Balanced management of innovative sustainable development of the petroleum and gas chemical complex

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Abstract. The article discusses the issues of balanced management of innovative sustainable development, taking into account the vitality factor to improve the efficiency of innovative processes of organizations. The significance of a complex of management measures in the general management system in the process of introducing innovations in conditions of uncertainty and risks is determined. The interrelation of the components within the framework of the balanced management model of the company is considered; the role of the internal state of the economic system in this process is determined, as well as the restrictions, the impact on which will increase efficiency of the processes under consideration are identified. Based on the results of the study, a model for assessing balanced management is proposed, taking into account the innovative nature of the company’s development and the factor of the organization’s vitality. Thanks to this technique, it is possible not only to determine the quality of the management system for innovative sustainable development, considering the state of vitality of the economic system, but also to identify directions for its improvement and development.

1. General formulation of the problem

Currently, the development of complex economic systems cannot be imagined without innovation. They are involved in various processes and procedures and penetrate most areas of the company. They provide competitive advantages for companies, serve as triggers for increasing efficiency, but at the same time they are a source of perturbation and risks of various scales and levels.

Indeed, most of the innovations that are implemented by an organization have a dual effect on it, on the one hand, generating an impetus for innovative development, on the other hand, causing outrage in the system itself, which leads to the emergence of risks [12]. The continuous nature of innovative changes requires organizations to constantly involve all available resources in the innovation process. However, their size is limited and sometimes insufficient to achieve consistency of innovative transformations in the economic system. This causes the emergence of many stochastic processes that, due to their unpredictability and weak controllability, negatively affect the effectiveness of innovations.
In this regard, the emerging economic conditions create preconditions for the formation of new approaches to the management of innovation processes in complex economic systems of various levels. In our opinion, such an approach can be a balanced management of innovative development, which takes into account various characteristics of the company in the implementation of innovative processes and gives them the characteristics of dynamic stability.

It is well known that the founders of this approach to management are D. Norton and R. Kaplan, who in their works reflected a set of tools for a complex impact on the development of an organization, accompanied by an increase in the uncertainty of decision-making in order to increase its flexibility and adaptability to the changes being implemented [8, 18]. However, their concept does not take into account the internal capabilities of companies to change these parameters and ignores some aspects of innovative development, which reduces the effectiveness of the proposed models.

2. Analysis of the latest achievements and publications
The emergence of a new approach to management seems legitimate, due to changes in the development of the external environment and is associated with the theory of limitations by E. Goldratt [12], but it does not consider the complex nature of ongoing processes, their interconnection in the course of the implemented innovative changes. The subsequent researchers expanded this approach to balanced management of company development (E. Deming, D. Norton, R. Kaplan, etc.) [2, 11], but their research also does not fully take into account the specifics of innovation processes, internal capabilities and needs of organizations in the implementation of innovations, their desire for sustainable development in the face of uncertainty and risks.

Modern researchers complement the formed approach to balanced management, for example, P. Timoshenko in his work distinguishes between internal and external balance. At the same time, the state of external balance of development is understood as ensuring the compliance of the industrial complex of the region with the requirements of the business environment, first of all, such as the priorities of industrial innovation, investment, scientific, technical and trade policies of both federal and regional authorities, solving problems associated with structural transformations and shifts [6, 9, 20].

Management of the internal balance of the petrochemical complex development implies its infrastructure support, a consistent link between operational and strategic management, formation of portfolios of mutually beneficial and interrelated, complementary innovative projects [16, 20, 23].

Modern researchers mainly consider sustainable development through the process of achieving a harmonious state. They propose the means and ways to ensure it, highlight principles and rules that should form the basis for building a balanced industrial system [20]. However, in the works of various authors, unified criteria for the balance and harmony of key performance indicators have not been established, which could ensure comparability of the assessment of industrial enterprises in the context of innovative changes. As before, the disadvantages of most of the existing methods include insufficient attention to assessing the state of the environmental and social component of the development of an organization, as well as the exclusion from the system of issues related to assessing the safety of the economic system. In the face of increasing uncertainty, this leads to a decrease in the objectivity, complexity and efficiency of this monitoring system and the approach to management based on it.

In addition, the proposed models lack methods for assessing the balance of management of industrial systems in the context of innovation. The development of new approaches that take into account the innovative aspect of development is of particular relevance in modern conditions.

In the process of innovative development of an enterprise, the destruction and creation of existing links and interactions between elements of the internal and external environment occurs, which leads to the creation of links and interactions of a higher quality system and leads to the achievement of strategic goals. In this regard, balanced management of the development of a petrochemical complex
enterprise presupposes continuous improvement and access to a new, higher-quality level of
development of both the system itself and all its elements to increase competitiveness. This leads to a
violation of the existing balance in the economic system, emergence of new risks of increasing the
uncertainty of the effectiveness of its changes. This, in turn, requires coordinated and timely
management actions, taking into account the capabilities of the company itself, the quality of its
management system, as well as the required speed and level of its innovative development.

3. Goal formulation and setting work tasks
This study is devoted to the problem of forming a balanced management of sustainable innovative
development of complex economic systems, taking into account their internal capabilities in
conditions of uncertainty and risks. At the same time, it is important to determine the interrelation
of the components within the framework of the company’s balanced management model; determine the
role of the internal state of the economic system in this process, as well as identify those restrictions,
the impact on which will increase the efficiency of the processes under consideration.

4. Main research material
As noted earlier, the classical model of balanced management does not take into account a number of
issues related to the growth of uncertainty in the course of innovative development. This means that
the management system in this case does not consider such factors as innovative changes and risk,
which sharply reduces the efficiency of its use in modern conditions [4]. At the same time, little
attention is paid to assessing the internal state of the organization to these changes, its ability to
withstand the emerging stochastic effects during the implementation of innovations. In other words, it
is not determined whether the system is capable of performing the necessary part of its functions in the
face of increasing risks, to overcome internal inconsistency that arose in the course of innovative
changes, and to form a new dynamically stable system as a result of the implementation of innovative
processes.

In modern economic conditions, this is of particular importance, in view of the ongoing growth of
uncertainty and an increase in the risk load on companies, due to the implementation of large-scale
force majeure events, which experts attribute to the ‘black swan’ group. These events expand the
group of risks existing at enterprises, increasing the predicted background risk, complicating the
management decisions making (Table 1).

Table 1. Calculated values of the indicator of background risk of accidents at enterprises for 2017-
2018. (The table was compiled by the authors based on the statistical data of Rostechnadzor) [4]

| Industries | 2017 | 2018 |
|------------|------|------|
|            | Numb of hazardous facilities | Numb of accidents | Expected background risk | Estimated background risk | Numb of hazardous facilities | Numb of accidents | Estimated background risk |
| PP         | 7864 | 16   | 2   | 2.034 | 7522 | 9   | 1.19 |
| OP         | 4389 | 20   | 3.8 | 4.556 | 4721 | 12  | 2.54 |
| TPT        | 4273 | 6    | 2.4 | 1.4   | 4310 | 12  | 2.78 |
| SS         | 61113| 43   | 0.4 | 0.7   | 60697| 23  | 0.37 |

It can be seen from Table 1 that even under more favorable planning conditions, the forecasted
value of the background risk by Rostechnadzor experts for 2017 does not converge with the calculated
values in all industries. Thus, the most correlated results are observed only for oil production. The
deviation for petrochemical products was 19.8%, for TPT there is a decrease of 41% from the
predicted values, for SS there is an increase in the background risk by 75% of the planned ones [1, 12].
At the same time, comparison of data for 2017 and 2018 on the background risk already indicates that
the management system at hazardous production facilities is not balanced. Every year there are fluctuations in the positive or negative direction, almost twofold [5, 12]. In this regard, industrial enterprises and government agencies need to develop a strategy to ensure accident-free operation of the petrochemical complex by introducing a model of balanced management of innovative sustainable development, considering internal capabilities of companies, to resist disturbances that can be characterized as survivability.

Within the framework of the study, survivability will be defined as the ability of a system to adapt to new operating conditions, to resist disturbing actions (including the consequences of emergency situations) without disrupting implementation of the main function. In other words, the survivability of the system enables it to ensure the achievement of the set goal in the event of stochastic effects of innovation. With regard to economic systems, we will understand survivability as the ability of industrial and economic facilities to perform their main functions, despite the damage to individual elements as a result of emergency circumstances (even with an acceptable loss of the quality of their implementation), and then implement an optimal recovery strategy, taking into account the constraints that arise. [15].

To form a new model for assessing the degree of balance of innovative sustainable development of enterprises for management purposes, the indicators were grouped according to several particularly significant areas: the degree of innovative development of the company, the level of its sustainable development and the state of vitality (Table 2). The table is based on research data from the following authors: S. Valeev [21, 22], M.A. Zotov [13, 14], E.N. Kadeeva [3, 7], S.I. Ponikarov [10], A.S. Ponikarova [15], A.A. Salin [17].

Each of the level indicators can include various combinations of components depending on the specifics of the industry, requirements of the management system and objectives of the analysis. To calculate the levels, it is necessary to calculate the integrated values determined by formulas 1-3, taking into account the weight coefficients.

\[ I_{d'i} = \sum_{j=1}^{n}(I_{d'j} \cdot k_{d'j}) \]  

where \( I_{d'i} \) – an integrated indicator of the level of innovative development; \( I_{d'j} \) - indicators describing the state of innovative development, selected depending on the specifics and characteristics of the industry, region, enterprise; \( k_{d'j} \) - weight coefficients determined by the method of expert assessments according to the degree of influence for each indicator; \( n \) - the number of indicators and the corresponding weight coefficients.

\[ S_{u'i} = \sum_{j=1}^{m}(S_{u'j} \cdot k_{u'j}) \]  

where \( S_{u'i} \) – an integrated indicator of survivability level; \( S_{u'j} \) – indicators describing the state of survivability, selected depending on the specifics and characteristics of the industry, region, enterprise; \( k_{u'j} \) - weight coefficients determined by the method of expert assessments according to the degree of influence for each indicator; \( m \) – number of indicators and corresponding weights.

\[ S_{r'i} = \sum_{j=1}^{p}(S_{r'j} \cdot k_{r'j}) \]  

where \( S_{r'i} \) – an integrated indicator of the sustainable development level; \( S_{r'j} \) – indicators describing the state of sustainable development, selected depending on the specifics and characteristics of the industry, region, enterprise; \( k_{r'j} \) - weight coefficients determined by the method of expert assessments according to the degree of influence for each indicator; \( p \) – number of indicators and corresponding weights.
### Table 2. Model for assessing the degree of balance of innovative sustainable development of enterprises (Table compiled by the authors)

| Innovative development level (ID) | Sustainable development level (SD) | Survivability level (Sur) |
|----------------------------------|-----------------------------------|--------------------------|
| Indicator of the number of employees engaged in research and development from the average number of employees. | Worker Injury Rates: Lost Time Injury Rates (LTIFR), Fatal Injury Rates (FIFR), | Indicators of financial survivability of the object: realized at its own expense; realized with borrowed funds; organization survivability autonomy |
| Indicator of the share of registered patents, utility models, know-how of the total amount of research. | Indicator of the background risk of accidents | Indicator of economic efficiency of changing the level of survivability |
| Indicator of the number of advanced technologies created | Indicator of costs for labor protection, industrial and fire safety, from the total cost | Indicator of the quality of survivability change |
| Indicator of export-import of advanced technologies | Occupational disease detection rate (ODR) | Indicator of the ability of an object to maintain survivability level over time |
| Indicator of the share of costs for technological innovations in the total volume of products shipped by organizations implementing technological innovations | Indicator of plant downtime as a result of accidents | Indicator of personnel training in the elimination of accident consequences |
| Indicator of the share of innovative products in the total volume of products shipped by organizations implementing technological innovations | Indicator of expenses for implementation of social policy of the enterprise, rubles of total revenue | Indicator of the personnel ability to eliminate consequences of an accident |
| Indicator of innovative susceptibility | Indicator of captured hydrocarbons in relation to total emissions | Indicator of personnel readiness for an emergency |
| Indicator of innovative activity | Indicator of recycling water use, own waste processing, processing depth; energy intensity | Indicator of the elimination system effectiveness |
| Indicator of organization quality and communication | Indicator of the amount of investments aimed at environmental protection, of the total amount of investments | Indicator of the implementation speed of the system of measures to eliminate consequences |
| Indicator of intangible costs in the cost of production | Indicator of the ratio of standard and excess emissions | Economic efficiency indicator of response; effectiveness of improving responsiveness. |
| | Financial stability indicators: autonomy, creditworthiness, solvency, etc. | Indicator of the environmental protection system effectiveness |
The number of components in defining integrated indicators may not be the same for different systems. This allows comparing generalized coefficients even in the absence of some of the parameters or data on their change.

The maximum value of each of the three integral indicators cannot exceed one. Since for calculating the indicators, previously developed methods are used that have different boundary values, it is proposed to bring them to unity by determining the proportions and the Harrington desirability function to achieve level comparability. After determining the levels of innovative development, survivability and sustainable development, an integral indicator of the state of balance of innovative sustainable development of the organization is found, which can be described by the function (formula 4)

\[ S_M = f(S^u, S^v, I^d) \]  

In real conditions for enterprises, achieving optimum performance is almost impossible in view of resource constraints and the influence of the external environment [16, 19]. In this regard, for the formation of the permissible values range, it is proposed to select a range from one to zero. This will allow to graphically depict hard-to-reach areas of values that will be in the range from 0.2 to 0, and in the area of optimum values the function will tend to zero. The modified numerical values of the Harrington scale represent the linguistic assessment and the ranges of values of the desirability function \( d(x) \): 'very bad' - 0.8-1; 'bad' - 0.63-0.8; 'satisfactory' - 0.63-0.37; 'good' - 0.37-0.2; 'very good' - 0.2-0. A graphic representation of the distribution of admissible values area of the assessment of the management balance of innovative sustainable development, taking into account the state of survivability, is shown in the figure 1.

![Figure 1. Graphic representation of a model for assessing balanced management of innovative sustainable development, taking into account the survivability factor](image)

The graphical representation of the assessment model for the balanced management of innovative sustainable development is a cube bounded by the maximum value along the X, Y, Z axes equal to the unit. The model is aimed at the continuous simultaneous development of the three main components of enterprise development in modern conditions. On the X-axis, the most significant indicators characterizing the level of sustainable development of an enterprise, complex, industrial cluster, region or state as a whole are plotted. These include three main components: environmental, economic and social. On the Z-axis, indicators of the level of survivability of the enterprise are plotted. The Y-axis represents the most significant indicators for determining the level of innovative development. Depending on the sectoral and regional characteristics, the specifics of innovative development may differ significantly, for example, the content of R&D, the speed of technical and technological innovations, access to new technologies and knowledge, innovative activity and the influence of
institutional factors. In this regard, it is necessary to select key indicators for assessing the level of innovative development, based on the specifics of the analyzed object.

After determining the values for each block of indicators to find the integral value of the assessment of balanced management of innovative sustainable development, taking into account the survivability factor, it is necessary to assign a significance coefficient to each of the three indicators, depending on the specifics of the industry affiliation of the organization, its territorial, climatic position and other conditions for the implementation of activities, as well as features of the ongoing processes. The integral value will determine the overall quality level of the balanced management system, and the values for individual blocks will determine the directions for its optimization, considering the internal development of the economic system and changes in the external environment.

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