

Nonlinearity and Stability of an Industrial Enterprise in the Information Analysis of Management

Sergey Vitalievich Chuprov
Baikal State University, Irkutsk, Russia

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Abstract: The development of theoretical views, methodological and applied tools of sustainability management of industrial enterprises is now a priority among the urgent economic tasks for managers of industrial enterprises and the business community. Within the framework of ensuring reliable competitive positions of enterprises and their successful innovative modernization, professional analytics focuses on the conditions and features of the functioning of enterprises that are affected by growing globalization and the crisis of the world and domestic economy. The perturbed modes of behavior generated by them and their own triggers demonstrate features of nonlinearity with their inherent restructuring, oscillation, loss and gain of stability. The study goal is to use the insights of system analysis, cybernetics, nonlinear dynamics, catastrophe theory and information to analyze and interpret the metamorphosis that industrial enterprises undergo. In view of this, the article presents an economic explanation of scenarios for the transformation of industrial enterprise and the linking of its evolution with the amount of information, entered by the management system and materialized in the means of enterprise production. At the same time, for information analysis, a significant analytical aid is the modification of exponential dependence of the disordered functioning of enterprises controlled complex, the amount of accumulated control information and the enterprise economic effect (according to V. Trapeznikov), which makes it possible to introduce into this dependence the indicator of management excellence level achieved at industrial enterprise and assess the impact of the latter on the amount of information inherent in it. In the conditions of incompleteness of the initial information, the task of using and processing both quantitative and poorly formalized qualitative information is actualized due to the use of the fuzzy sets apparatus. The study significance is to enrich the concept, technology and algorithms of adaptive management of an industrial enterprise in a highly perturbed and knowledge-intensive business environment.

1 INTRODUCTION

The era of rapid and intense changes in the political and social space dynamizes the environment of regional and corporate economic systems, subjecting their structure and functioning to increasing perturbation and the risk of weakening the competitiveness and degradation of industrial enterprise resources. In view of this, traditional approaches to the design of its management and sustainability management of the enterprise in a stationary environment retreat to the time demands, need theoretical and methodological verification and revision, taking into account the postulates of both social and natural science branches of knowledge. And the information analysis of the nature of their restructuring and tools to ensure the vitality of industrial enterprises in a vortex environment with a

sequence of stable and unstable states acquires priority importance in understanding the evolution of developing economic systems.

Currently, studies on the sustainability of economic systems go back to both the classical concepts of fundamental property of dynamic systems (Chuprov, 2016) and expand the range of analytical works on the problems of ensuring the sustainability of innovative development in an uncertain and dynamic external environment (Khudyakova, Shmidt, 2018) and the formation of a new technological order of economic structures (Alekseeva, Babkin, Makhmudova, Yung, 2020). In this context, we have recently seen a surge of interest in the modernization of management technologies for making management decisions based on the use of intellectualization of the search for solutions (Veretyokhin, Yachmeneva, Sevastyanova,

Osmanova, Yachmenev, 2020) and digital platforms (Belyakova, Belyakov, Fokina, Shpak, 2020; Griбанov, Bezrukova, 2018).

In order to develop the stability management of nonlinear functioning of industrial enterprises, the task is to ensure the use of poorly formalized source information and algorithms of fuzzy sets in management technology, which opens up the possibility of saturating it with valuable knowledge about the properties of enterprise behavior in the face of increasing threats. As a result, it is possible to increase the information transparency of decision-making environment and the adaptability of industrial enterprise by responding to emerging risks in advance by maneuvering its resources.

2 MATERIALS AND METHODS

In the range of natural-scientific and economic views on the stability of motion of dynamic systems, the achievement of study goal is achieved by attracting the ideas of systems analysis, cybernetics, nonlinear dynamics, catastrophe theory and information theory. Thanks to application in the complex of these concepts and methodological principles, it becomes possible to perform an information analysis of metamorphosis of nonlinear activity of an industrial enterprise, the bizarre combinations of stable and unstable phases of its functioning.

3 RESULTS AND DISCUSSION

Conceptually, it became undeniable that with the "jump into the market" on the transformation of domestic enterprises was extremely powerful pressure of overwhelming economic dynamics, coming from the reformers' plan of rapid denationalization and privatization of the property of economic complexes. Obviously, the orthodoxy of monetarism left no other levers to manage the transition processes except free pricing and money supply regulation, which against the background of radicalization of institutional change caused an unprecedented steepness of the processes caused by them.

Chaotization of the economic space has become an inevitable consequence not only of structural discontinuities, among which the network irregularity of input and output commodity flows and interactions with counterparties, but also of the confusion with the economic activity rules.

Meanwhile, it is theoretically argued and practically confirmed that in a highly disturbed environment, replete with critical overloads and burdened by the lack of effective government support, the work of industrial enterprises was shackled by fading or arrhythmia of supply of consumed resources (raw materials, materials, energy, products, etc.), a shortage of their own financial funds, uncertainty of partnerships, demand for manufactured products and their supply. The undermined reproduction of the enterprises' resources resulted in the containment, or even the damping of business activity, a sharp drop in output and sales, the exorbitant growth of debts and the risk of bankruptcy.

The commodity-money imbalance and turbulence of the transitive Russian economy gave rise to critical transition processes and, with the liberalization of pricing, inflationary waves running over each other and the entrenchment of depressive tendencies. Shocks of supply and demand, as a reaction to the shocks of the country's deformed economic complex, rocked its financial and economic mechanism and condemned enterprises to exhaustion and depletion of resources. Within the framework of monetarism postulates, which ignored the methods of state regulation, there was no need to rely on the damping and repayment of the prohibitive "bursts" of inflation (Chuprov, 2017).

The dynamic picture of the enterprise functioning is undergoing restructuring, closing the slow and fast, smooth and "explosive" phases of behavior. In particular, during the evolution of enterprise, its state of stable equilibrium may merge with an unstable equilibrium, after which the equilibrium disappears and the enterprise economic system radically changes mode, making a leap (a "catastrophe" occurs).

Phenomena of this kind are studied and described by catastrophe theory, in which a dynamic system loses stability of an equilibrium state due to both bifurcation of this state and a spontaneous process (Arnold, 1990). Moreover, with the loss of equilibrium state, the system either moves to another equilibrium, or two such states appear: stable and unstable equilibrium.

It would appear that this scenario of industrial enterprise's transformation is inherent in the first stage of its slide into crisis, when under the influence of perturbations, the enterprise is gradually "squeezed" out of a stable equilibrium and over time it weakens and disappears. After that, the perturbed mode of enterprise's functioning evolves to another equilibrium state, different from the previous equilibrium. The enterprise is drawn into the process of disintegration and deterioration of resource

balance, and because of decline in the efficiency of their use, the enterprise's business activity falls. With acquisition of new state of equilibrium, it can become stable, if it is unshakeable to the perturbations rendered, or unstable, easily disturbed by them in the chaotic activities of the enterprise.

Meanwhile, another scenario is real, in which a stable state of equilibrium in an industrial enterprise dies out, in which it degenerates into a limit cycle, and then the equilibrium becomes unstable. With the emergence of an oscillating periodic regime, the transition process reflects the unfolding of crisis in passing, which unfolds as the cyclical reproduction of enterprise resources suffers. In fact, this refers to the unstable operation of the enterprise, which is characteristic in a disturbed environment, which proceeds in an excited mode, which differs little from the equilibrium one with a slight deviation of mode from the point of loss of stable equilibrium (Chuprov, 2016).

Quite a typical case is when the loss of stable equilibrium of an industrial enterprise passes quickly enough and the loss in the equilibrium position of limit cycle is accompanied by disappearance of the latter, after which the equilibrium becomes unstable. Before that, the random disturbances acting on the enterprise's activity force the enterprise system to leave the attraction area of the previously established regime, the intensity of its financial and economic activity changes dramatically and the enterprise jumps into a qualitatively different regime. After such a violent metamorphosis, the enterprise, by catastrophe theory, is drawn to a new stable stationary mode or submits to a stable fluctuation or even more complex motion (Arnold, 1990).

Meanwhile, restructuring in a chaotic economic system is characterized by change in the orderliness of its behavior, organically related to the amount of information contained in the system. In the process of non-ordinary transformations, it is distinguished in the process of evolution by value of entropy as a measure of energy dissipation in terms of thermodynamics and statistical physics. In information analysis, V. Trapeznikov's concept is valuable, according to which there is an exponential dependence of the effect of system functioning on the disorder of its behavior and the amount of control information in it (Trapeznikov, 1983):

$$E = E_{\max} \left[1 - B_0 e^{-\frac{I}{I_0}} \right], \quad (1)$$

where E – the effect of functioning complex;

E_{\max} – the effect of perfectly functioning complex (maximum possible effect);

B_0 – complex disorder in an initial state;

I_0 – the amount of information that is specific to this control object;

I – the amount of control information.

Simple mathematical operations allow us to modify equality (1) and obtain the following expression regarding the amount of information in the economic system:

$$I = I_0 \ln \left(\frac{B_0}{1 - \frac{E}{E_{\max}}} \right) \quad (2)$$

Ratio $\frac{E}{E_{\max}}$ B. Trapeznikov called the level of management excellence. Its value is determined by the amount of information input into the system and its usefulness, depending on perfection of devices and software for collecting, processing and influencing the control information on the system. From the equations (1) - (2) for information analysis, find the basis for the statement: with a given disordered behavior of the system and its saturation with useful information, the effect of system functioning increases, but with the approach to its maximum value, the increase in the effect exponentially decreases.

From the perspective of information paradigm, the stability management system of industrial enterprises relies on a wide application of professional knowledge, algorithms for finding and maintaining a sustainable mode of the enterprise in a highly perturbed environment and the scarcity of available information about it. The technology structure of such adaptive management includes the blocks of forecasting changes in the external environment, adapting the management system, forming the production plan and simulating its implementation, assessment and analysis of enterprise stability on the forecasted background, their diagnosis, correction of planning conditions and ensuring the implementation of industrial production plan.

The use of heuristic models built on the basis of algorithms of fuzzy sets theory makes it possible to enter and process both quantitative and poorly formalized qualitative information, which better meets the peculiarities of analysts' thinking and tradition to operate with fuzzy categories. Innovative support for adaptive management and sustainability

management of industrial enterprises is carried out through analytical functions and intellectualization of participants in computer dialogue, and, above all, their ability to perceive poorly structured problems and exchange heuristic information, which facilitates the generation of new knowledge about the properties of enterprise sustainability.

Thus, the objectivization of picture of its behavior logically leads to the need to develop information analysis of the industrial enterprises' functioning, which corresponds to the condition of their innovative development. At the same time, the use of ideas about bifurcations and catastrophes in nonlinear processes brings us closer to understanding the essence of abrupt changes in the economy, when the measured course of the process under influence of small perturbations is replaced by rapid and loses its previous stability. It seems that the transfer of knowledge with its embodiment in technology, means and products of labor can both strengthen the stable mode of enterprises' operation, and under certain conditions lead it into the area of future bifurcations.

In the current highly indignant and uncertain economic situation, it is advisable to talk not only about the development of adaptive management technology for the sustainability of industrial enterprises, but also about the fact that it has an "innate" ability to innovative modernization and build up "skills" action of permissible external and internal interference. It should have the property of active self-learning with the priority on extraction and mastering of new knowledge in the professional skill of enterprise personnel, production and computer technology management.

In short, saturation in such a "foggy" risk environment of enterprise operation with knowledge-intensive information and its materialization in management and production activities will (at least partially) weaken the emerging chaotic processes in its functioning and make up for its lack for effective development. Otherwise, the non-equilibrium behavior of the enterprise may become stable, but not due to the innovative type of progressive transformation, but under the influence of the dominance of degradation tendencies. And then, when the bifurcation points are reached, the trajectory of the enterprise will be poorly predictable and will be determined by the conditions of transition process. Therefore, in the course of computer experiments, it is necessary to assess the enterprise's adaptability and the effectiveness of implemented solutions, which deepens the knowledge of nature and patterns of crisis processes, and therefore contributes to the acquisition

of personnel skills in diagnosing and managing the stability of an industrial enterprise.

4 CONCLUSIONS

In conclusion we summarize that the development of methodology, technology and tools of modern management of industrial enterprise allows not only to comprehend the metamorphosis of its nonlinear behavior, economic evolution and anti-crisis management of the enterprise, but also to achieve in practice to maintain its stability, through the design and implementation of information and algorithmic developed management system.

Achieving and maintaining sustainable operations of an industrial enterprise in a highly perturbed environment is supported by the development of intellectualization tools that open up the possibility of applying poorly structured qualitative information in management models, making up for its incompleteness in a dynamic and poorly defined environment.

The prospects for further research on the discussed problems are associated with the functional development of adaptive management technology, which will ensure the strengthening of the competitive position of industrial enterprises in the globalization of world economic relations, the establishment and expansion of innovation economy sectors.

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