Organization behavior control of spatial cluster-network integration of the oil and gas complex

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Abstract. The article presents, substantiates and tests the author's methodological tools based on a set of economic and mathematical models reflecting the processes of formation, development, state and organization behavior control of spatial cluster-network integration of the oil and gas complex. The object of the research is the interregional and intersectoral interactions of the oil and gas complex, considered by the example of the regions of the Volga Federal District of the Russian Federation. The authors understand spatial cluster-network integration as a production pool of mutually beneficial cooperative ties of autonomous business structures based on related interdependent types of economic activity and forming a common space of socio-economic interests regardless of industry and territorial affiliation. The organization behavior control of spatial cluster-network integration requires taking into account the interests of all interested stakeholders, which can be represented using the structural-functional model of the four-link spiral concept. This organization behavior control approach, based on the cluster-network nature of spatial integration, will strengthen territorial and sectoral relationships; a harmonized synthesis of disparate resource potentials will contribute to the rationalization of their use; form the competitive advantages of business structures, the region and the country as a whole.

1 Introduction

A slowdown in economic growth, an increase in sanctions pressure on the domestic system, and comprehensive digitalization require the search for new approaches to creating, strengthening and assessing the effectiveness of industrial development organization behavior control. In this case, an important role is played by the organization behavior control of spatial cluster-network integration, in both intra-inter-sectoral and inter-regional interaction.

The purpose of the article is to test the author's tools based on a set of economic and mathematical models that reflect the processes of formation, development, state and organization behavior control of spatial cluster-network integration of the oil and gas complex. The object of the research is the interregional and intersectoral interactions of the oil and gas complex, considered by the example of Volga Federal District of the Russian Federation (hereinafter – VFD). The subject is instrumental and methodological support for improving the organization behavior control process of spatial cluster-network integration of subjects of the oil and gas industry.

The analysis of the theories of spatial development of socio-economic systems of different levels allowed the authors to formulate the following definition: spatial cluster-network integration is a production pool of mutually beneficial cooperation ties of autonomous business structures based on related interdependent types of economic activity and forming a common space of

socio-economic interests, regardless of branch and territorial affiliation [4].

At the same time, the organization behavior control of spatial cluster-network integration requires taking into account the interests of all interested stakeholders, which can be represented using the structural-functional model of the concept of a four-link spiral. This organization behavior control approach, based on the cluster-network nature of spatial integration, will strengthen territorial and sectoral relationships; a harmonized synthesis of disparate resource potentials will contribute to the rationalization of their use; form the competitive advantages of business structures, the region and the country as a whole. Consequently, the increase in cluster-network integrations is a fresh direction in the development of the regional economy.

2 Materials and Methods

Organization behavior control of these integration processes is impossible without appropriate instrumental and methodological support for assessing and predicting the development of cluster-network interaction. The author's developments are based on the works of domestic and foreign authors [3, 9, 11].

Graphically, the methodology and main indicators in this work are presented in Figure 1.

The author's methodological approach is based on the concept of "cluster load index", which shows the region's predisposition to the creation or development of existing cluster-network integrations, also indicates the presence

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of industry dominance in the region, thereby predetermining the subject as a region with one or another (other) types of economic activities. In the long term, the cluster load index makes it possible to assess the direction of the region to select strategic benchmarks.

Figure 1. Methodology for managing spatial cluster-network integrations

The proposed toolkit allows for a broader analysis of the integration development of business structures, takes into account the sectoral specifics of regional development. It also takes into account the differences in statistical methods of analysis according to All-Russian classifier of economic activities for the analyzed period 2005-2019. This leads to a more informative, accurate calculation and forecasting of systems development [8]. This methodological approach includes several steps.

Step 1. A quantitative assessment of the parameters of the cluster load index is made according to Eq. 1.

$$k_i = \sqrt{\frac{\sum_{j=1}^n \left(\frac{w_{ij}}{W_j} - \frac{\overline{w_{ij}}}{\overline{W_j}} \right)^2}{E}},$$

where k_i is cluster load index;

w_{ij} is specific indicator of j -th sub-industry of shipped products for any type of economic activity in i -th region;

$\overline{w_{ij}}$ is average value of j -th sub-industry of shipped products for any type of economic activity in i -th region for selected year;

W_j is specific indicator of j -th sub-industry for Russia as a whole;

$\overline{W_j}$ is the average value of the subsectors of shipped products for any type of economic activity for Russia as a whole for the selected year;

$i \in I, I = \overline{1, m}, m$ is number of regions;

$j \in J, J = \overline{1, n}, n$ is number of all subsectors for the selected period; E is multiplier calculated by Eq. 2:

$$E = \frac{n_g^*}{\max(n)}, \quad (2)$$

where n_g^* is the number of current subsectors for the selected year.

Multiplier $E \in (0; 1]$ is calculated to correctly determine the index due to differences in the editions of the methodology for including industries according to OKVED for the selected period 2005-2019. The more informative and more accurate calculated cluster load index is achieved by decreasing the amplitude of the monotonic function under the root in Eq. 1. That is, taking as a dimensional space all indicators calculated for a different time period with a different number of sub-sectors according to the corresponding All-Russian classifier of economic activities, a single dimensional space is formed $n(R^n)$.

In paper [5], dependence k_i , cross regional product and profit of enterprises are considered. For training a neural network and subsequent modeling of dependence and forecast, the cluster load index k_i is normalized.

The disadvantage of formula (1) is that the resulting values are unlimited on any domain of definition. To solve this problem, rationing is proposed.

The normalization can be performed in different ways, but in the current work it is proposed to use a function similar to the Gaussian function, which takes values from 0 to 1, which has the following form (Eq. 3):

$$f(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{(\alpha_k x - \beta_k)^2}{2}}, \quad (3)$$

where α_k, β_k - empirical parameters. Then, in our case, the normalized cluster load index $k_{i \text{ norm}}$ will take the following form (Eq. 4):

$$k_{i \text{ norm}} = \frac{1}{\sqrt{2\pi}} e^{-\frac{(\alpha_k k_i - \beta_k)^2}{2}} = \frac{1}{\sqrt{2\pi}} e^{-\frac{\left(\alpha_k \sqrt{\sum_{j=1}^n \left(\frac{w_{ij}}{W_j} - \frac{\overline{w_{ij}}}{\overline{W_j}} \right)^2} - \beta_k \right)^2}{2E}}, \quad (4)$$

(1) where $k_{i \text{ norm}} \in \left(0; \frac{1}{\sqrt{2\pi}} \right]$.

Step 2. Formation of spatial cluster-network interactions within the framework of the creation of an integral cluster presupposes interregional interaction of two or more regions capable of developing a single strategy aimed at increasing the competitive potential of the parties, while optimal sectoral and inter-sectoral localization should be attractive to all interested stakeholders: the state, business structures and the population [6].

The degree of development of the infrastructure basis for interactions plays an important role, especially the presence of the development of the transport sector, which contributes to the optimization of logistics flows. The formalization of the logistic component can be represented in the form of Eq. 5.

$$L_i = \omega_1 L_i^{\text{Estb}} + \omega_2 L_i^{\text{Ast}}, \quad (5)$$

where L_i is traffic density in i -th region;

L_i^{Estb} is density of public railways (kilometers of tracks per 1000 km² of the territory);

L_i^{Ast} is density of public roads with hard surface (kilometers of tracks per 1000 km² of the territory);
 ω_1, ω_2 are weight coefficients, where $\omega_1 + \omega_2 = 1$,
 $\omega_1 = \frac{L_i^{Esb}}{L_i^{Esb} + L_i^{Ast}}, \omega_2 = \frac{L_i^{Ast}}{L_i^{Esb} + L_i^{Ast}}.$

In the same way, we normalize for L_i ; then the normalized indicator $L_{i\text{norm}}$ is calculated as follows (Eq. 6):

$$L_{i\text{norm}} = \frac{1}{\sqrt{2\pi}} e^{-\frac{(\alpha_k L_i - \beta_k)^2}{2}} =$$

$$= \frac{1}{\sqrt{2\pi}} e^{-\frac{(\alpha_k (\omega_1 L_i^{Esb} + \omega_2 L_i^{Ast}) - \beta_k)^2}{2}} = \frac{1}{\sqrt{2\pi}} e^{-\frac{\left(\alpha_k \cdot \left(\frac{L_i^{Esb^2} + L_i^{Ast^2}}{L_i^{Esb} + L_i^{Ast}}\right) - \beta_k\right)^2}{2}}$$

$$L_{i\text{norm}} \in [0;1] \quad (6)$$

The author's methodology is based on the calculation of the integral indicator – “potential of development of cluster-network integration” (hereinafter CNI), which reflects the relationship between the cluster load index of a region and the development of its traffic flows. A quantitative estimate of the parameters of the CNI potential is calculated by Eq. 7.

$$M_i = k_{i\text{norm}} \cdot L_{i\text{norm}} = k_{i\text{norm}} \cdot \frac{1}{\sqrt{2\pi}} e^{-\frac{\left(\alpha_k \cdot \left(\frac{L_i^{Esb^2} + L_i^{Ast^2}}{L_i^{Esb} + L_i^{Ast}}\right) - \beta_k\right)^2}{2}} \quad (7)$$

where M_i is development potential of cluster-network integration.

The transformed author's model can be formalized in the form of Eq. 8.

$$M_i = \frac{1}{\sqrt{2\pi}} e^{-\frac{\left(\alpha_k \cdot \sqrt{\sum_{j=1}^n \left(\frac{w_{ij}}{W_j} \cdot \frac{w_{ij}}{W_j}\right)} - \beta_k\right)^2}{2n_g^* \max(n)}} \times \frac{1}{\sqrt{2\pi}} e^{-\frac{\left(\alpha_k \cdot \left(\frac{L_i^{Esb^2} + L_i^{Ast^2}}{L_i^{Esb} + L_i^{Ast}}\right) - \beta_k\right)^2}{2}} \quad (8)$$

Thus, the value of the potential for the development of cluster-network integration, assessed using the author's methodology, can allow all interested stakeholders to make balanced organization behavior control decisions aimed at enhancing or restraining their joint efforts in the field of these interactions. Thus, there is an opportunity for business structures and regions to increase their attractiveness through the optimal use of resource potential.

According to the authors, the target function of the model, taking into account the most important challenges of the current stage of development, among which, during the development of the model, the following were highlighted:

- increasing the efficiency and effectiveness of the development parameters of all socio-economic systems;
- implementation of optimal accumulation, redistribution and use of resource potential in conditions of harmonization of interests of all stakeholders.

These organization behavior control requirements are implemented through the formalization of the target

setting - the search for the maximum potential for the development of cluster-network integration, under a certain system of restrictions (Eq. 9):

$$M_i^* = \max(M_i) = \max[k_{i\text{norm}} \cdot L_{i\text{norm}}] =$$

$$= \max \left[\frac{1}{\sqrt{2\pi}} e^{-\frac{\left(\alpha_k \cdot \sqrt{\sum_{j=1}^n \left(\frac{w_{ij}}{W_j} \cdot \frac{w_{ij}}{W_j}\right)} - \beta_k\right)^2}{2n_g^* \max(n)}} \times \right.$$

$$\left. \times \frac{1}{\sqrt{2\pi}} e^{-\frac{\left(\alpha_k \cdot \left(\frac{L_i^{Esb^2} + L_i^{Ast^2}}{L_i^{Esb} + L_i^{Ast}}\right) - \beta_k\right)^2}{2}} \right] =$$

$$= \max \frac{1}{\sqrt{2\pi}} e^{-\frac{\left(\alpha_k \cdot \sqrt{\sum_{j=1}^n \left(\frac{w_{ij}}{W_j} \cdot \frac{w_{ij}}{W_j}\right)} - \beta_k\right)^2}{2n_g^* \max(n)}} \times$$

$$\left[\frac{1}{\sqrt{2\pi}} e^{-\frac{\left(\alpha_k \cdot \left(\frac{L_i^{Esb^2} + L_i^{Ast^2}}{L_i^{Esb} + L_i^{Ast}}\right) - \beta_k\right)^2}{2}} \right], \quad (9)$$

$$w_{ij} \in [\tilde{w}_{ij} - \delta_j; \tilde{w}_{ij} + \delta_j] \subset [0;1],$$

$$\sum_{j=1}^n \delta_j = 0,$$

$$i \in [1; m],$$

$$i \in [1; n].$$

where M_i^* is the maximum potential for the development of cluster-network integration;

$\tilde{w}_{ij}$ is the specific indicator of j -th sub-industry in the volume of shipped products by the type of economic activity “Manufacturing” of i -th region for the calculated year;

δ_j is the point neighborhood $\tilde{w}_{ij}$.

Due to the fact that the organization behavior control impact has a certain time lag and the subjects are not immediately able to reorient themselves, it is especially difficult to change the sectoral specifics of regional systems, therefore the authors made the assumption that δ_j -neighborhood varies in the range of ± 0.05 ($\pm 5\%$

of current values $\tilde{w}_{ij}$) with the condition $\sum_{j=1}^n \delta_j = 0$.

Step 3. Analysis of the long-term perspective of cluster-network integration is one of the significant criteria for enhancing the interest of stakeholders in cluster-network integration.

According to the authors, one of the key indicators based on retrospective data that can become the primary guideline for making managerial decisions is logistic-sectoral attractiveness (hereinafter – LSA), expressed by a dynamic change in the integral indicator – “the development potential of cluster-network integration”, this indicator is calculated according to Eq. 10:

$$D_{sch} = \frac{M_i^*|_t - M_i^*|_{t-1}}{M_i^*|_t}, \quad (10)$$

where D_{sch} is the indicator of logistics and industry attractiveness;

$M_i^*|_t$ is the current value of the potential of the functional orientation of the region;

$M_i^*|_{t-1}$ is the previous value of the potential of the functional orientation of the region.

Values M_i^* for each region in the work is estimated in increments of 1 year.

Thus, the proposed author's methodology makes it possible to more comprehensively assess the long-term prospects of cluster-network integration, serves as one of the criteria for activating the interest of stakeholders.

3 Results and Discussion

The author's approach and methodology were tested in the regions of Volga Federal District (VFD), initial indicators are presented in the official publications of Federal state statistics service (Rosstat) [6,7]. As shown by the analysis, Volga Federal District as a region is focused on the manufacturing industry, therefore, the cluster load index is calculated for the manufacturing industry (the type of economic activity "manufacturing").

In the work, the calculation of the index is presented using the example of Perm Krai and Volga Federal District in dynamics for the period under review of 2005-2019. If the cluster load index grows, therefore, the entity is positioned as a region with one dominant sectoral strategy - the manufacturing industry. In our case, there is a harmonious change in the index indicators relative to Volga Federal District, which indicates the presence of another industry that makes a significant contribution to the formation of the socio-economic component of the region.

In Perm Krai, as well as in Volga Federal District, one of the leading directions is the oil sector. Figure 2 shows the prevalence of the oil and gas complex both in Volga Federal District and in Perm Krai.

Figure 2. Relationship between the cluster load index of Perm Krai and Volga Federal District

Figure 3. Sectoral indicators of Perm Krai and Volga Federal District

The cluster load index of the Perm Territory for the same period from 2005 to 2019 has three most obvious periods of change: 1) from 2005 to 2013 the cluster load index of the region decreased from 4.5 to 3.1, although it can be seen that it had a period of slight growth at that time; 2) from 2013 to 2016 the cluster load index of the region slightly increased to 3.4 in 2014, and then adjusted downward to 3.2 in 2016. that is, during this period, the cluster load index of the region practically

did not change significantly and had a value in the interval from 3.05 to 3.4; 3) from 2016 to 2019. The cluster load index of the region increased from 3.1 to 4.4 and had a period of rapid growth from 2016 to 2017, and also had a slight decline in 2018, possibly caused by the economic crisis of 2018.

The diagrams also show that Perm Krai increases the average value of VFD cluster load index, i.e. in Perm Krai there are already all the opportunities for the development of existing clusters and the creation of new ones within the manufacturing industry, associated mainly with oil refining, since the oil sector plays one of the main roles in the overall development of both the entire district and Perm Krai (see Figure 3).

For example, in case of modeling changes in the dynamics of growth of logistic-sectoral attractiveness, we have negative dynamics, it is necessary to exert a stronger influence on the redistribution of sub-sectors, thereby expanding the range of changes (for example, ± 0.05 ($\pm 5\%$ of current values $\overline{w_{ij}}$)).

4 Conclusion

The analysis of the development of the regions of the Volga Federal District, the processes of cluster-network integration made it possible to reveal the importance of methodological and organizational tools in the processes of their development; the most important place is also given to the choice of a strategy corresponding to the current socio-economic situation of regions and industries. The inefficiency of spatial cluster-network integration is caused by the following reasons:

- advanced directions of cluster policy are financed primarily from the state budget (mainly from the federal budget), the advantages of the project-oriented approach are not used fully enough;
- poor coordination of stakeholder actions requires stimulating the development of public-private partnerships and related infrastructure, including programs for the development of human resources of relevant ministries and departments;
- the absence of a unified methodology for assessing the effectiveness of spatial cluster-network integration, adopted at the state level, complicates the implementation of industrial and regional policies, and the adoption of appropriate strategic decisions.

The presented author's methodology can be applied to all regional socio-economic systems, used by enterprises of any field of activity and all stakeholders.

In this paper, it is hypothesized that if instead of k_i we use a neural network for training M_i (this approach is presented in [5]), then control is reduced to the fact that, due to the monotonicity of the function (Eq. 5). Somehow affecting the logistics infrastructure, expressed by the density traffic flows L_i we influence on k_i , which in turn predetermines the level of GRP and the profit of enterprises-potential participants in cluster-network integration.

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