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SYNCHRONIZATION OF TECHNOLOGICAL DEVELOPMENT OF RESOURCE-PRODUCING TERRITORIES BASED ON THE MODEL OF AN INNOVATIVE HYPERCLUSTER IN SUBSURFACE MANAGEMENT

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A B S T R A C T

The study elaborates on the model of innovative hypercluster platforms in environmental management, which is regarded as a unique kind of innovation cluster developing on the basis of digital environments. A cluster analysis of the technological developments of subsurface management industries is presented, along with the analysis of the main problems arising from the synchronisation of technological development in resource-exctracting industries. In the context of the digital transformation of subsurface management industries, the interaction between various cluster types, digital platforms, and ecosystems is discussed. The primary economic systems and businesses that act as hubs for innovation promotion and serve as the basis for technical synchronisation within the context of an innovative hypercluster in subsurface management are identified for resource-extracting territories. The main directions for synchronising the technological development of these territories are systematized. The emphasis is on digital and intelligent technologies that intersect to establish innovative hyperclusters. In the context of subsurface management, two primary development vectors for innovative hyperclusters have been identified: innovative hyperclusters of resource-saving and sustainable mining businesses and innovative hyperclusters of digital green technologies.

1. INTRODUCTION

Subsurface management plays a crucial role in luring investments in fixed assets and generates high labour productivity; therefore, it is vital to the economies of Russia and many other countries. New technologies that enable not only maintaining the level of raw material production at existing sites but also reorienting to those that are located in remote and hard-to-access areas are one of the fundamental elements influencing the competitive climate of subsurface management industries.

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Resources-producing regions must adopt a proactive policy of technical growth due to the expanding processes of global disintegration, high volatility in the global energy markets, and increased competitiveness in the high-tech product markets. Two opposing tendencies are prevalent in global practice and have a significant impact on resource-producing regions' innovative development.

On the one hand, there are more and more chances for the geographical separation of innovative development processes within the framework of general digitalization. However, the emergence of large technological hubs in the major oil and gas capitals of the world suggests that concentrating technological potential in one location can have an important synergistic effect. In Russia, the innovative activity of those involved in the oil and gas sector contributes 13.9% of innovative goods and 12.1% of innovation costs to the national industrial sector. Subsurface management industries have made a substantial contribution to the growth of the national economy, but they still face a number of challenges, including the requirement to import substitute technologies, boost resource management efficiency, reduce administrative barriers, and train highly skilled personnel. (Mochalova, 2019).

In the context of sustainable development of resource-producing territories (Polianskaya et al., 2019; Dushin et al., 2020), the process analysis of intersectoral integration and establishing value chains by companies in the mineral, fuel, and energy sectors, as well as the analysis of the processes of competition and cooperation between innovatively developed regions and regions rich in resources, is increasing its relevance.

The Concept of Long-term Socio-economic Development of the Russian Federation for the period up to 2020 set a precedent in 2008 for the development of mining-focused territorial clusters in Russia using cutting-edge technologies. The task of analysing and theoretically understanding the impact of cluster development processes on the consistency of technological development in the field of subsurface management is made relevant by the need to protect both national technological sovereignty and the sustainability of the socio-economic development of Russian regions.

In many Russian resource-producing regions, which date back to the Soviet era of planned economic development, there are significant imbalances in the innovative development of production in a market economy. Additionally, there is a lack of a "critical mass" of enterprises in one subsurface management industry for the formation of a cluster, which poses a challenge to synchronising the technological development of resource-producing territories based on the cluster approach.

The meaning of the "cluster" category must also be made clear in light of the multidimensionality of clustering processes under contemporary circumstances, particularly those brought on by the effects of digital closeness and the digital transformation of the economic environment. The emergence of a new, extensive initiative of economic clustering in Russia that involves resource-producing areas that are underserved by existing clustering mechanisms and have not kept up with innovative development is particularly intriguing. The timely approach and relevance of this trend are determined by the active development and introduction of digital technologies into subsurface use, the establishment of globally competitive Russian digital platforms and ecosystems, and the shift from traditional territorial production systems to cyberphysical and cybersocial industrial ecosystems (Ignatyeva et al., 2021; Mochalova et al., 2021; Upadhyay et al., 2023).

Based on the presumption that inventive hyperclusters in environmental management can serve as an organisational model for the chronification of resource-producing regions' technological growth, the study offers a hypothesis. The term "hypercluster" (Greek: hyper, over, beyond) refers to a particular kind of innovative cluster that is based on digital environments and platforms. Its characteristics include multi-industry specialisation, trans-regional economic activity, and the multicore structure of participant network interactions.

2. MATERIALS AND METHODS

It was necessary to apply research methods like abstraction and concretization, analysis and synthesis, induction and deduction, comparison and opposition, in order to solve the set research tasks. We applied methodological instruments from such research domains as regional economics and economic geography. The following methods must be applied in order to complete the aforementioned tasks: systematisation of the examined regional economic systems, clusters and their components, statistical and economic analysis, comparative analysis, and systematic analysis.

For our research, we examined sixteen major resource-producing regions in Russia that are part of five macroregions (Federal Districts) and have the capacity to create and grow cutting-edge subsurface management clusters (Abashkin et al., 2022). These regions include: the Republic of Bashkortostan, the Republic of Tatarstan, the Udmurt Republic, the Perm Territory, the Samara Region, the Orenburg Region (Volga Federal District); the Komi Republic and the Arkhangelsk Region together with the Nenets Autonomous Okrug (Northwestern Federal District); Astrakhan Region (Southern Federal District); Tyumen Region together with Khanty-Mansiysk and Yamalo-Nenets Autonomous Okrugs (Ural Federal District); Krasnoyarsk Territory, Tomsk Region, Irkutsk Region (Siberian Federal District); the Republic of Sakha

(Yakutia) and Sakhalin Region (Far Eastern Federal District).

3. RESULTS AND DISCUSSIONS

3.1 Cluster aspect of technological development of subsurface management industries

The level of federal support for cluster efforts in the Russian regions had drastically plummeted by the beginning of the third decade of the twenty-first century. Based on the dynamics of cluster formation programme implementation, including resource-producing programmes, we can draw conclusions regarding the ultimate downfall of the Russian economy's "first wave" of clustering, which peaked between 2012 and 2015. (Figure 1).

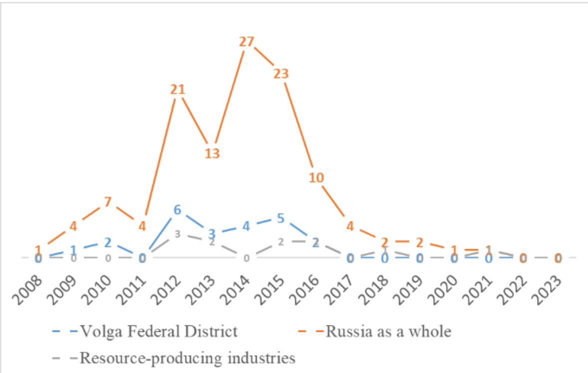

Figure 1. Dynamics of clusters emerged in the Russian Federation and in the subsurface management sector (compiled by the author)

The most industrially developed region of Russia, the Volga Federal District, is used as an example of the subsurface management sector. The unfavourable macroeconomic climate and the inadequate stability of the cluster development model under current Russian conditions are the two main causes of this trend. Meanwhile, the cluster model of economic development keeps performing well in both developing and developed countries. (Morisson & Doussineau, 2019).

Over the past ten years, there have been a number of concurrent changes to the institutional framework of the strategy of clustering and the innovative development of the Russian subsurface sector (Kutsenko et al., 2017). Initially, the resource-producing clusters in Russia emerged within the national "technological modernization" vector, which refers to the technological renewal of production (the initiative for the development of innovative territorial clusters). Then, the political landscape progressively moved in the direction of "import substitution" and "neo-industrialization" (development of the Russian Federation's Register of Industrial Clusters). The innovative transformation of the economy, which primarily represents the shift of Russian industry to the fifth and sixth technological modes, is the technological core of these sectors of national policy.

Throughout the course of the research, every region in Russia was analysed to determine which areas were the most developed in terms of the overall number of businesses engaged in subsurface management and the overall amount of money generated from mining in those areas. Figure 2 displays the number of mining companies operating in Russian Federation entities in 2022.

Figure 2. The number of enterprises engaged in mining in the entities of the Russian Federation in 2022 (compiled by the author)

From the available data, it can be inferred that Russia has an unequal distribution of subsurface management enterprises. Therefore, a number of resource-producing regions can be identified where favourable conditions for the concentration of subsurface management enterprises have arisen. These territories are mainly located in the Volga region, the Urals, Siberia, and the Far East. The Republics of Tatarstan and Bashkortostan, the Khanty-Mansiysk Autonomous Okrug - Yugra, and the Samara Region lead the way in terms of the number of companies operating in the upstream sector of the oil and gas industry. In total, more than 40% of upstream companies operate in these regions. Figure 3 displays the total revenue from mining that the regions of the Russian Federation's enterprises obtained in 2022.

Figure 3. The total mining revenue of enterprises in the regions of the Russian Federation, in rubles (compiled by the author)

Figure 3 illustrates how unevenly mineral extraction is distributed throughout the country's economic landscape. The vast distances that separate the country's central region from the largest reserves, as well as the difficult transportation infrastructure in the mineral-rich Arctic and Far Eastern regions, all exacerbate this issue. (Tolstov et al., 2017; Grigoreva, 2019).

The study included the identification of possible subsurface management clusters in these areas, which included resource-producing businesses involved in the following types: crude oil and natural gas mining, metal ore mining, coal mining, extraction of other minerals, and mining services. Table 1 lists the number of resource-producing businesses that could be involved in innovative subsurface management clusters.

Table 1. The number of resource-producing businesses, potential participants in innovative clusters of subsurface management in Russian regions in 2023 (compiled by the author)

Entity of the Russian Federation	Mining	Crude oil and natural gas	Metal ores	Coal	Other minerals	Mining services
Volga Federal District						
Republic of Bashkortostan	575	32	63	3	317	160
Republic of Tatarstan	487	49	2	1	230	205
Udmurt Republic	191	32	8	0	101	50
Perm Region	243	40	6	0	112	85
Samara region	287	26	15	1	109	136
Orenburg region	313	47	30	1	139	96
North-Western Federal District						
Komi Republic	172	40	8	9	71	44
Arkhangelsk Region and Nenets Autonomous Okrug	76	10	2	0	56	8
Southern Federal District						
Astrakhan region	39	9	0	0	22	8
Ural Federal District						
Tyumen Region Khanty-Mansiysk Autonomous Okrug, and Yamalo-Nenets Autonomous Okrug	796	99	24	1	197	475
Siberian Federal District						
Krasnoyarsk Territory	591	10	349	29	158	45
Tomsk region	134	17	6	1	61	49
Irkutsk region	495	32	210	40	175	38
Far Eastern Federal District						
The Republic of Sakha (Yakutia)	779	20	572	30	132	25
Sakhalin region	123	13	11	19	66	14

3.2 The model of the innovative cluster in subsurface management

The digital transformation of subsurface management sectors can be severely impeded by institutional hurdles that exist within the borders of particular resource-producing areas and by inventive gaps that exist between the elements of the classic innovation model of the "triple helix." One way to get around these would be for innovative cluster participants to interact with one another via digital platforms and ecosystems. (Kapoor, 2018; Klejner, 2019).

The following vectors of development of digital platforms and ecosystems are identified by drawing comparisons with the models of interaction between the Information Society's sectors: Business-to-Business (B2B); Business-to-Consumer (B2C); Business-to-Education (B2ED); Business-to-Finance (B2F); Business-to-Government (B2G); Business-to-Non-Commercial (B2N); Business-to-Science (B2SC); Science-to-Finance (SC2F); Education-to-Citizen (ED2C); SC2ED (Science-to-Education); SC2SC (Science-to-Science).

The potential of the cluster management organisation and other cluster development institutions is greatly increased by the establishment of digital platforms within the innovative cluster. (Prodani et al., 2019). Digital platforms can be used to provide the cluster members with a range of services targeted at lowering the transaction costs associated with innovative activities. These services can also include platforms for the autonomous coordination of scientific, engineering, and production projects. (Perren & Kozinets, 2018).

Three primary generalised variables underlie the integration of high-tech production in the form of innovative clusters, which we have identified owing to the generalisation of the attributive features of innovative clusters (Smorodinskayan & Katukov, 2019): 1) spatial concentration of production; 2) innovative business networks; 3) institutional environment. The digital environment functions as the fourth component in the processes of the economy's digital transformation, which actualizes the consideration of the "points of intersection" of the first three factors (Figure 4).

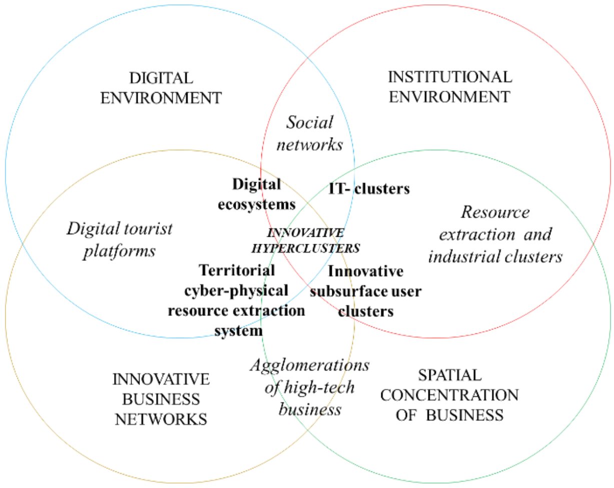

Figure 4. The ratio of different types of clusters, digital platforms and ecosystems in the context of digital transformation of subsurface use industries (compiled by the author)

The integration of businesses in the subsurface management industries is proposed based on the model of an innovative hypercluster in the subsurface use sector, which corresponds to the unique features of the development of the Russian Federation (technological, informational, spatial, infrastructural, institutional, etc.) as well as promising trends in the global economic landscape.

Houston, USA, is one example of a hub for the establishment and development of an innovative hypercluster in subsurface management. Houston's high concentration of intellectual talent has made it possible for the city to emerge as the global leader in science and technology, leading the way in the oil and gas industry as well as a host of other fields. By 2020, this area was home to 67 technological businesses, over 20 research centres, and over 30 incubators, accelerators, and co-working spaces with a focus on different aspects of the fuel and energy industry.

The potential for innovation is also expanding quickly in other fields, including high-tech medicine, space technology, and alternative (green) energy. Nineteen out of the forty corporate research centres in Houston are no longer associated with oil and gas businesses, while eighty-five percent of the area's more than five hundred digital startups operate in non-energy-related fields. (Greater Houston Partnership, 2021).

Russia's St. Petersburg Energy Technology Centre (Energotechnohab) is one example of a hub for the establishment of a cutting-edge hypercluster in the area of subsurface management. Joining "electronic residents" is another crucial element. Techhubspb.ru is a unique online portal designed for this purpose. By registering on “Energotechnohub's” web platform, users can interact directly with potential customers and have access to business tasks from the largest energy companies. (Abashkin et al., 2022).

As of March 2021, the St. Petersburg Power Engineering Hub comprises 130 participating enterprises, representing 20 regions of Russia, Belgium, and Austria. The first prosperous projects emerged, the outcomes of which attracted the attention of several major international oil and gas companies (Middle Eastern and Chinese), in addition to Russian clients.

3.3 Synchronization of technological development of resource-producing territories based on the innovative hypercluster model

Coordinating resource-producing regions' technological development processes within the framework of an innovative hypercluster is considered a cross-cutting activity implemented at three levels:

1. Innovative transformation of the economy in the Russian Federation entities by establishing new clusters related to subsurface use industries, corresponding to both promising trends in the development of the world economy and the specifics of the development of the Russian Federation.
2. Development of interregional economic relationships both inside and beyond the macroregion in order to strengthen the Russian Federation's economic sector by using digital platforms and ecosystems.
3. Diversification of the sectorial structure of macroregions is due to more the adaptable (smart) specialization of Russian Federation entities with a developed extractive industry.

This strategy will make it possible to develop a complex model of technological synchronisation appropriate for the current state of digital transformation, which will serve as the cornerstone for sustainable development in resource-producing regions. In the course of the study, functional clusters, cutting-edge infrastructure, and leading academic and scientific institutions serving as "cores" for the establishment of an innovative hypercluster in the field of subsurface management were located within the designated resource-producing territories. (Table 2).

Table 2. Clusters, innovative infrastructure facilities and institutions acting as centres for the establishment of an innovative hypercluster in subsurface management

Entity of the Russian Federation	Clusters and objects of innovative infrastructure in subsurface management	Leading academic and industrial research institutions in subsurface management
Republic of Bashkortostan	Petrochemical territorial cluster; Eurasian Scientific and Educational Center; ROSOIL Technopark.	Bashkir State University; Ufa State Petroleum Technological University; LLC "RN-BashNIPIneft"
Republic of Tatarstan	Kama innovative cluster "Innokam"; Scientific Center "Rational development of liquid hydrocarbon reserves of the planet"; Technopolis "Himgrad"; Alabuga Special Economic Zone.	Kazan Federal University; Kazan National Research Technological University; Almetyevsk State Oil Institute; V.D. Shashin Tatneft; Nizhnekamsk Neftekhim
Udmurt Republic	Udmurt industrial cluster for the production of oil and gas equipment; Technopark "Industrial"	Udmurt State University; Kalashnikov Izhevsk State Technical University; Izhevsk Petroleum Research Center
Perm Region	Scientific and Educational Center "Rational subsoil use"	Perm State University; Perm National Research Polytechnic University; Perm Nipineft; Novomet-Perm
Samara region	Scientific and educational center: "Engineering of the Future"; Tolyattisintez Industrial Park; Zhiguli Valley Technopark	Samara State Technical University; Samara State Aerospace University named after academician S.P. Korolev; Togliatti State University; Samaraneftegaz
Orenburg region	Mining and Geological Technopark ZBO	Orenburg State University; Institute of Steppe of Ural branch of Russian Academy of Science; Gazprom Georesurs.
Komi Republic	Oil and gas cluster	Komi Scientific Center of the Ural Branch of the Russian Academy of Sciences;
Nenets Autonomous Okrug	Scientific and Educational Center "Russian Arctic: new materials, technologies and research methods"	Ukhta State Technical University
Astrakhan region	Special Economic zone "Lotus"	Astrakhan State Technical University; Gazprom Astrakhan Mining
Tyumen region	Oil and gas cluster; West Siberian Innovation Centre; Industrial Part “Borovsky”	Tyumen State University; Industrial University of Tyumen; TyumenNIIgiprogaz; Gazprom Projecting.
Khanty-Mansiysk Autonomous Okrug	Gas processing cluster; High-tech Technopark	Yugra State University; Nizhnevartovsk State University; Lukoil – Western Siberia.
Yamalo-Nenets Autonomous Okrug	Yamal Regional Technopark	Gazprom Yamburg Mining, Gazprom Urengoy Mining, Gazprom Noyabrsk Mining.
Krasnoyarsk Territory	West Siberian Interregional Scientific and Educational Center	Institute of Chemistry and Chemical Technology of the Siberian Branch of the Russian Academy of Sciences; Siberian Federal University; Reshetnev Siberian State University of Science and Technology; RUSAL ITC.
Tomsk region	Petrochemical cluster; Tomsk Special Economic Zone.	Institute of Petroleum Chemistry of the Siberian Brunch of the Russian Academy of Sciences; National Research Tomsk State University; National Research Tomsk Polytechnic University
Irkutsk region	Petrochemical cluster; Technopark of Irkutsk National Research Technical University	Institute of the Earth's Crust of the Siberian Branch of the Russian Academy of Sciences; L.A. Melentiev Energy Systems Institute of the Siberian Branch of the Russian Academy of Sciences; Irkutsk State University; National Research Irkutsk State Technical University
The Republic of Sakha (Yakutia)	Oil and gas professional and educational cluster; The Yakutia Technopark.	Yakutsk Scientific Center of the Russian Academy of Sciences; Institute of Oil and Gas Problems of the Russian Academy of Sciences; V.P. Larionov Institute of Physical and Technical Problems of the North of the Siberian Branch of the Russian Academy of Sciences; M.K. Ammosov North-Eastern Federal University.
Sakhalin region	Sakhalin Oil and Gas Industrial Park	RN-Sakhalinmorneftegaz.

Within the context of an innovative hypercluster in subsurface management, the economic systems and organisations represented in the table serve as both hubs for the dissemination of innovations and the foundation for coordinating the technological development of resource-producing regions. The Republic of Tatarstan's oil and gas cluster is the largest research and development centre among innovative clusters. It makes up 17% of all

Russian patent applications submitted between 2010 and 2018 that deal with oil and gas issues. Innovative clusters of the Tyumen Region, the Republic of Bashkortostan, and the Samara Region should be identified as the leading educational centers. Between 2010 and 2020, 14% of graduates got qualified in oil and gas industry-related programmes delivered by higher education institutions located in these regions.

In order to strengthen their competitive advantages, these regions have to boost the pace of innovation and integrate universities, research institutions, and businesses into clusters that use digital platforms and ecosystems. The technology startups in resource-producing regions are drawn to the novel hypercluster's digital mechanisms, which also provide remote interactive support from technological and scientific centres located at a substantial distance.

The study outlines the main opportunities for resource-producing regions to coordinate their technological advancements, as well as the digital and intelligent technologies that, on the basis of these, constitute an innovative hypercluster in subsurface management. (Table 3).

Table 3. Main direction for the synchronization of technological development of resource-producing territories (compiled by the author)

The main directions of synchronization of technological development of resource-producing territories	**Digital and intelligent technologies forming innovative hyperclusters**
Hydrocarbon mining	
Technologies for the development of limited, hard-to-reach and alternative natural resources; Technologies for processing and interpreting geophysical studies of wells; New equipment for the development and production of oil and gas in difficult conditions; New types of energy, gas turbine installations, gas and oil pumping stations; New submersible oil production equipment	Digital counterparts of production processes in the field of raw materials extraction, digital technologies for automation and control of technological processes; Intelligent systems for oil and gas production processes ("intelligent field"); Unmanned autonomous field, technologies of service robotic and intelligent systems.
Solid minerals mining	
New technologies for prospecting and exploration of mineral deposits; Technologies for the development and operation of mineral deposits; Technologies for deep and safe mining; Technologies for the complete extraction of minerals from hard-to-enrich ores	Technologies for intelligent monitoring of mining sites; Technologies for robotic extraction and transportation of solid minerals; Technologies for digital modeling of the behavior of materials, machines, structures; An unmanned autonomous deposit
Technologies of rational subsurface management	
New systemic approaches to ensuring human safety, processes, territories; Technologies for minimizing accumulated man-made environmental damage to mining territories; Nature-like technologies for mining, processing of minerals.	Technologies for digital modeling of the behavior of natural objects and many large-scale technical systems; IoT technologies applied to resource-saving industries; Digital environmental quality control and management systems.

The study also identifies two main vectors for the development of innovative hyperclusters within the framework of subsurface use:

1. Innovative hyperclusters of resource-saving and sustainable mining industries, including the following clusters, digital platforms, and ecosystems: clusters of innovative materials for advanced nanoelectronic components and systems, clusters of advanced lightweight materials for energy-efficient structures, clusters of supercapacitors and new materials for energy storage, clusters of membrane distillation and gas separation technologies, clusters of technologies for the efficient use of mineral and metal by-products in raw material processing, clusters of functional multicomponent structures; digital platforms for small-scale extraction of natural resources, digital platforms for monitoring and supervision of exploration and production in deepwater areas, digital platforms for optimizing industrial systems and lines, digital platforms for tracking raw material flows in complex supply chains, digital ecosystems of construction and repair using advanced energy and resource-saving technologies.

2. Innovative hyperclusters of digital green technologies, including the following clusters, digital platforms, and ecosystems: clusters of laser technologies for environmentally friendly industries, clusters of advanced technologies and materials for storing and using hydrogen, clusters of biomaterial production, clusters of production of robotic systems with artificial intelligence, clusters of defect-free and waste-free production technologies, clusters of new technologies environmentally neutral metallurgy, clusters of technologies for responsible raw material mining; digital platforms for the valorization of construction waste, digital platforms for the use of plastic waste as cyclic raw materials for industrial production, digital platforms for determining the availability of secondary raw materials and ensuring the circulation of composite materials, digital compliance verification platforms for buildings and infrastructure, digital platforms for the design and optimization of energy flexible industrial processes, digital platforms for distributed industrial environments managed on the basis of data; digital industrial and urban ecosystems for the utilization of energy, water, industrial waste and by-products.

3.4 Discussion

The concepts and areas of spatial development theory and cluster theory constitute the methodological foundation of the study. The foundations of the theory of cluster development are elaborated in the works of the following foreign researchers: M. Porter (2008), Ketels and Protsiv (2021), O. Solwell (2009), M. Enright (2000), etc. The Diamond Model of Michael Porter should be emphasised as one of the cluster modelling methods that underpin our research. In the context of the current digital transition, Porter's work (2008) offers a more pertinent model of the mutual intersection of the four competitiveness criteria of innovative clusters and cluster-type systems.

In contrast to neoclassical cluster analysis methods, which consider such factors as add value, supply, and demand within the same economic activity category, this research considers the number of businesses operating in different subsurface use industries, such as coal, metal ore, crude oil, and natural gas mining, as well as mining services.

In contrast to M. Enright's (2000) regional cluster model, the new hypercluster model takes macroregions into account when synchronising technological progress. This approach goes beyond regional boundaries.

The network model of interaction between the clustered companies by O. Solvell (2009) and the cluster institutional model by Ketels and Protsiv (2021), in which the clusters are established as a result of integration around industrial enterprises of state institutions, academic institutions, and private investors, is complemented by such elements as innovative infrastructure facilities (technoparks, special economic zones), digital platforms, and ecosystems.

The suggested concept of an innovative hypercluster is of great significance in terms of subsurface management because it combines the interdimensional economic foundation with a multilevel approach to cluster development policy at the macro, meso, and micro levels.

The possibility of forming new transnational hyperclusters in subsurface management with Eurasian Economic Union members (Armenia, Belarus, Kyrgyzstan), observers (Uzbekistan), and prospective partners (Egypt, India, China, Mongolia, Tajikistan, Thailand) is still relevant for Russian regions. Cluster projects based on digital ecosystems gain further potential for development in Russian areas within the framework of the Eurasian partnership and the establishment of relationships with African and Latin American countries within the BRICS.

The hypercluster concept enables the synchronisation of the subsurface management transformation of individual sectoral and territorial segments at the meso-level. Examples of such segments include mono-sectoral old industrial cities and underperforming raw material regions. For resource-producing territories, it is also suggested that in the processes of innovative development, additional consideration be given to the possibility of hyperclusterization of IT businesses and reasonable environmental management in general to sustain the required level of socioeconomic development in these territories.

The hypercluster model examines the potential and opportunities for labour mobility at the micro level, both within and between organisations and clusters, as well as the network implications of their concurrent presence in several clusters. We will also discuss the challenges associated with cluster organisations' cooperation, competition, and presence in the digital sphere. Additionally, we will analyse how digital accessibility affects cluster businesses and how this increases the distribution of cluster impacts' distance.

4. CONCLUSION

Based on the concept of an innovative hypercluster in subsurface management, it was possible to present the author's method for coordinating the technical advancement of resource-producing regions pursuant to the study's findings. The cutting-edge hypercluster in subsurface management is seen as an important component in maintaining the integrity and connection of the economic environment as well as a catalyst for the engineering advancement of resource-producing regions.

Clusters continue to be a crucial tool for improving the effectiveness of the integration of digital platforms and ecosystems with the actual economy. The following global challenges in the field of innovation and high-tech production have led to the need to develop mechanisms for synchronising the scientific and technological development of regions based on innovative hyperclusters: the increase in the amount of scientific and technological information, the development of new methods and tools for processing data, the compression of the innovation cycle's time frame, and the blurring of subject and industry boundaries in research and development.

Comparing the innovative hypercluster in the field of subsurface use to other industrial and resource-producing clusters, one might view it as a more open and dynamic system due to the fact that its participants use digital environments and platforms. At the meso level, organisational, sectoral, and spatial changes are essential for the establishment of innovative hyperclusters in subsurface management. At the micro level, the participating businesses are networking via digital platforms.

Theoretically, an innovative hypercluster may be able to mitigate the barriers to resource-producing regions' technological advancement that arise from the distributed nature of innovative centres and resource-rich areas throughout the country's economic area. Although this is insufficient for the autonomous execution of cluster efforts, the innovative hypercluster model does imply the incorporation of resource-rich periphery territories' industrial and human resource potential. Being a part of the hypercluster enables the participating businesses to disperse efficient institutions established in innovation-active areas throughout their borders and to use the advantages of digital proximity for scientific and technical collaboration with premier innovative centres.

The findings of this study may serve as the foundation for further research into the forms, mechanisms, and tools of digital platforms, innovative clusters, and digital ecosystems integration.

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