European Proceedings of
Social and Behavioural Sciences
EpSBS

www.europeanproceedings.com

e-ISSN: 2357-1330

DOI: 10.15405/epsbs.2022.06.24

AMURCON 2021
AmurCon 2021: International Scientific Conference

STABILITY AND CRITERIA FOR SELF-ORGANIZATION OF INDUSTRIAL ECONOMIC SYSTEMS

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Abstract

Rapid changes in the geopolitical and economic space generate high disturbance in the business environment, which can both open up favourable opportunities for mastering the production of new types of products and markets for its sale and undermine the competitive position of industrial enterprises. In a chaotic environment, their economic systems are at risk of disorganization and loss of operational stability due to both the accelerated introduction of high-tech products and the degradation of available resources and immersion in a crisis. The purpose of this research is to theoretically and methodologically analyze and comprehend the self-organization of industrial economic systems under the influence of entropic and information processes to model the management of their development in a disturbed environment. Revealing the nature of the behaviour of industrial economic systems experiencing the influence of disturbances, it is reasonable to draw on the views and methods of systems analysis, thermodynamics, statistical mechanics, cybernetics, information theory and synergetics. Thanks to the application of these concepts, it becomes possible to advance in solving the problem of enriching technologies for adaptive management of industrial enterprises. The conditions for the feasibility of self-organization of the industrial economic system presented in the article will find application in the algorithms for analyzing scenarios of stable activity and innovative development of enterprises in the space of tricky disturbances.

Keywords: Chaos, enterprise, entropy, information, innovation

https://doi.org/10.15405/epsbs.2022.06.24
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eISSN: 2357-1330

1. Introduction

In the face of overwhelming turmoil in world commodity markets and the revolutionary impact of technological and product innovations on industrial production, the theoretical and applied importance of analytics and interpretation of dynamic processes in economic systems is increasing. The imperious regularity of the industry's functioning has become the widespread use of unique ideas in manufactured products and the creation of mechanisms for the formation and development of the knowledge economy, and with the transition to intelligent computer platforms, the digital economy (Alekseeva et al., 2020; Babkin et al., 2020; Golovina et al., 2020; Kirishchieva et al., 2021; Shevchenko et al., 2020).

At the same time, modern challenges and threats are not only an incentive to accelerate scientific research and the application of its results in design and technological developments but also an impetus to deepen research on extraordinary phenomena inherent in the behaviour of economic systems in highly disturbed environments. In the vortex flow of changes, the functioning of an industrial enterprise is subordinated to the search and testing of an adaptive model of activity that ensures the preservation of its competitive advantages and a preventive response to critical anomalies arising in the business of the enterprise. Therefore, its management is aimed at preventing the extinction of the company's business activity and the disruption of the stability of key financial and economic indicators of its work (Chuprov et al., 2017; Kozin et al., 2021; Zhdanov et al., 2021).

The uncommonness of such a task lies in the fact that both the introduction of risky innovations and their neglect in anticipation of possible complications and failures in carrying out organizational and technological restructuring is fraught with one or another chaotization of the behaviour of economic systems. In the first case, due to the need to spend resources, technical reequipment and (or) readjustment of production processes to master the release of innovative products without guaranteeing their successful introduction to the market, and in the second case, due to the annoying lag in the competition due to conservatism and the manufacture of rapidly ageing for product consumers. In a word, the inevitability of deviations from a stationary mode of functioning and chaos in the activities of an industrial enterprise prompts the management of the stability and development of economic systems in the course of innovative modernization of technology and manufactured products in an environment saturated with disturbances (Akberdina & Smirnova, 2021; Antipin, et al., 2020; Krivenko, 2021; Maximova & Eid, 2021).

2. Problem Statement

A response to the increased needs of economic science and economic practice of industrial enterprises in mastering the adaptive mechanism against the background of sudden and large-scale changes was the revival of discussions and an increasing number of publications on the arsenal of tools designed to protect the prospects for enterprise development from the vicissitudes of the market environment and maintain stability and competitive positions. The emerging metamorphoses in the activities of industrial enterprises attract the attention of analysts by the combination of slow and fast processes and the appearance of nonlinear trajectories in them. Open and susceptible to threats and flows of innovation, economic systems respond to the disturbance of the environment by restructuring their

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functioning and the struggle in their behaviour of order and disorder associated with the thermodynamic concept of entropy.

The problem of the influence of entropy and innovation processes on economic systems determined the formulation of the problem of studying the dynamics of their functioning in the relationship of their inherent properties of organization and self-organization to manage the stability and development of industrial economic systems. In particular, the search for and compliance with the criteria of their self-organization, formulated in the context of entropy and the amount of information in the industrial economic system, are related to each other. Determination of the formalized restrictions imposed on them makes it possible to maintain the self-organization of the industrial economic system, despite the possible chaotization of its behaviour due to the impact on the system of both assertive threats and cardinal technological and product innovations.

3. Research Questions

In the course of the research, the following issues were subject to discussion and solution:

1. Study of the nature of chaos in the behaviour of the industrial economic system under the influence of disturbances in the business environment.

2. Substantiation of the necessity and expediency of attracting for this research the concepts of natural science doctrines in systems analysis, thermodynamics, statistical mechanics, cybernetics, information theory and synergetics.

3. Formalization and interpretation of the relationship between the rate of change in the industrial economic system of the value of entropy and the amount of information with indicators of order and disorder in the system.

4. Analysis of the obtained mathematical expressions of the criteria for the feasibility of the process of self-organization in the industrial economic system.

5. Argumentation of the use of the obtained research results for the applied tools of adaptive management of stability and development of industrial enterprises.

4. Purpose of the Study

The purpose of this research is to theoretically and methodologically analyse and comprehend the self-organization of the industrial economic system under the influence of entropic and innovative processes for the model support of stability management and its development in a disturbed environment.

5. Research Methods

To achieve the goal of the study, the views and research methods of systems analysis, thermodynamics, statistical mechanics, cybernetics, information theory and synergetics have been applied.

6. Findings

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The global geopolitical changes that are haunting the world and domestic economies, a series of energy and financial crises are sources of turbulence and chaos in the environment of industrial enterprises. The realities of the present time are the introduction of packages of economic sanctions, the collapse of exchange trading, the blocking of interstate relations and foreign trade transactions. Sharp fluctuations in commodity and financial markets, arrhythmias and interruptions in the movement of resources and, as a consequence, anomalies in the functioning of economic systems and the rooting in them of combinations of slow and fast, smooth and abrupt states became typical.

In a nonstationary space, the behaviour of industrial economic systems undergoes extraordinary transformations, metamorphoses and branching of trajectories. Gripped by disorderly movement, the economic system becomes disequilibrium, runs the risk of losing the stability of its functioning and degeneration as a reaction to the forced introduction of high-tech products, and plunge into a protracted and deep crisis.

The idea of the research presented in the article is to conduct a systematic analysis of the attribute of self-organization of the industrial economic system, relying on a wide range of natural science teachings, aimed at identifying patterns of behaviour of open dynamic systems. The theoretical and methodological arsenal of interdisciplinary sciences makes it possible to more fully reveal the nature of the behaviour of industrial economic systems experiencing the pressure of daring disturbances. Among such tools is information theory (Shannon, 1949), developed based on concepts of thermodynamics and statistical mechanics (Boltzmann, 1970; Gibbs, 1982) and won recognition among scientists due to the versatility of its analytical apparatus.

The penetration of the classical doctrines of entropy and information into economic research has long outgrown the framework of abstract reasoning and has become a widely applied tool for analysing the functioning of production and management processes. A systematic analysis of the activity of industrial economic systems goes back to the fundamental views on cybernetic systems in which information flows circulate and are subject to processing. At the same time, as you know, surrounded by an information space, industrial enterprises consume, accumulate, transform the incoming information and send it to the external environment.

With the emergence and development of information theory, economists have acquired not only a theoretical and methodological approach to the study of the functioning of complex systems but also methods of quantitative analysis of the entropy and information processes occurring in them. Now the exchange of information of economic structures with their business environment, as well as information interactions within the structures themselves, can be described, measured and interpreted in terms of probabilities and uncertainty. The information criterion for the development of economic systems and management complexes is legitimate and logical in the environment of the industry undergoing innovative modernization and the digital economy.

In this aspect, it is essential that information not only fills the channels of its transmission and is stored on carriers and in storage devices, but also finds itself in a converted form as professional knowledge, skills, the experience of personnel and embodied in the form of innovations in the acquired components (units, aggregates and others), production and management techniques (equipment, apparatus, communications, etc.), applied production and management technologies, ready-to-sell products. Information absorbed from the outside reveals the state of the business environment and its

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trends, serves as initial data for management, after which the control action aims to neutralize the arising obstacles to the behaviour of economic systems and increase orderliness and consistency in the work of enterprise personnel.

But having to resist the influence of destructive external and internal factors on the functioning of the enterprise, useful information also carries innovative signals from the environment. Their recognition and identification make it possible to assess the novelty and effectiveness of the development of potential organizational, technological and product innovations, taking into account the resources and development prospects of the enterprise. At the same time, the introduction of innovations is associated with the emergence of a transient process, during which production and (or) management are restructured, as a result of which the order/disorder of the activities of industrial enterprises changes, associated with a decrease/increase in its chaos, respectively.

In this respect, it is fruitful to use the paradigms and formal apparatus of information theory operating with the attributes of uncertainty, entropy and information. The identity of entropy with the concept of chaos turned out to be constructive in assessing and analysing the degree of order or disorder in the functioning of economic structures. When the orderliness of the behaviour of the system increases, its chaos and entropy decrease, and vice versa, with a decrease in the ordering (increase in disorder) of the behaviour of the system, chaos and its entropy increase.

Meanwhile, the growth of chaos in the functioning of the system triggers all sorts of rearrangements in it with a change in ordered and disordered states, with the birth and withering away of self-organization. Currently, such processes are in the field of view of synergetics (Haken, 2005; Prigogine & Stengers, 2005), in the focus of which is the change in the phases of the system's behaviour and, in particular, how the order in it is replaced by chaos, but in chaos, a new order arises. In an entropic context, only evolving complex systems have the property of self-organization since the struggle between order and chaos in nonequilibrium systems leads to a change in the stages of stable and unstable motion and the formation of ordered structures.

To measure the degree of order R in the system, H. Foerster proposed to identify it with the relative entropy or the index of redundancy (Foerster, 1964), which he borrowed from the founder of information theory Shannon (1949):

$$R = 1 - \frac{H}{H_m}, \tag{1}$$

where H - is the entropy of the information source;

H_m - the maximum possible entropy of the information source.

Meanwhile, from the point of view of information theory, the value R is the eliminated uncertainty of the system's behaviour and, if in the initial position the system was in a chaotic state with maximum entropy, the amount of information extracted I will be determined by the difference:

$$I = H_m - H, \tag{2}$$

and then expression (1) can be expanded in the following form:

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$$R = 1 - \frac{H}{H_m} = \frac{H_m - H}{H_m} = \frac{I}{H_m} \quad (3)$$

The process of chaos and the dynamics of the industrial economic system is influenced by situational factors of its external and internal environment, properties, resources and the nature of the functioning of the system. From the point of view of statistical mechanics, a dynamical system exposed to random disturbances to one degree or another contains chaos generated at industrial enterprises by various kinds of obstacles. Among them are anomalies in the course of production caused by deviations in technology, organization and management of production of products: deviations from the norms of resource consumption, interruptions in the supply of raw materials, components, materials and energy, forced downtime, equipment failures, product defects, industrial accidents at the enterprise, conflicts in a team, etc.

Logically, the value determined by the addition of the order R exponent to its limiting value 1.0 is taken as the amount of disorder in the system, $\overline{R}$ i.e. considering (3)

$$\overline{R} = 1 - R = \frac{H}{H_m} \quad (4)$$

and has a clear meaning: if it is theoretically assumed that there is no entropy in the economic system **(** $H = 0$**),** the amount of disorder in it is also zero ($\overline{R} = 0$), and at maximum entropy ($H = H_m$), the indicator of disorder in the system reaches a maximum equal to one: $\overline{R}$ = 1.0.

The control information I introduced into the economic system of an industrial enterprise reduces the uncertainty of its functioning and, accordingly, entropy and chaos because problem situations are diagnosed in advance, localized and neutralized, proactive decisions are made, coordination of the work of subsystems and enterprise personnel is improved, resource losses (time, raw materials, materials, components, etc.), their reserves are used promptly and fully, etc. Therefore, the degree of order of the system serves as a measure of the eliminated entropy and "extinguished" chaos in it, and thus the organization and efficiency of the industrial enterprise.

Proceeding from the necessity for self-organization of the condition for increasing the order exponent **in** it ($\frac{dR}{dt} > 0$), H. Foerster obtained an inequality that satisfies it (Foerster, 1964):

$$H \frac{dH_m}{dt} > H_m \frac{dH}{dt} \ . \quad (5)$$

Thus, the observance of this ratio means that a process of self-organization takes place in the observed system, and therefore the disorder in its behaviour decreases, and the order increases. First of all, we note that since the value of the entropy in the system cannot exceed its maximum value ($H \leq H_m$), the satisfaction of condition (5) leads to the need to maintain the inequality. $dH_m > dH$. In other words, the self-organization of the system assumes that the differential of entropy, in this case, is

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inferior to the differential of the maximum possible entropy, which indicates a relative increase in the order in the system.

Starting from inequality (5), one can obtain several remarkable criteria for the self-organization of a system.

First, we find that inequality (5) by (4) can be written in a different form:

$$\frac{dH}{dH_m} < \frac{H}{H_m} = \overline{R} \qquad (6)$$

and formulate the first criterion for the feasibility of the process of self-organization of the industrial economic system. The limitation on the rate of change of entropy H related to the rate of change of the maximum entropy imposes the ratio of both quantities (6), which becomes their upper limit — an indicator of system disorder.

Secondly, it is useful to define a criterion for the amount of information contained in the economic system. For this, we continue transformations of formula (6), taking into account property (2):

$$\frac{dH}{dH_m} = \frac{d(H_m - I)}{dH_m} = \frac{dH_m}{dH_m} - \frac{dI}{dH_m} = 1 - \frac{dI}{dH_m}$$

and taking into account inequality (6), we see that

$$\frac{dH}{dH_m} = 1 - \frac{dI}{dH_m} < \frac{H}{H_m}$$

Using the formula (2), we get from it:

$$\frac{dI}{dH_m} > 1 - \frac{H}{H_m} = \frac{H_m - H}{H_m} = \frac{I}{H_m}$$

and with equality (3) in the final form we have

$$\frac{dI}{dH_m} > \frac{I}{H_m} = R \qquad (7)$$

a criterion for self-organization of an industrial economic system, which sets the lower limit for the rate of change in the amount of information in it — an indicator of order R in the system. It implies an obvious confirmation that the rate of increase in the amount of information should outstrip the rate of increase in the maximum entropy in the industrial economic system.

And thirdly, we transform inequality (5) into the form

$$\frac{dH}{dt} < \frac{H}{H_m}\frac{dH_m}{dt}$$

and then regroup

$$\frac{dH}{dt} < \frac{H}{H_m}\frac{dH_m}{dt} = H\frac{1}{H_m}\frac{dH_m}{dt}$$

and since on the right-hand side, we notice that

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$$\frac{1}{H_m}\frac{dH_m}{dt} = \frac{d\left(\ln H_m\right)}{dt}$$

as a result, we obtain the required inequality

$$\frac{dH}{dt} < H\frac{d\left(\ln H_m\right)}{dt}$$

or by the same property of the derivative of entropy, an equivalent expression for the criterion:

$$\frac{d\left(\ln H\right)}{dt} < \frac{d\left(\ln H_m\right)}{dt}. \quad (8)$$

Conclusion: for the self-organization of an industrial economic system, it is necessary that for the values of its entropy H and maximum entropy H_m the condition of exceeding the rate of the latter in the logarithm over the rate of growth of the logarithm of the current entropy is met. Moreover, since the graph of the logarithmic function has a convex form, with an increase in the value of the maximum entropy, the rate of its growth slows down over time. Thus, the possibilities of saturating the industrial economic system with information and increasing the degree of its organization are improved with the possession of the necessary resources for generating and entering the corresponding volumes of information into the system.

Finding the criteria as mathematical conditions (6) - (8), under which the process of self-organization of the industrial economic system proceeds, increases the methodological and instrumental support of the technology for managing the stability and development of the activities of industrial enterprises in the environment of innovative disturbances (Chuprov, 2019; Plakhin et al., 2018).

For the adaptive management of industrial enterprises, it is advisable to simulate the scenarios of their functioning in non-stationary environments with a change in the classes of disturbances experienced by enterprises, generated by geopolitical and economic changes and caused by the needs of society for innovative products. Using computer experiments, it becomes possible to analyse the nature of transient processes and the conditions for the loss and restoration of the stability of the activities of enterprises. At the same time, the modes of chaotization and self-organization of economic systems and the influence on them of useful information to prevent the loss of competitive positions of industrial enterprises and timely prevent their degradation and crisis are of interest.

7. Conclusion

The entry of the economy into an era of new technological orders against the background of growing challenges and threats prompts the business and scientific community to comprehend the intricate scenarios of the functioning of industrial enterprises experiencing an overload of destructive influences and the need to ensure the stability and innovative development of their activities.

The promotion of methods and tools for economic, mathematical and meaningful analysis of the dynamic properties of entropy and information in an evolving industrial economic system enriches the theoretical provisions and applied tools for studying self-organization processes and their stability with

applications in the design and modernization of adaptive management of industrial enterprises in a disturbed space.

References

Akberdina, V., & Smirnova, O. (2021). Innovations in Industry as a Factor of Structural Changes in the Economy: Russian Experience. *SHS Web of Conferences, 110*, 01051.

Alekseeva, N., Babkin, A., Yung, A., Krechko, S., & Barabaner, H. (2020). Digital Transformation Impact on the Intellectual Capital of an Innovatively Active Industrial Cluster. *Pervasive Health: Pervasive Computing Technologies for Healthcare,* (1), 1-7.

Antipin, D., Bagaynikov, M., & Badmaev, A. (2020). Some Approaches to The Identification of Innovative Enterprises in The Region. TIES 2020 International conference «Trends and innovations in economic studies». *European Proceedings of Social and Behavioural Sciences, 96*.

Babkin, A., Alekseeva, N., Makhmudova, G., & Yung, A. (2020). Research and assessment of innovatively-active industrial cluster development. *Pervasive Health: Pervasive Computing Technologies for Healthcare*. https://doi.org/10.1145/3444465.3444485

Boltzmann, L. (1970). *Stat'i i rechi [Articles and Speeches].* Moscow, Nauka Publ.

Chuprov, S. (2019). Self-Organization and Adaptation of Industrial Economic Systems in Dynamics of Its Entropy-Information Processes. International science and technology conference «Earth science». *IOP Conf. Series: Earth and Environmental Science, 272*(3)*,* 032199.

Chuprov, S., Babkin, A. V., & Tashenova, L. V. (2017). Management of sustainability and development of systems in the context of the synergetic paradigm. *Proceedings of 2017 IEEE 2nd International Conference on Control in Technical Systems*, CTS, 318-321.

Foerster, H. (1964). *Samoorganizuyushchiyesya sistemy [Self-organizing systems].* Mir Publ.

Gibbs, J. (1982). *Termodinamika, Statisticheskaya mekhanika [Thermodynamics. Statistical Mechanics].* Nauka Publ.

Golovina, E., Evloeva, M., Yu, J., & Kylie, L. (2020). The Economic Goals of Digital Business Transformation. TIES 2020 International conference «Trends and innovations in economic studies». *European Proceedings of Social and Behavioural Sciences, 96.*

Haken, H. (2005). *Informatsiya i samoorganizatsiya makroskopicheskiy podkhod k slozhnym sistemam [Information and self-organization. A macroscopic approach to complex systems].* KomKniga Publ.

Kirishchieva, I., Skorev, M., Mishchenko, O., & Grafova, T. (2021). Risks and threats to economic security in the digital economy. *SHS Web of Conferences*, *110,* 01028.

Kozin, P., Alekseeva, N., & Krechko, S. (2021). Sustainable digital technologies in the management of infrastructure property complexes. *E3S Web of Conferences, 258*, 03007.

Krivenko, N. (2021). Opportunities and Threats for Innovative Import Substitution in Russia. *SHS Web of Conferences, 110*, 01002.

Maximova, T., & Eid, N. (2021). Analysis of innovation system and technology transfer. *SHS Web of Conferences*, *110*, 01025.

Plakhin, A., Semenets, I., Ogorodnikova, E., & Mironov, D. (2018). Improvement of tools for decision support systems (DSS) in corporate information systems of industrial enterprises. *MATEC Web of Conferences, 178*, 08002.

Prigogine, I., & Stengers, I. (2005). *Poryadok iz khaosa: novyy dialog cheloveka s prirodoy [Order out of Chaos: Man's new dialogue with nature].* KomKniga Publ.

Shannon, C. (1949). *The Mathematical theory of Communication*. The University of Illinois Press.

Shevchenko, E., Efremova, A., Oshovskaya, N., & Artyukhova, I. (2020). The Modern Concept of The Becoming of The Digital Economy in Russia. TIES 2020 International conference «Trends and innovations in economic studies». *The European Proceedings of Social and Behavioural Sciences, 96*.

Zhdanov, V., Vinnichek, L., Vizirskaya, M., & Zhdanov, I. (2021). Theoretical approaches to determining the economic sustainability of enterprises. *SHS Web of Conferences, 110*, 01019.