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Russia's Arctic Agenda: Projects, Problems, Digital Solutions

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ABSTRACT

Relevance. Fundamentally new infrastructure and production solutions implemented in the Arctic macroregion can subsequently be scaled both in the subarctic regions and in the country as a whole, which determines the importance of analyzing Arctic projects, problems, decisions made and updates research into various aspects of the subject area.

Objective of the study: to study the content of Arctic projects (in the context of priority projects of development support zones), problems and digital solutions in their implementation. Research objectives: to characterize priority projects of development support zones; to study advanced cases of oil and gas companies of China and the Russian Federation in the field of artificial intelligence.

Research methods: systems approach, logical analysis, synthesis, content analysis of open sources, modeling. Results. The introduction of digital technologies in the implementation of Arctic resource projects consists in the preliminary application of intelligent equipment, the use of big data, machine learning and other IT technologies in the processing and analysis of data for exploration and development. The implementation of AI technologies in the resource industries has just begun and, despite the operational effect obtained, has not yet brought the desired large-scale results. The assessment of the effectiveness of Arctic investment projects should be based on a set of indicators of commercial, socio-economic and budgetary efficiency. The proposed conceptual model for assessing the economic efficiency of DT includes three levels of assessment depending on the maturity of the twin and the genesis of the formation of the economic effect. The maximum economic effect from the implementation of DT is achieved through the automation of decision-making, the integration of DT into production processes in real time and a significant reduction in total operating costs. Autonomous and cognitive DT of a high level of maturity provide management flexibility, a strategic increase in the value of the company and the ability to quickly respond to changes in the external environment.

Keywords: Arctic, development, strategic sustainability, support zone, project, digital technologies, digital twin, artificial intelligence, assessment, efficiency, maturity.

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Арктическая повестка России: проекты, проблемы, цифровые решения

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РЕФЕРАТ

Актуальность. Реализуемые в Арктическом макрорегионе принципиально новые инфраструктурные и производственные решения впоследствии могут быть масштабированы как в субарктических регионах, так и в стране в целом, что обусловливает значимость анализа арктических проектов, проблем, принимаемых решений и актуализирует исследования различных аспектов предметной области.

Цель исследования: изучение содержания арктических проектов (в разрезе приоритетных проектов опорных зон развития), проблем и цифровых решений при их реализации. Задачи исследования: характеристика приоритетных проектов опорных зон развития; изучение передовых кейсов нефтегазовых компаний КНР и РФ в области искусственного интеллекта.

Методы исследования: системный подход, логический анализ, синтез, контент-анализ открытых источников, моделирование. Результаты. Внедрение цифровых технологий в реализации ресурсных арктических проектов заключается в предварительном применении интеллектуального оборудования, использования больших данных, машинного обучения и других ИТ-технологий в обработке и анализе данных для разведки и разработки. Внедрение технологий ИИ в ресурсных отраслях только началось и, несмотря на полученный операционный эффект, пока не принесло желаемых масштабных результатов. Оценка эффективности инвестиционных арктических проектов должна базироваться на совокупности показателей коммерческой, социально-экономической и бюджетной эффективности. Предлагаемая концептуальная модель оценки экономической эффективности DT (Digital Twin) включает три уровня оценки в зависимости от зрелости двойника и генезиса образования экономического эффекта. Максимальный экономический эффект от внедрения DT достигается за счет автоматизации принятия решений, интеграции DT в производственные процессы в реальном времени и значительного сокращения совокупных операционных расходов. Автономные и когнитивные DT высокого уровня зрелости обеспечивают управленческую гибкость, стратегическое повышение стоимости компании и возможность оперативного реагирования на изменения внешней среды.

Ключевые слова: Арктика, развитие, стратегическая устойчивость, опорная зона, проект, цифровые технологии, цифровой двойник, искусственный интеллект, оценка, эффективность, зрелость.

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Introduction

Relevance of research. Given the current geo-economic and geo-political context, the Arctic emerges as a key area for development for our country and receives considerable attention from the state, especially in relation to national priorities and global partnerships. The architecture of the PEF program (18–21 June 2025), held under the motto “Common values — the basis for growth in a multipolar world”, confirms it. Thus, within the thematic area “Russian economy: new quality of growth” on the first day there was a session “Maritime route along the northern coast of Russia: 500 years of history”, on the second day within the thematic area “E Business Development: Ensuring Growth” — session “The North Sea Route: Economy of Discoveries”; the session “Arctic in trend” was held on the third day of the forum, before a plenary meeting with the participation of President V. V. Putin. Formulating effective public policy for the Arctic requires a dual focus: first, a rigorous analysis of its evolving processes, and second, the articulation of a developmental vision for this circumpolar region. This vision must champion mutually beneficial cooperation and accommodate the interests of diverse actors, a necessity in today’s polycentric world. The choice of policy tools is contingent upon this prior strategic assessment [19]. Development here is always a “compromise between the need, on the one hand, to ensure environmental protection and adaptation to the effects of climate change and, on the other hand, the need to develop economic activities” [13].

Currently, the Arctic Strategy of Russia is based on the industrial development of the territory of the Arctic Zone with the support of strategically priority projects in the field of mineral exploitation and maritime transport along the North Sea Route, which in today’s geo-economics is becoming the Trans-Arctic Transport Corridor linking Europe and Asia. In the Arctic macro-region, novel structural and production solutions are currently being executed. These solutions have the potential to be expanded in sub-Arctic regions and throughout the nation, highlighting the necessity to analyze Arctic projects, decision-making processes, and to update research on various facets of the subject area.

Purpose and objectives of the study. The aim of the study is to examine the content of Arctic projects (in terms of priority projects of support zones for development), problems and solutions for their implementation. Research objectives: to determine the attributes of Arctic projects; to characterize the main projects in the development support zones; to study notable instances of new gas companies from the People's Republic of China and the Russian Federation in the area of artificial intelligence.

Materials and methods

The foundation of this study's theoretical and methodological aspects was based on the works of both domestic and foreign researchers focusing on the developmental challenges faced by the Arctic zone of the Russian Federation, the implementation of investment projects, and the integration of digital technologies to enhance the efficiency of Arctic investments. The research methodological framework involved a systems approach, logical analysis, synthesis, content analysis of accessible sources, and modeling.

Results

In accordance with the Presidential Decree dated October 26, 2020, № 645 titled "On the Strategy for the Development of the Arctic Zone of the Russian Federation and ensuring national security for the period until 2035", the cornerstone of the State's Arctic strategy is the industrial advancement of the Arctic Zone of the Russian Federation (hereafter referred to as AZ of the Russian Federation) through the establishment of development zones centered around strategic priority projects (hereafter referred to as SDZ). SDZ enables the simultaneous deployment of related instruments aimed at territorial and sectoral development, alongside mechanisms for the realization of investment projects, incorporating the principles of public-private partnership (hereafter — PPP) and municipal-private partnership (MPP). Considering the gradual establishment of production and social infrastructure, the localization and effect of mineral-resource centers should lead "…to the subsequent growth of associated business for population services and main production areas in the Arctic" [7, p. 135]. When implementing investment projects in the Russian Federation, a wide range of financial and economic mechanisms are used to attract investments from various sources. For instance, the execution of the integrated project "Yamal LNG" is facilitated through private investments from PAO "NOVATEK". The construction of the Arctic seaport at Sabetta, located on the Ob Bay of the Kara Sea, is supported by state investments from the federal budget, while the development of the motor section of the bridge over Ob River on the Northern Latitude Railway (Yamal peninsula) is conducted under a concession scheme, augmented by contributions from the regional budget of AO Khanty-Mansiysk.

The following key features of Arctic projects can be highlighted: complex production conditions; fragility of the Arctic ecosystem and its extreme vulnerability; use of PPP with leveraged finance. If the initial two characteristics of project implementation arise from natural climatic and geographical conditions, then the third characteristic pertains to the necessity of securing external funding sources (such as life cycle contracts with extrabudgetary financing or concessions), which can account for over 80 percent of the total extrabudgetary funds in infrastructure projects. [5].

The priority projects of most SDZ involve the establishment of mineral resource centres as points of growth and development of the economy of the territory (Table 1).

Table 1

Characteristics of the supporting development zones of the Arctic Zone of the Russian Federation

Development hub	Area, km^2	Key industries and projects
Arkhangelsk	185 617	Shipbuilding and ship repair (military specialization), civil shipbuilding — in perspective
Kola	139 523	Base of production potential — enterprises of mineral resources sector, mining and metals sector, chemical sector and fisheries sector; tourism development
Nenets	176 810	Basis — development of hydrocarbon resources of the shelf and the land part of the Timano-Pechora oil and gas province
Taymyr-Turukhan	1 095 095	Specialization — production of fuel and energy resources (Vankorsky oil and gas cluster and Taimyr coal mining center, in perspective — Ust-Yenisei and Khateng oil and gas clusters)
Karelian	43 377	The industrial potential is represented by a mineral resource complex for the development of deposits of common and strategic fossil fuels; its development — due to the biotechnology cluster, combining projects in the field of deep processing of forests, bio-resources of the White Sea, minerals
Yamalo-Nenets	769 667	Transit corridor linking the industrial centres of the Urals and the oil and gas centres of Yamal with the European part of Russia
Vorkutan	24 180	Specialization — development of port logistics complexes for the transcontinental connection of the ports of Karsk, Barents and White Sea with the ports of the Pacific
Chukot	723 489	Development of Chaune-Bilibinskaya (polymetals mining) and Anadyrskaya (development of traditional fuel and energy resources) industrial zones
North Yakut	593 875	Anchor projects: diamond, rare-earth and oil and gas projects of the Anatolian territory; Zyryanskiy coal center

Source: Compiled by the author according to the data [16].

In this context, when we talk about the strategic plans and development programs of the Russian Federation, we consider it necessary to correlate them with the strategic stability of the Arctic regions.

The category "strategic sustainability" of economic systems of different levels has long been included in the conceptual and terminological apparatus and is the subject of research both Russian [2; 6; 8; 11] and foreign [17; 20; 21] researchers; nevertheless, it should be noted, that most of the research is devoted to strategic sustainability of micro-level economic systems (enterprises, organizations).

For the purposes of our study, we will correlate the strategic sustainability of the Arctic regions with the "strategic sustainability of the region's enterprise complex". The structural stability of the complex of enterprises in the region is characterized by the ability of enterprises of large, medium and small businesses in the region to ensure long-term economic growth rates sufficient for the development of the economy and social conditions in the region, achievement of strategic objectives and implementation of strategic priorities while preserving the environment in the context of transition and increasing uncertainty and risk on the basis of balanced and continuous development of the enterprise complex of large, medium and small businesses in the region, rational use of material and intangible factors of the development of enterprises in the region, increase their participation in interregional and territorial division of labor.

According to the methodology [8] containing the results of cluster analysis (SPSS Statistics 29, which implements the Varda method using the Euclidean distance square and normalization of indicators), based on the database of professional analysis of markets and companies by the agency Interfax (SPARK-Interfax), Federal Tax Service, rating agency RAEX, all regions of the Russian Federation were divided into 8 clusters. According to the data presented in Table 2, which provides information on 8 subjects of the Russian Federation classified under A3, we can draw the following conclusions: half the regions have a strategic stability that is identified as high (HSS) and above-average (AASS); half the regions have medium strategic stability (MSS)

In our view, these findings can be regarded as evidence supporting the significant likelihood of achieving the anticipated outcomes in the development process of the Arctic macro-region. This is particularly relevant given that one of the key Arctic entities of the Russian Federation, namely the Tyumen oblast' (which encompasses Yamal-Nenets Autonomous Okrug and Khanty-Mansiysk Autonomous Okrug), along with Chukchotka Autonomous Okrug, exhibits "high strategic stability" (final clusters 6, 5, and 7). In the past ten years, a new global mining province has emerged in the northern region of Yamal-Nenets AO: it includes the internationally renowned facilities PAO "NOVATEK" — "Yamal LNG" and "Arctic LNG-2", as well as the less publicized yet more extensive field development initiatives — Bovanenkovsky and Kharazavaysky gas (PAO "Gazprom"), Novoport and East-Messoyakh oil (PAO "Gazprom oil" and PAO "Rosneft").

In the Taimyr area and the northeastern section of the Republic of Sakha (Yakutia), PAO "Rosneft" is carrying out the remarkable megaproject "East Oil", which is the largest project not only for Russia but also for the international economy. The establishment of a new oil and gas province known as East Oil will demand investments totaling 11.753 trillion rubles, with a timeline for project completion set for 2036, during which 83,000 jobs will be created. The execution of this initiative will help meet the targets set by the President of the Russian Federation, which include increasing freight traffic through

Table 2

Rating of strategic stability of the Arctic regions

№	**Subject of the Russian Federation**	**Final cluster**	**Cluster title**
1	Chukotka Autonomous Okrug	7	HSS
2	Tyumen region (including Yamal-Nenets AO and Khanty-Mansiysk AO)	6,5	HSS
3	Komi Republic	6	AASS
4	Krasnoyarsk oblast'	6	AASS
5	Republic of Karelia	5	MSS
6	Arkhangelsk region (including Nenets AO)	5	MSS
7	Murmansk oblast'	5	MSS
8	The Republic of Sakha (Yakutia)	5	MSS

Source: Compiled by the author according to the data [8, p. 49].

the Northern Sea Route to 80 million tons by 2024 and 216 million tons by 2030. The realization of the NSR development plan is expected to contribute over 16 trillion rubles in taxes and nearly 28 trillion rubles in value added to the country's economy by 2035. The characteristics of resource projects that are currently being implemented or are planned within the SDZ of AZ of the Russian Federation are outlined in Table 3.

Arctic investments are "difficult" investments, because the harsh conditions of production objectively require high operating costs, which along with increased investment risks reduces the economic efficiency of investments. Given the lack of population in the region, it can be argued that the introduction of advanced technologies to automate and digitize production facilities are potential commercial solutions for increasing the efficiency of Arctic investments.

Table 3

Resource projects implemented or planned for implementation within the framework of the Arctic Zone of the Russian Federation development support zones

Development hub	Planned projects	Volume and sources of financing, billion rubles	Executive agent
Kola	Reconstruction of the factory with annual capacity increase	6,145 (own funds)	AO "Apatit"
	Modernization of the production capacity of the Kovdor mining and processing plant	4,419 (own funds)	AO "Kovdor GOK"
Arkhangelsk	Development of the Pavlovsky Lead-zinc ore deposit	Total — 18,525 (federal budget — 2,9; extrabudgetary sources — 15,625)	AO "Atomredmetzoloto", AO "Pervaya Gornorudnaya Compania"
Taymyr-Turukhan	Investment projects of the development strategy of "Norilskiy Nickel" mining and smelting enterprise	224,757 (own funds)	Polar division PAO «MSE "Norilskiy Nickel"
Yamalo-Nenets	Implementation of the project "Yamal LNG"	150.0 (federal budget)	PAO "NOVATEK"
Chukotka	Development of coking coal fields	Phase 1 — 8 Stage 2 — 40.3 Phase 3 — 65	OOO "Beringprom ugol'" (ZAO "Severo-Tikhookeanskay ugolnaya kompania")
North Yakut	Creation of mineral and raw materials industrial cluster "UstJana"	1,225 (estimated cost of pilot project, sources unknown)	OAO "Yanolovo", ZAO MSE "Deputatskiy", AO "Corporatia Razvitiya Republic of Sakha (Yakutia)"
	Tymylyr FEC	2500 (approximate cost)	OOO "Arctic uglesintez"; Ministry of Energy of Russia
	Anavar diamond mining center	87 (approximate cost)	AO "Almazi Anabara"
Nenets	Exploitation of hydrocarbon resources on Taimyr	Estimated cost and funding sources not identified	

Source: Compiled by the author according to the following data [16].

The optimization of business processes using modern information technologies with elements of artificial intelligence (hereinafter — AI) allows to reduce costs and increase the efficiency of production activities of companies in the Russian Federation.

Digital transformation of business requires significant investment resources (purchase of equipment, software, expansion of the workforce, payment of integrator services, etc.); regular contingent-permanent costs, required to support the operation of the information system after completion of the project under industrial conditions, represent the cost of ownership. Along with the specific characteristics of digital projects (short life cycle, accelerated moral wear, high degree of differentiation of projects), they are associated with increased risks.

Significant prospects have the results of using three main digital technologies, which already today demonstrate a huge potential for the Russian oil and gas industry: intelligent artificial lift systems (Artificial Lift Systems Smart Well); solutions based on the internet of things (IoT); blockchain technology. Each of these technologies has unique characteristics and potential to affect different segments of the industry.

AI technologies are part of the broad spectrum of Industry 4.0 digital technologies. It should be noted that there is currently no quantitative data on the level of use of AI by enterprises in the real sector of the economy, so it is not possible to reliably estimate the «advanced» companies in this segment of digital technologies, but the focus of AI application strategies in resource industries is already understood (Table 4).

Table 4

AI application focus and technology leaders of the largest subsoil users in the world

Companies — partners	Range of tasks	Platform with AI
BP — Beyond Limits, Belmont Technology	Unified workspace combining seismic exploration and production to hydrocarbon processing for maximum optimization of decision speed and identification of production bottlenecks	Sandy
Shell — Microsoft	Initial focus of the platform — horizontal drilling. Solving the problems of minimizing uncertainties, wrong location of wells and risk of colliding wells in one place, improving safety. The platform will be used to optimize production, sales and financial management	Geodesic
Exxon Mobil — Microsoft+, Dynamics 365	Collection, storage and optimization of data, solutions to optimize the drilling of wells and their finishing in production and simulation of new technologies	XTO
Total — Google	Intelligent E&P, AI solutions for mining forecasting, seismic interpretation and digital core	Cloud Platform
Chevron — Microsoft, Schlumberger	The industry's first tripartite collaboration to accelerate the creation of innovative petrochemical and digital technologies. Covers a wide range of fields: exploration and production, storage and transport of hydrocarbons	DELFI
Schlumberger — Microsoft, Chevron	Covers a wide range of fields: exploration and production, storage and transportation of hydrocarbons. Difference — focus on seismicity and geology, management of filter flows in the stratum made in the format of cloud platform Open Subsurface Data Universe (OSDU) Data Platform	DELFI
Baker Hughes — NVIDIA, Microsoft	Seismic modelling, fault prediction and supply chain optimization	Azure

End of Table 4

Companies — partners	Range of tasks	Platform with AI
Halliburton — Microsoft	Determination of formation characteristics and modelling within the framework of the Landmark platform. Creation of a platform for advanced remote operations in real time. Advanced analytics with Halliburton Data Lake using machine learning and AI	Azure
PetroChina — Huawei	There is a wide range of tasks in the segment “exploration and production”. Digital basins, mining interpretation and data collection, intelligent geophysical exploration, drilling and completion of wells, oil production, fracking and equipment with data collection function	Dream Cloud Platform, Cognitive Computing Platform
Sinopec — Ali	General formulations of creation of digital duplicates of productions, intellectual fields	Oilfield Smart Cloud Industrial Internet Platform
CNOOC — Ali	Smart fields with high-tech drilling systems in the sea. Digital documentation and data management for offshore drilling	Intelligent Oilfield Technology Platform

Authored by source: Artificial intelligence in China’s oil and gas industry https://ngv.ru/articles/iskusstvennyy-intellekt-v-neftegazovoy-industrii-kitaya/?ysclid=m5520 o6wc6772342922.

Data presented in the Table 4, make it possible to conclude that the largest resource companies (subsoil users) are industrial partners of IT companies in developing AI technologies through the creation of integrated analytical platforms. The interaction is quite effective, and the prospects of our companies’ cooperation with partners from PRC are highly appreciated. China, which has observer status in the Arctic Council, has developed its Arctic strategy (“White Book”), according to which it respects the sovereignty of Arctic states and undertakes to comply with international laws on the Arctic. Its interests are primarily related to the exploitation of the Northern Sea Route (in Chinese documents the international term is used “North-East Passage” or “Arctic Blue Corridor”); active activities of Chinese companies are also noted in the sphere of subsoil use [3; 4].

The Asian regional AI market segment, led by the PRC, India and Japan, is growing most rapidly. By 2030, these countries are projected to generate up to $3.0 trillion in annual value added from the use of AI technologies in health care, retail trade, financial sector, manufacturing and transport. [10, p. 62].

In 2017, the People’s Republic of China adopted the strategic initiative “Project for the development of artificial intelligence of the next generation”, enabling Chinese AI developers to become a world leader by 2030. [18, p. 510]. Competences of use of AI by enterprises of mining and oil and gas industry of the PRC have already been formed. For example, a fuzzy neural network has revealed complex relationships between different factors that influence the performance of the gold mining enterprise and the optimal allocation of resources [14].

Consider the experience of Chinese companies in applying AI technologies to the oil and gas sector using three key state-owned corporations: PetroChina (an international energy company that is the largest producer and supplier of oil and gas in China), Sinopec (specialising in gas production and oil refining), CNOOC (mainly producing coal and gas from China’s offshore fields).

Thus, PetroChina, participating in the implementation of joint projects "Yamal LNG" and "Arctic LNG-2", in partnership with Huawei has created a cognitive computing platform E8 that uses the results of processing data sets to make faster and more informed management decisions.

Sinopec started AI development back in 2012 with the creation of the Oilfield Smart Cloud Industrial Internet Platform. The platform solution is based on deep integration of new generation information technology and corporate strategy, promotes modernization and digital transformation of business processes of enterprises.

Offshore oil corporation CNOOC, operating internationally through subsidiary company CNOOC Limited, as an investor in the Russian market is present since 2019 after buying 10% of shares in the project "Arctic LNG-2". In March 2020, a plan for its digital transformation was published. The aim of this plan is to create an intelligent oilfield technology platform for forming intellectual fields and achieving data management for exploration and development.

We will also provide Russian successful cases, which reflect the best experience of leading companies in the domestic oil and gas sector.

Thus, the PAO "Lukoil" Information Development Program has been implementing new approaches and digital solutions through pilot projects and their testing since 2010; in 2016, a system was created that is the basis of the company's flagship digital project — "Intellectual Property". The main objective of the project is to improve the operational model of oil and gas production management; its concept covers the complete production cycle from the exploration stage to the completion of development, includes integrated modelling and planning units, as well as an integrated operations center.

PAO "Tatneft" implemented an automated system of remote control and management (AC DCU), based on the concept of AI and IoT, which allowed to optimize the main business processes in terms of operational control and management of the development of the field, monitoring of technological processes, Real-time emergency prevention.

PAO "Gazprom" together with IBM and Skolkovo Institute of Science and Technology developed a self-learning program capable of adjusting the trajectory of the well shaft to prevent the outflow from the productive zone. A brand-new digital tool that uses machine learning capabilities to quickly analyze the parameters coming from the drilling equipment; application of the program allows for more accurate prediction of changes in the composition of surrounding rock (90% is planned).

PAO "Gazprom Oil" is currently implementing five key digital transformation projects ("Digital Oil", "Digital Drilling", "Cognitive Geologist", "Optima", "Diagnostics of equipment in factories"), in which the most important technological component is the use of AI technologies. In 2014, digital projects were collected into a single concept document, which received the name of Technology Strategy within the framework of implementation of the "Program for innovative development of PAO "Gazprom oil" until 2025".

It is estimated that the expected effect of its implementation via reducing operating costs by 2025 will be more than 100 billion rubles [1]. AI increases well drilling accuracy: the program developed at the scientific and technical center (STC) determines rock composition by analyzing pressure, drilling speed, load on equipment and 10 other parameters to adjust the drilling trajectory.

Separately, it should be noted the development and commissioning of PAO "Gazprom Oil" Complex Automatic Planning Interactive Transportation of Arctic Oil (CAPTAIN). Functional complex — planning, management of the fleet, analysis, predictive analytics. It takes into account 6760 parameters per day: own data (speed of movement, route, fuel consumption), external data (production and accumulation schedule, ice flotation schedule, export schedule, bunkering), independent data (weather, ice conditions, tide/ebb). The effect of the implementation of the complex is formed by increasing safety, reducing costs for Arctic logistics (by 10–12 %), reducing the time of calculation and

Table 5

Characteristics of artificial intelligence methods

AI methods	Characteristics and features of the method
Adaptive neuro-fuzzy method (ANFIS)	Adaptive network based on Takagi-Subeno fuzzy inference system, corresponds to set of fuzzy rules IF-THEN which have the ability to train for non-linear functions approximation
Artificial neural network (ANN) method	Implements an approach based on mathematical models inspired by biological neurons; used to solve complex problems (image recognition, natural language processing, prediction)
Support vector method (SVM)	A set of similar learning algorithms used for classification and regression analysis tasks; the property of this method is continuous reduction of empirical error of classification and increase of gap

Source: Compiled by the author.

coordination of shipping operations. Economic effect generation: optimization of tanker operation costs by choosing the best routes; fuel savings; reduction of ice trenching costs; reduction of downtime; maximization of oil production.

If we consider the process of hydrocarbon development, using methods of adaptive neuro-fuzzy system output, artificial neural network, support vectors (Table 5), one can predict such key petrophysical properties of the layers as porosity and permeability, as well as the water content and stability of the well shaft, which allows to optimize business processes and reduce operating costs.

Digital transformation projects, including AI, are quite costly and small companies generally do not have the necessary financial resources to implement them as part of their corporate strategies.

Of course, the use of algorithms has increased the level of integrated analytical software, and built-in chips have allowed to create intelligent equipment, but oil and gas exploration and production operations are fraught with multiple solutions, small samples etc. which makes it very difficult to spread the use of AI.

Consequently, although leading Russian companies in the oil production and development sector have achieved certain results through the use of AI (primarily in the preliminary application of intelligent equipment, the use of big data, machine learning, and other IT technologies for data processing and analysis in exploration and development, as well as an emphasis on the creation of integrated analytical platforms), this endeavor is still in its infancy and has not yet yielded the anticipated large-scale outcomes.

Discussion

Two theses are put forward for consideration: the first concerning the assessment of the overall effectiveness of investment projects, while the second pertains specifically to the evaluation of the effectiveness of digital initiatives, particularly digital twins (Digital Twin — DT).

1. Considering the specifics of Arctic investment projects, we believe that evaluation of their effectiveness should be based on a set of indicators of commercial, socio-economic and budgetary efficiency. When calculating the commercial efficiency of a project, its debt sustainability should be assessed using appropriate indicators: debt service ratio; debt service ratio; the rate of coverage of debt payments for the duration of the project. When calculating the socio-economic performance of a project, account should also be taken of the monetization of external effects and their subsequent inclusion in the financial model [15].

Table 6

Model for assessing the economic efficiency of DT

Maturity DT level	Direction of economic impact generation	Method and performance indicators
Early maturity (visualization and monitoring DT	Reducing project and operational costs by improving the quality of source data, reducing processing time and improving communication between departments	Cash flow discount methods and revenue performance calculation
Intermediate level of maturity (predictive and recommendatory DT)	Improvement of forecasting accuracy, optimization of maintenance schedules, reduction of unplanned equipment downtimes, more efficient allocation of resources	Calculation of internal rate of return, modified internal rate of return, discount period
High level of maturity (autonomous and cognitive DT)	Maximum economic impact through automated decision making, real-time integration of DT into production processes and significant reduction in operating costs	Methods for estimating real options, adjusted present value and economic value added

Source: Compiled by the author.

2. Digital technologies of “Industry 4.0” are significantly different from the technologies of “Economy 3.0”, as they are based on the use in the design process of cross-cutting digital technologies, which allows to increase efficiency and effectiveness of their implementation. The main characteristics of digital projects are their “focus, technological basis, dynamics and speed of change, work with large volume of data, orientation to digital transformation, complexity and connectivity, security” [12, p. 52].

The methodological approach to investment analysis of the introduction of digital technologies in the oil and gas industry requires adaptation of traditional assessment tools to the specificities of the industry and characteristics of digital transformation. The fundamental elements of this methodology are: discounted cash flow considering the specific risks of digital projects, scenario analysis with modelling different levels of external shocks, analysis of sensitivity of key indicators to changes in the external environment.

For projects involving Digital Twins (DT), the essential aspect of economic efficiency is the maturity level, which reflects the depth of its development: from basic visualization to full cognitive management. Thus, the resulting economic effects vary: at the lower maturity levels, these effects include cost reduction and greater transparency of processes, while at higher maturity levels, they encompass strategic flexibility, adaptability, and the maximization of corporate value. A paper [9] outlines the key technological benefits of utilizing DT in resource industries that impact the operational efficiency of companies, which are identified as increased output of commercial products and an enhanced line penetration rate of equipment. This progression contributes to a rise in EBITDA and cash balance by the end of the reporting period. The following conceptual model can be proposed to assess the economic performance of DT according to its maturity levels (Table 6)[1].

[1] The results of the research conducted by student M.Yu. Khromykh were used in preparation for her final qualifying work, "Development of a conceptual model for creating integrated digital twins to improve the efficiency of company management in the oil and gas industry" (supervisor: E.A. Kuklina, professor of the Department of Business Informatics, Doctor of Economics, professor).

Conclusion

Based on the results of the study, it is possible to draw the following conclusions.

1. Arctic projects are characterized by complex production environments, fragile and highly vulnerable Arctic ecosystems, as well as the use of PPP with leverage. At the same time, a fairly high probability of obtaining the desired results of the development process of the Russian Federation depends on the strategic stability of the Arctic regions.

2. The potential commercial solutions for increasing the efficiency of Arctic investments in mineral and raw material track is the introduction of advanced technologies to automate and digitize production facilities. Currently, the introduction of digital technologies in resource-based Arctic projects involves the prior application of intelligent equipment, the use of big data, machine learning and other IT technologies in data processing and analysis for exploration and development; focus on creating integrated analytical platforms.

3. The introduction of AI technologies in resource industries has just begun and, despite the operational effect obtained, it has not yet brought the desired large-scale results. According to our estimates, it should take at least another 3–5 years for an objective assessment of the economic results achieved.

4. The assessment of the effectiveness of Arctic investment projects should be based on a combination of commercial, socio-economic and budgetary performance indicators. However, the project's debt sustainability should be assessed using appropriate indicators for calculating commercial performance (Debt service ratio, debt service ratio, project debt ratio). When calculating the social-economic performance indicators of a project, one should consider the monetization of external effects and their subsequent inclusion in the financial model.

5. The proposed conceptual model for evaluating DT's economic efficiency includes three levels of evaluation depending on the level of digital maturity and, respectively, the genesis of economic effect formation: initial (visualization and monitoring DT), intermediate (predictive and recommendatory DTs) and high level (autonomous and cognitive DTs).

6. At the initial maturity levels, the economic impact of DT implementation is formed by reducing project and operational costs due to improved data quality, reduced processing time and improved communication between departments; The evaluation of the effectiveness of DT is carried out mainly by means of cash flow discount methods and calculation of relative profitability.

7. At intermediate maturity levels, the economic effect of DT implementation is increased by improving forecasting accuracy, optimizing maintenance schedules, reducing unplanned equipment downtime and more efficient allocation of resources; It is critical to consider cash flow trends and possible changes in operating activities, which makes the use of internal rate of return indicators necessary for assessing the effectiveness, a modified internal rate of return and discounted investment payback period.

8. At advanced stages of maturity, digital transformation (DT) achieves its greatest economic benefits through the automation of decision-making processes, the real-time integration of DT into production workflows, and a substantial decrease in overall operating expenses. In such scenarios, it is pertinent to employ valuation methods such as real options valuation, adjusted present value, and the calculation of economic value added, as mature DTs offer management flexibility, a strategic enhancement of the company's value, and the capacity to swiftly respond to fluctuations in the external environment.

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Conflict of interests
The author declares no relevant conflict of interests.

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