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DEVELOPMENT MECHANISMS AND METHODS FOR ASSESSING THE PETROCHEMICAL PRODUCTION SYSTEMS EFFECTIVENESS

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Abstract

The modern industrial production development tasks determine the relevance of the research presented in the article. One of the determining factors for the efficiency of a modern industrial enterprise is resource conservation. At the same time, given the importance of the Russian economy's petrochemical industry, it should be understood that the organization of effective resource conservation in this industry is one of the essential tasks of the country's socio-economic development. In turn, the activation of resource-saving processes requires high-quality analytical support, which will reveal the factors and directions for increasing resource use efficiency. The identified issues have become a prerequisite for the study conducted by the authors. The purpose is to improve assessment methods and develop directions for increasing the resource efficiency of petrochemical production systems. Modern monitoring and integral assessment of the resource efficiency of an industrial enterprise have been investigated and systematized. Based on the studied methodological aspects, a system for monitoring the petrochemical production system's resource efficiency was proposed. Based on the assessment results, problematic aspects and reserves for increasing the level of resource conservation of the studied enterprises were identified.

Keywords: Cluster form of production organization, monitoring, petrochemical industry, resource efficiency, resource saving

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1. Introduction

Resource saving is one of the determining factors of the efficiency of a modern Russian industrial enterprise. This is confirmed by the national project "Labor productivity and employment support", the goal of which is a 20% increase in labor productivity by 2024. Its content indicates that resource conservation issues at specific enterprises are becoming a priority of state support.

The problem of resource conservation is exacerbated in the context of increasing competition and economic crises of various levels. The current situation gives rise to challenges requiring the search for optimized production and economic solutions. Integration is one of the time-tested solutions. However, economic integration through the pooling of equity capital and other forms of merger of business entities has, to a certain extent, exhausted itself. The current economic conjuncture requires forms of integration that retain the key driver of technological and economic development of enterprises – competition.

A well-known form of integration of industrial enterprises, based on the principles of fair competition and effective cooperation, is the cluster form of organization of production (Ketels et al., 2006). The effectiveness of the cluster form of the territorial organization of production is confirmed by the high level of socio-economic development of the territories of location and the leading positions of companies participating in world famous clusters, such as the world leader in the field of computer technology - Silicon Valley (USA); the market leader in the perfumery and cosmetics industry - Cosmetic Valley (France); automotive cluster in southern Germany; cluster of high technologies "Valley of Sapporo" (Japan).

The cluster mechanism for the development of production systems in Russia has been implemented since 2008. The cluster mechanism for the development of production systems in Russia has been implemented since 2008. The priority project of the Ministry of Economic Development of Russia, "Development of innovative clusters - leaders of investment attractiveness of the world level" indicates that the cluster form of the territorial organization of production is a key tool for socio-economic development.

The cluster mechanism for the development of production systems is very effectively synchronized with resource saving tools. This is due to the fact that under the conditions of the correct operation of the cluster, a single resource and technological base is formed, which provides the participants with the necessary human, material, technical and information resources (Fomin et al., 2017). Moreover, an efficiently functioning cluster management apparatus makes it possible to rationalize the use of resources and increase the return on their use. Among other factors, this is due to the synergy effect arising from the pooling of experience, technology transfer and diffusion of innovations in the cluster. Factors of cluster efficiency as a form of territorial-industrial integration are the focus of many modern studies (Charykova & Markova, 2019; Ivanova, 2018). The innovative orientation of the cluster form of organization of production makes, in modern conditions, makes it a locomotive for the development of national industry. The methodology of innovative industrial development based on the clustering of territories is the subject of research by many authors (Lubnina et al., 2017; Razminiene & Tvaronaviciene, 2018; Zaraychenko et al., 2016).

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In this regard, the development of projects for cluster development of territorial production systems is an urgent task of the general strategy of resource conservation of the Russian economy. Moreover, the domestic conditions for the functioning of production and business, as well as the sectoral specifics of production systems, require the development of existing methods for monitoring and assessing the efficiency of production enterprises. It is on the solution of the designated tasks that the authors' research is focused on the development of a cluster development strategy and methodology for the integral assessment of petrochemical production systems.

2. Problem Statement

At the end of the 20th century, the category "cluster" appeared in domestic and foreign economic literature (Porter, 1990). From the standpoint of economics, a cluster is a new form of organization of production and cooperation in business. Its theoretical origins are reflected in the studies of representatives of three scientific schools:

- American school of new forms of organization of production.
- British school of new forms of organization of production.
- Scandinavian school of new forms of organization of production.

The American school of new forms of organization of production is represented by Porter's concept of industrial clusters (Porter, 1990), Enright's theory of regional clusters (Enright, 2003), as well as oter scientific research (Maskell & Larenzen, 2003; Rosenfeld, 1997).

The British school is based on the eclectic OLI paradigm of Dunning, the concept of interaction between the value chain and the cluster by Humphrey and Schmitz, as well as the concept of the technical and economic paradigm of Freeman.

The theoretical basis of the Scandinavian school of new forms of territorial organization of production is the theory of the economics of teaching Danish scientists Lundvall and Johnson, the Norwegian theory of the regional innovation system by Asheim and Isaksen.

Russian scientists are also actively involved in the development of the theory of the cluster form of organization of production. The cluster strategy of territorial development has become widespread in Russia largely due to the methodological foundations developed by specialists of the Institute of World Economy and International Relations of the Russian Academy of Sciences Gazimagomedov and Kondratyev.

Along with a significant number of studies devoted to the theoretical aspects of the formation and development of clusters (Markov, 2015; Kudryavtseva et al., 2015; Shinkevich et al., 2016), there is a relative lack of works in the literature focusing on the tasks of monitoring the resource efficiency of clusters.

In addition to the methodological problem of monitoring, there is also the task of activating Russia's cluster initiatives. This can be facilitated by the rich heritage of the territorial-production complexes formed in the USSR. They left behind territorially concentrated production capacities, united by single technological chains. Large enterprises of the former territorial production complexes can form a cluster's core and determine its industry specialization. The task of cluster development is the integration of the production core with the social and innovative infrastructure of the territory and the

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formation of a centralized management apparatus based on the principles of public-private partnership. The united structure should in every possible way contribute to the economic and technological development of the territory, while simultaneously solving the national tasks of resource conservation.

3. Research Questions

The designated problems form a number of questions that must be resolved within the framework of the study:

- Search for suitable territorial production systems for the formation of petrochemical clusters. In this context, it is advisable to focus on the so-called potential clusters, i.e. territories within which there is already a certain level of cooperation between business entities and the state and infrastructure. The key task of the cluster development of such territories is the creation of a unified management apparatus, the development of a strategy for cooperative development and the pooling of efforts for the implementation of joint projects, including those aimed at solving resource conservation problems.
- Development and systematization of identifiers and parameters of the level of resource efficiency of the production system of a petrochemical cluster.
- Preparation of optimal management decisions to increase the level of resource saving of cluster enterprises.

4. Purpose of the Study

The purpose of the research covered in the article is to develop a methodology for monitoring the resource efficiency of a petrochemical cluster's production system. The proposed system should facilitate the identification of problematic aspects of integrated enterprises' functioning and the preparation of management decisions for their optimization. The object of research is the potential Nizhnekamsk petrochemical cluster. Based on the approbation results, it is supposed to identify the level of resource saving of cluster enterprises and identify specific problem points of the production system.

5. Research Methods

Ensuring the efficient functioning and sustainable development of the production system is difficult without regular and high-quality monitoring. The methodological part of the research is devoted to this task. In the literature, there are many approaches to assessing and monitoring the performance parameters of industrial enterprises (Shevchenko et al., 2020). This study is based on a resource-based approach. The level of resource conservation of a manufacturing enterprise can be characterized by such an integral indicator as resource efficiency **(RE)**. In the context of this study, resource efficiency should be understood as the rationality and efficiency of the use of three types of resources:

- Investments in fixed assets **(IFA)** - investment resources attracted to form active (equipment) and passive (industrial buildings, structures) fixed assets, on the basis of which production processes are carried out.

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- Material and technical resources **(MTR)** - circulating production assets, or objects of labor, including raw materials, basic and auxiliary materials, energy resources, as well as production assets of high (cash for industrial purposes) and average (consumer receivables) liquidity.
- Human resources **(HR)** - a set of employees of various professional and qualification groups employed at the enterprise, included in its payroll and possessing the necessary physical capabilities, mental abilities and competencies necessary to participate in production activities.

Certain methods for assessing the effectiveness of cluster initiatives are based on mathematical processing of data obtained using the expert method (Kapoguzov et al., 2019). This approach is typical for studies that use qualitative characteristics as indicators of cluster performance that can be assessed only through an expert survey. The resource-based approach allows the use of quantifiable parameters of the production system, as well as the use of known and development of new performance indicators, the quantitative values of which can be easily interpreted. Based on the indicated categories of resources, it is proposed to evaluate the resource efficiency of the enterprise and the production system as a whole by three analytical units. To prepare analytical indicators adequate to the tasks of monitoring the resource efficiency of an integrated production system, a variety of methodological studies were analysed (Kudryavtseva, Shinkevich, Ostanina et al., 2016; Razminiene et al., 2016).

It should be noted that only relative indicators were selected for the monitoring system. Absolute indicators do not always reflect the performance of the enterprise. For example, the profit may be negligible compared to the investment that brought it. Or a large amount of income can come from a huge workforce. Therefore, it is advisable to correlate the absolute indicators characterizing the result with the resources' quantitative parameters, due to which this result was obtained.

The indicators of the efficiency of using fixed assets included indicators of profitability and profitability of fixed assets, as well as capital-labor ratio. The efficiency of using current material and technical resources is determined by the parameters of the turnover of the main categories of current assets. As for labor resources, their efficiency is determined by the parameters of productivity, profitability and capital-labor ratio.

The authors of this article do not claim to be exclusive of the proposed set of indicators. On the contrary, we believe that the methodology for monitoring complex integrated production systems should leave room for parameter variation. This explains the flexibility of the proposed valuation model.

The main requirement for the technique is the possibility of an integral mathematical assessment of the values of the studied indicators. In other words, the indicators of one analytical block should have ranges of values that can be used to identify the level of resource efficiency of the enterprise. If this requirement is met, then the level of resource efficiency can be assigned numerical values and further mathematical analysis of the data obtained.

Table 1 shows the key indicators selected for each analytical unit.

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Table 1. Resource efficiency monitoring system

Analytical Unit (AU)	**Indicators of Resourse Efficiency (IRE)**
Efficiency of investments in fixed assets **(EIFA)**	Fixed assets turnover: $FAT = \frac{\text{Revenues from sales}}{\text{Average annual cost of fixed assets}}$ The indicator reflects the amount of income from the sale of goods, products, works and services per ruble of the average annual cost of fixed assets of the enterprise, characterizes the degree of efficiency of using fixed assets. Profitability of fixed assets: $PFA = \frac{\text{Net profit}}{\text{Average annual cost of fixed assets}}$ Reflects the amount of profit per ruble of fixed assets, characterizes the profitability of investments in fixed assets. Labor capital ratio: $LCR = \frac{\text{Average annual cost of fixed assets}}{\text{Average number of employees}}$ Reflects the degree of provision of personnel with basic means of production, indirectly characterizes the degree of mechanization and automation of labor.
Efficiency of using material and technical resources **(EMTR)**	Inventory turnover ratio $ITR = \frac{\text{Revenues from sales}}{\text{Average annual cost of inventory}}$ It reflects the number of revolutions made by production stocks during the year, characterizes the rate of involvement of raw materials and materials in the production process, as well as the rate of manufacture and sale of finished products. Cash turnover ratio: $CTR = \frac{\text{Revenues from sales}}{\text{Average annual cost of cash}}$ Reflects the number of revolutions made by the company's cash during the year, characterizes the rate of use of money on accounts and in the cash desk, as well as cash equivalents for production purposes. Accounts receivable turnover ratio: $ARTR = \frac{\text{Revenues from sales}}{\text{Average annual cost of accounts receivable}}$ Reflects the number of revolutions made by the average annual value of the accounts receivable formed in the course of the economic activity of the enterprise during the year. It characterizes the speed of settlement with clients on the commodity loans issued to them.
Human resource efficiency **(HRE)**	Production per employee: $PPE = \frac{\text{Revenues from sales}}{\text{Average number of employees}}$ Reflects the amount of revenue attributable to an average of one employee of the enterprise. Characterizes labor productivity and the efficiency of labor resources use. Staff profitability: $SP = \frac{\text{Net profit}}{\text{Average number of employees}}$ The average amount of profit, conditionally brought by each employee of the enterprise. The indicator reflects the efficiency and profitability of the personnel. Labor capital ratio: $LCR = \frac{\text{Average annual cost of fixed assets}}{\text{Average number of employees}}$ Reflects the degree of provision of personnel with basic means of production, indirectly characterizes the degree of mechanization and automation of labor.

Based on the presented indicators, the level of resource efficiency of the enterprise can be assessed. It is proposed to use the method of rank rating to assess the integral indicator of the RE. Resource efficiency can be assigned one of the following ranks:

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- RE 3 – resource efficiency of the third (high) level.
- RE 2 – resource efficiency of the second (middle) level.
- RE 1 – resource efficiency of the first (low) level.

Resource efficiency is assessed using the algorithm presented below:

1) The values of the resource efficiency indicators **(IRE)** presented in table 1 are calculated.

2) The average statistical value of each IRE is calculated by the formula 1:

$$\overline{IRE} = \frac{\sum_{i,j=1}^{n} IRE\ ij}{n}, \quad (1)$$

i – year; j – cluster enterprise; $\overline{IRE}$ *the average value of the resource efficiency indicator for i years for j enterprises; IREij – value of the resource efficiency indicator of the i-th year of the j-th enterprise; n (= i * j) – number of observations in the sample.*

3) The range is determined, which corresponds to the annual value of IRE. Based on this operation, the rank of IRE is determined:

- low IRE (rating value Rt = 1), if IRE ≤ 0,5* $\overline{IRE}$;
- middle IRE (rating value Rt = 2), if 0,5* $\overline{IRE}$ < IRE ≤ $\overline{IRE}$;
- high IRE (rating value Rt = 3), if IRE > $\overline{IRE}$.

4) The annual rating value of each analytical unit (**AU:** EIFA, EMTR, HRE) is calculated using the formula 2:

$$AUe = \frac{\sum_{i=1}^{n} Rt_i}{n}, \quad (2)$$

i – certain IRE; n – number of IRE in the analytical unit; AUe – annual AU rating of the enterprise; Rt_i *– the rating value of the i-th IRE.*

5) The annual rating value of the resource efficiency of the cluster enterprise is calculated as the arithmetic average of the annual rating values of analytical blocks (formula 3):

$$REe = \frac{\sum_{i=1}^{n} AUe_i}{n}, \quad (3)$$

i – certain AU; n – number of AU in the monitoring system; AUe_i *– annual rating value of the i-th analytical unit; REe – the annual rating value of the resource efficiency of the enterprise.*

6) The annual rating value of the resource efficiency of the cluster is calculated as the arithmetic average of the annual rating values of the resource efficiency of its enterprises (formula 4):

$$REc = \frac{\sum_{i=1}^{n} REe_i}{n}, \quad (4)$$

i – REe of a specific cluster enterprise; n – number of cluster enterprises; REe_i *– resource efficiency of the i-th cluster enterprise; REc – rating value of resource efficiency of the cluster production system.*

Table 2 presents the interpretation of the ranks of the resource efficiency of the cluster.

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Table 2. Resource efficiency monitoring system

Integral indicator	Characteristics of the ranks of integral indicators		
	HIGH (THIRD)	**MEDIUM (SECOND)**	**LOW (FIRST)**
Efficiency of investments in fixed assets **(EIFA)**	The enterprise (or cluster) uses fixed assets with a high degree of efficiency, there is a high level of profitability of fixed assets, mechanization and automation of labor.	The enterprise (or cluster) effectively uses fixed assets, there is a normal level of profitability of fixed assets, mechanization and automation of labor.	The enterprise (or cluster) effectively uses fixed assets, there is a normal level of profitability of fixed assets, mechanization and automation of labor.
Efficiency of using material and technical resources **(EMTR)**	The enterprise (or cluster) maintains a high turnover rate of current assets, which is due to the highly efficient use of resources.	The enterprise (or cluster) maintains a normal rate of turnover of current assets.	The enterprise (or cluster) uses current assets ineffectively, which is manifested in a low degree of their return.
Human resource efficiency **(HRE)**	There is a high degree of personnel labor productivity at the enterprise (or cluster), the number of personnel is optimized.	There is a normal degree of labor productivity at the enterprise (or cluster), the number of personnel is within the norm	The personnel of the enterprise (or cluster) is working inefficiently, presumably there is an excessive number of personnel
Resource efficiency **(RE)**	An enterprise (or cluster) uses production resources with a high degree of efficiency. There is an increased (compared to the normal level) profitability and profitability of production assets, which actualizes the attraction of additional investments and the expansion of production activities.	An enterprise (or cluster) uses production resources with a characteristic degree of efficiency. Profitability and return on assets are normal. This situation actualizes the development of recommendations for the development of the production potential of the enterprise (or cluster).	The enterprise (cluster) uses the available production resources inefficiently. Investments in production assets are low-profit. The current situation requires urgent measures to improve the efficiency of economic activity, since the production system is in a state of crisis.

Further, it is advisable to present the results of approbation of the developed methodology on the example of assessing the resource efficiency of the Nizhnekamsk petrochemical cluster.

6. Findings

The Nizhnekamsk petrochemical cluster was chosen as the main object of research. This cluster has not been officially formed and is in fact part of the larger Kama innovative territorial production cluster. However, NNHK has a huge production potential and, to one degree or another, meets the criteria for identifying potential and latent clusters. The Nizhnekamsk territorial production complex, which includes such giants of the oil refining and petrochemical industry as PJSC Nizhnekamskneftekhim, PJSC Nizhnekamskshina, JSC TAIF-NK and JSC TANECO, can become a production platform for the formation and development of the Nizhnekamsk petrochemical cluster. The main characteristics that define the designated Nizhnekamsk production system as a potential cluster include:

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- Geographic concentration of potential participants. Most of the NHC potential participants are concentrated within the city of Nizhnekamsk with adjacent territories with a total area of approximately 63.5 square kilometers.
- General scope of activity. Nizhnekamsk industrial complex traditionally specializes in the oil refining and petrochemical industries.
- The critical mass of the number of participants. 29 manufacturing and innovation organizations can become members of the cluster based on the goals of their activities and industry specialization, which corresponds to the threshold values of European standards. In addition, the potential cluster includes 15 market organizations and 29 engineering infrastructure organizations (from a total of 44 supporting infrastructure organizations).
- The critical mass of a quantitative indicator of production. The total oil refining level of the two largest refineries in Nizhnekamsk is 16 million tons, which is 5.6% of the gross volume of primary oil refining in the country. PJSC "Nizhnekamskneftekhim" is one of the TOP-10 world producers of synthetic rubbers, is the world's largest producer of polyisoprene (43% of the world market) and is one of the three leading world companies for the production of butyl and halobutyl rubbers.The share of PJSC "Nizhnekamskshina" in the total production of tires in the Russian Federation, including both domestic and foreign tire factories localized in the territory of the Russian Federation, was 20%.

It should also be noted that enterprises and organizations of a potential cluster are linked by close personalized ties and a network form of interaction in terms of joint social and economic projects implemented in the city. According to many researchers, the Nizhnekamsk production site has a significant potential for innovative development of petrochemical production (Malysheva et al., 2018; Shinkevich et al., 2019)

As indicated earlier, the production system of the Nizhnekamsk petrochemical cluster was used as an object for testing the developed monitoring methodology. Table 3 presents the annual AUe rating values of cluster enterprises for the period 2015-2019.

Table 3. Rating values of analytical blocks of resource efficiency by enterprises of the Nizhnekamsk petrochemical cluster

Analytical unit	Year	PJSC Nizhnekamskneftekhim	JSC TAIF-NK	JSC TANECO	PJSC Nizhnekamskshina
EIFA	2015	2,33	3,00	1,67	1,67
	2016	2,33	3,00	1,67	1,67
	2017	2,00	3,00	1,67	1,67
	2018	2,00	3,00	1,67	1,33

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	2019	2,67	2,00	1,67	1,67
	2015	3,00	2,33	1,00	3,00
	2016	2,33	2,33	1,67	2,67
EMTR	2017	2,67	2,33	2,00	2,67
	2018	2,67	1,67	2,33	2,67
	2019	2,33	1,67	2,33	2,67
	2015	1,67	3,00	1,67	1,00
	2016	1,67	3,00	1,67	1,00
HRE	2017	1,33	3,00	2,00	1,00
	2018	2,00	3,00	2,00	1,00
	2019	2,67	3,00	2,00	1,00

Table 4 presents the results of assessing the resource efficiency of enterprises separately and the production system of the cluster as a whole for the period 2015-2019.

Table 4. Rating values of resource efficiency of the Nizhnekamsk petrochemical cluster

Year	PJSC Nizhnekamskneftekhim	JSC TAIF-NK	JSC TANECO	PJSC Nizhnekamskshina	Nizhnekamsk petrochemical cluster
2015	2,33	2,78	1,44	1,89	2,11
2016	2,11	2,78	1,67	1,78	2,08
2017	2,00	2,78	1,89	1,78	2,11
2018	2,22	2,56	2,00	1,67	2,11
2019	2,56	2,22	2,00	1,78	2,14
Average value for the period	2,24	2,62	1,80	1,78	2,11

Integral level of resource efficiency of the core of the Nizhnekamsk petrochemical cluster during the period 2015-2019. was at an average level, which indicates the presence of reserves for the development of the cluster through measures to intensify production activities. The proposed methodology allows us to carry out a factor analysis of the reserves for increasing the resource efficiency of the cluster. For this, the AUe values from Table 3 should be vertically summed for all enterprises for each year. The following results were obtained:

- total rating value EIFA – 41,7.
- total rating value EMTR – 46,3.
- total rating value HRE – 38,7.

Based on the obtained values, it is possible to calculate in percentage terms the degree of efficiency of the cluster's use of investment, material and technical and human resources. To do this, each of the obtained values should be divided by the maximum possible total AUe value for four enterprises (max = 60) and multiplied by 100%. Thus, the Nizhnekamsk petrochemical cluster is characterized by the following values of the degrees of resource use efficiency:

- the degree of efficiency of investments in fixed assets - 69.5%;
- the degree of efficiency in the use of material and technical resources - 77%;
- the degree of efficiency of human resources - 64.5%.

Thus, the reserves for the growth of resource efficiency of the cluster by increasing the efficiency of investments are 30.5% by increasing the efficiency of using material and technical resources - 23%, due to human resource management's efficiency - 35.5%.

7. Conclusion

So, as a result of the study, a methodology for monitoring the cluster's production system's resource efficiency was developed. The developed technique was tested on the example of the Nizhnekamsk petrochemical cluster. Based on the approbation results, reserves were identified for increasing the resource efficiency of the production system. It should be noted that the proposed monitoring system has a high degree of flexibility, since it can be filled with various indicators and allows you to assess the resource efficiency of an unlimited number of enterprises.

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