.

6. Outlines of the concept and technology for managing the industrial enterprise stability

Within the framework of the objective to design the applied aspect of providing the industrial enterprise stability and development there have been substantiated the concept, functions, structure and tools of the system to manage its stability. Based on the importance of the management system, the enterprise fulfils tasks aimed at providing the adaptive management – planning and assessing its performance, early diagnostics of problematic situations, modeling the process and recovery of enterprises stability, monitoring actual indicators and adjusting target indicators of its performance.

Elaboration and practical implementation of the suggested methodological principles in the

startup software product «Computer support for monitoring the enterprise activity (version 1.0)» (project manager Chuprov, Kanevsky's algorithmic support and software) allow us to research the dynamical properties of an enterprise and obtain a broad set of statistical characteristics, which enables carrying out forecasting, assessment, analysis and interpretation of the stability of enterprise performance indicators and represents a means of acquiring knowledge on its nonlinear operation and adaptation of the enterprise to the stability management system.

Our research proposes a promising approach to increase information capacity and efficiency of management solutions on the basis of using the mechanism of the theory of fuzzy sets which represents a tool for processing poorly formalized heuristic information and intellectualization of management systems. By introducing fuzzy sets in the algorithms of the startup software monitoring product there have been implemented operation of expert information to analyze the enterprises performance and obtained an opinion on their stability in the natural language.

Thus, the concept of modeling the computer technology to monitor the industrial enterprise stability is based on the expanded use of professional knowledge, algorithms for searching and maintaining the stable mode of the enterprise operation under the conditions of high disturbance of the environment and shortage of accessible information about it. The information and intellectual environment of this task provides for the integration of advantages of optimization and flexibility of searching management solutions in the models with fuzzy resource restrictions, adequate to incompleteness of information and diversity of states in production systems. As a result monitoring of industrial enterprise stability becomes an intellectual tool in the struggle for viability of enterprises in the environment of institutional and innovative transformations of the modern economy.

7. Conclusion

The progress of theoretical, methodological and applied tools of scientific cognition and demands for economic practice have given impetus to the research of the nature and conditions for providing the viable activity of industrial enterprises. Globalization and aggravation of competition have become dominants of our time, as well as the growth of the flow of changes and the related trial for the performance of industrial enterprises. A rapid rate of generation and implementation of innovations «exhausts» the enterprise performance and hereby making preconditions for changing the phases of equilibrium and nonequilibrium, stable and unstable functioning of its production systems, the behavior of which is subject to the regularities of nonlinear dynamics and synergetics.

However, cardinal transformation of the Russian economy and the related strongly disturbed background of transient processes bear no fewer threats. The profound and protracted crisis that swept Russian industrial enterprises has involved a dramatic slowdown in production volumes and degradation of their resources, which has led into the disturbance of enterprise stability and fatal consequences for many of them. In such an extreme situation quite a number of industrial enterprises have been affected by the systemic crisis, fated for destructive restructuring and turned out to be on the verge of survival and bankruptcy.

Such challenges have determined relevance and usefulness of creating and approving the concept and technology of managing industrial enterprise stability and development. They are based on evolving and synthesizing the natural-scientific and economic knowledge and provided with the tools for processing and analyzing both the numeric and poorly formalized qualitative (heuristic) information to conduct monitoring of enterprise stability. Besides, their information resource establishes conditions for achieving the required value of enterprises' operation effect and providing its stability, and the level of knowledge influences their financial performance.

I cherish the hope that the research results, stated in the article, also have applied significance as they can be used both in management of industrial enterprises and in the state and regional management in the case of developing the industrial policy strategy and innovative Russian industrial development programs. The proposed theoretical provisions and methodological tools for management of stability and development of industrial enterprises are also addressed to colleagues from higher educational institutions and academic community who have been dedicated to studying the stated problems and teaching educational subjects on corporative management, management of knowledge, innovation management, state management, regional economics, etc.

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REFERENCES

1. Science and Innovations. Federal State Statistics Service. URL: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/science_and_innovations/science/# (accessed August 18, 2015). (rus)

2. **Lyapunov A.** The general problem of the stability of motion. Moscow, Leningrad, ONTI, 1935. 386 p. (rus)

3. **Zhang W.-B.** Synergetic Economics. Time and Change in Nonlinear Economics. Moscow, Mir, 1999. 335 p. (rus)

4. **Malinetskii G., Kurdyumov S.** (ed.). The new in synergetics: prospection in the third millenium. Moscow, Nauka Publishing, 2002. 478 p. (rus)

5. **Sadtchenko K.** Laws of economic evolution. Moscow, Delo & Sevis, 2007. 272 p. (rus)

6. **Arnold V.** Catastrophe theory. 3th edition. Moscow, Nauka Publishing, 1990. 128 p. (rus)

7. **Chuprov S.** Management of production systems' stability: theory, methodology, practice. 2th edition. Irkutsk, BNUEL Publishing, 2012. 354 p. (rus)

8. **Prigogine I., Stengers I.** Time, chaos and the quantum. Towards the resolution of the time paradox. 6th edition. Moscow, KomKniga Publishing, 2005. 232 p. (rus)

9. **Nicolis G., Prigogine I.** Exploring complexity: An introduction. 2th edition. Moscow, Yeditorial URSS, 2003. 344 p. (rus)

10. **Haken H.** Advanced Synergetics: Instability Hierarchies of Self-Organizing Systems and Devices. Moscow, Mir, 1985. 423 p. (rus)

11. **Bohr N.** Life and Creation: collection of articles; editor in chief B.G. Kuznetsov. Moscow, Nauka Publishing, 1967. 344 p. (rus)

12. **Zadeh L.** Fuzzy sets. *Information and Control.* 1965, vol. 8, pp. 338–353.

13. **Zadeh L.** Outline for a New Approach to the Analysis of Complex Systems and Decision Processes. *IEEE Trans. Syst., Man., Cybern.*, 1973, vol. SMC-3, Jan., pp. 28–44.

14. **Shannon S.** The Mathematical theory of Communication. *Bell System Techn. J.*, 1948, no. 3(27), pp. 379–423; 1948, no. 4(27), pp. 623–656.

15. **Wiener N.** Cybernetics: Or, Control and Communication in the Animal and the Machine. 2th edition. Moscow, Nauka Publishing, 1983. 340 p. (rus)

16. **Brillouin L.** Scientific uncertainty and information. Moscow, Mir, 1966. 272 p. (rus)

17. **Trapeznikov V.** Management and scientific and technological progress. Moscow, Nauka Publishing, 1983. 224 p. (rus)

СПИСОК ЛИТЕРАТУРЫ

1. Наука и инновации. Федеральная служба государственной статистики. URL: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/science_and_innovations/science/# (дата обращения: 18.08.2015).

2. **Ляпунов А.М.** Общая задача об устойчивости движения. М., Л.: ОНТИ, 1935. 386 с.

3. **Занг В.-Б.** Синергетическая экономика. Время и перемены в нелинейной экономической теории: пер. с англ. М.: Мир, 1999. 335 с.

4. Новое в синергетике: взгляд в третье тысячелетие / отв. ред. Г.Г. Малинецкий, С.П. Курдюмов. М.: Наука, 2002. 478 с.

5. **Садченко К.В.** Законы экономической эволюции. М.: Дело и Сервис, 2007. 272 с.

6. **Арнольд В.И.** Теория катастроф. 3-е изд. М.: Наука, 1990. 128 с.

7. **Чупров С.В.** Управление устойчивостью производственных систем: теория, методология, практика. 2-е изд. Иркутск: Изд-во БГУЭП, 2012. 354 с.

8. **Пригожин И., Стенгерс И.** Время. Хаос. Квант. К решению парадокса времени: пер. с англ. 6-е изд. М.: КомКнига, 2005. 232 с.

9. **Николис Г., Пригожин И.** Познание сложного. Введение: пер. с англ. 2-е изд. М.: Едиториал УРСС, 2003. 344 с.

10. **Хакен Г.** Синергетика: Иерархия неустойчивостей в самоорганизующихся системах и устройствах: пер. с англ. М.: Мир, 1985. 423 с.

11. **Бор Н.** Жизнь и творчество: сб. статей / отв. ред. Б.Г. Кузнецов. М.: Наука, 1967. 344 с.

12. **Zadeh L.** Fuzzy sets // Information and Control. 1965, vol. 8, pp. 338–353.

13. **Zadeh L.** Outline for a New Approach to the Analysis of Complex Systems and Decision Processes // IEEE Trans. Syst., Man., Cybern., 1973, vol. SMC-3, Jan., pp. 28–44.

14. **Shannon C.** The Mathematical theory of Communication // Bell System Techn. J., 1948, no. 3(27),

pp. 379–423; 1948, no. 4(27), pp. 623–656.

15. **Винер Н.** Кибернетика, или Управление и связь в животном и машине: пер. с англ. 2-е изд. М.: Наука, 1983. 341 с.

16. **Бриллюэн Л.** Научная неопределенность и информация: пер. с англ. М.: Мир, 1966. 272 с.

17. **Трапезников В.А.** Управление и научно-технический прогресс. М.: Наука, 1983. 224 с.

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