THE USE OF DIGITAL INNOVATIONS IN THE DEVELOPMENT OF THE ARCTIC

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Abstract. The paper describes the application of Industry 4.0 technologies, gives an overview of previous research on digital innovations, and defines goals and objectives of the research. The core concept of «Industry 4.0 technology» and features of the ways to exploit it in the Arctic institutions have been examined. There has been carried out an analysis of international practices to apply Industry 4.0 technologies in all spheres of life. The flexible automated production of goods or services based on new generation robotics and factories in the Arctic zone has been considered as being the highest stage of complex automated production. An example of automated use of products and services are «smart houses», or «smart things». Methods of collection of advanced production technologies have been discussed. A strategy has been developed to select the most advanced production technologies for spheres of life and the best possible strategic option has been defined. Financial and time resources were chosen as optimization criteria.

Key words: Arctic; digital innovations; energy; development strategy; institutions.

1. Introduction

Among Russia’s strategic priorities there is a development of the Russian Arctic zone, a comprehensive exploitation and expansion of its natural resource, fuel and energy base, a year-round navigation along the Northern Sea Route, and security of the country, including military security sector, as well as the preservation of the fragile natural environment of the Arctic region. The Arctic has recently become one of the priority development areas of the world, regional and Russian economy and politics [1.2].

In the Arctic region, the economic, strategic and political interests of many countries, most notably the Arctic Council countries, are closely intertwined. The Arctic Council, which is the key top-level intergovernmental forum to coordinate decisions made by Arctic States’ governments, plays an important role in the development of Arctic resources, affecting various Arctic activities and facing adverse trends in the region [3 - 5]. The documents adopted by the Arctic Council countries contain consensus decisions on the outcomes of the Council’s offices and departments over the past two years and set coordinated Arctic development goals for the next two years.

In recent years, both Arctic and non-Arctic countries, having been acting as observers to the Arctic Council since 2013, developed national strategies and concepts to plan and implement integrated
policies in the Arctic. The Arctic resource development and cooperation strategy features newly emerged perspectives, the most important of which is the use of digital innovation in exploration and development of the Arctic region [6-8].

The main areas of Arctic research are:
- study and prediction of climate change in the Arctic as an important part of the research into the processes of global climatic change.
- assessing and updating data on mineral resources (hydrocarbon, etc) of the Arctic and prospects for their exploitation.
- human security and adaptation to climatic and environmental change in the Arctic.
- economic and social development of the Russian Arctic, thus improving the well-being of ethnic minorities of the North.
- analysis of the current situation and the development perspectives of mobile communication and transport infrastructure; prospects for air traffic and international navigation within the Northern Sea Route.
- impact of the Pandemic «Covid-19» on the health of the people living and working there and on the realization of sustainable development goals of the Arctic region [9].
- analysis of the impact of digital innovation on the transformation of production processes in terms of cyclical dynamics [10].
- assessment of prospects for innovative (digital) modernization of some selected spheres and the Russian Arctic zone as a whole.

The main regions of the Russian Arctic Zone are as follows: Krasnoyarsk Territory, Arkhangelsk Region, Sakha Republic (Yakutia), Komi Republic, Murmansk Oblast, Karelia Republic, Yamal-Nenets Autonomous Area, Nenets Autonomous Area, Chukotka Autonomous Area and the Arctic Sea shelf (that is potentially an area of the Lomonosov Ridge).

The purpose of this paper’s research is to determine the possibility of using Industry 4.0 technologies in the spheres of human activity in the Russian Arctic.

2. Theoretical basis of the study
Theoretically and methodologically, the research is based on a decision-making theory toolkit. A decision-making process is modelled as a decision tree and a predictive alternative graph. Using the decision tree and the predictive alternative graph one can easily generate a variety of possible events that allow for alternatives and finally result in selecting the only best procedure evaluated by a combination of material costs, time and probability of occurrence. The decision tree features technological predictions, project development schemes, and the use of foresight methodology. The foresight procedures simulate potential scenarios for us to be ready to face, and propose strategies to increase the flexibility and adaptability of an enterprise to the dynamic world market environment.

Scenarios and road maps are the most commonly used procedures of technology foresight [11, 12]. The process to design a scenario will model situation images of the future so that the potential randomized conditions of future events might be determined. Therefore, road mapping is a technology foresight practice which makes it possible to reduce the level of uncertainty.

3. Results
Besides the studies by Russian leading scientific research institutions, the interest in Arctic issues have been growing in many foreign centres and universities, including the Arctic Centre, the University of Lapland, Finland; the Netherlands Institute of Maritime Law, the University of Utrecht; the Institute of Fridtjof Nansen, Norway; Korea Marine Research Institute; Ocean University of China, Qingdao, Polar Institute of Woodrow Wilson International Center for Scholars, Washington, USA, etc. Of the utmost importance is the integration of leading Russian and foreign research centers into studies of complex Arctic issues.

The analysis has shown that in recent years Russia and other countries have increased investment in Arctic projects. In the medium term, the total investment in Russian Arctic projects will amount to
more than 10 trillion rubles. Gazprom Petroleum has claimed to increase investment in the digital transformation of the company and its divisions. VTB Bank plans to increase its lending to Arctic development projects up to 1 trillion rubles in the next two years, which means that VTB is ready to allocate 10% of its total capital investment there. The current rate of investment in Arctic research projects of the VTB portfolio is up to RUB 400 billion in loans and RUB 100 trillion in bank guarantees. VTB is planning to double these figures by 2022 [13].

The studies revealed a number of features characterizing a new development stage of the Arctic Zone, which require more intensive research by global and Russian scientific institutions. First, as part of global climate change, the Arctic has faced global geo-climatic changes characterized by gradual global warming and melting of multiyear ice, which offer considerable opportunities to expand economic and logistic processes in the Arctic islands, the Arctic marine shelf and Arctic sea expanses [14,15].

Second, the Arctic zone is to increase estimated mineral reserves (that is, bio-resources, hydrocarbons and other resources of the Arctic) and enhance prospects for their exploitation, particularly in the Arctic shelf [16].

Third, the research is being intensified into the Arctic environment and a range of issues related to adaptation of individuals and groups of residents to climate and environmental changes in the Arctic in the framework of sustainable development concept.

Fourth, the research proved it urgent to accelerate industrial and social growth of the Russian Arctic Zone through strengthening international cooperation, developing the resource base of the region and international navigation along the Northern Sea Route.

Fifth, another feature is to achieve comprehensive security of the Arctic (Arctic securitization) and the Arctic countries, which includes bio-environmental security through biodiversity conservation, ecosystem-based marine management, etc.; political and military security under increasing competition among Russia, Canada, Norway, USA, and China in the Arctic region, considering the fact that the latter formulated its goals and priorities in the region in its «Arctic Policy White Paper» in 2018; technological safety, the safety of navigation, prevention and cleaning-up possible oil spills.

Sixth, development and adoption of international regulatory instruments bring about improvement of the institutional and legal regulation in the Arctic zone (e.g., universal standards of international maritime law, legal regimes for Arctic sea expenses and the use of the Arctic marine shelf under the requirements of sustainable development concept.

Finally, the development and introduction of digital innovation encourages innovative modernization and development of the Arctic zone of Russia and other countries.

Basing on the results of the study, we can highlight a number of promising technological innovations that contribute to the dynamic digital transformation of all sectors and areas of the Arctic economy:
- development of integrated digital platforms and Big Data collection and processing systems;
- development of industrial, logistic and social Internet of things;
- development of cyber-physical systems and their adoption in industrial sectors, in energy, transport, etc. as well as at homes;
- digital design, algorithmic modelling and digital engineering based on neural-network based artificial intelligence;
- generation of digital twins (and digital shadows) of products, devices, equipment, and business processes that include a multi-level matrix of target figures, resource constraints and algorithms of collecting and processing data related to the cloud digital platform;
- setting up engineering centers in order to design, develop and apply innovative products and technologies in the Arctic Zone of the Russian Federation;
- development of digital oil fields and their automated monitoring, operation and effective management systems;
- building up production of competitive high-tech equipment to explore, extract and process raw materials;
- setting up proof grounds (or testing facilities) to run trial of new samples of oil, gas and industrial equipment, as well as to perfect off Arctic design and construction technologies;
- improvement of the environmental safety and flexibility of transport, drone, pipeline and energy systems;
- development of a digital energy infrastructure and digital systems for uninterrupted (optimal) energy supply for industrial and residential facilities;
- extensive use of digital CML-AI systems of intellectual assistants and digital certification of investment projects and business processes in the Arctic;
- construction of a trans-Arctic submarine fibre-optic backbone link connecting local lines of communication to major ports of the northern maritime transport corridor and Arctic settlements;
- development of a high-elliptical space system which provides high-resolution geo-meteorological data in Arctic zones;
- building up a satellite constellation in high-elliptic orbits which provide a stable uninterrupted satellite connection throughout the Arctic;
- designing a real-time system to monitor, assess and forecast continuously the risks of transboundary transport of industrial hazardous waste, dangerous pollutants and infections.

A promising direction to pursue is the alternative energy sector and new unconventional types of energy sources [17] which are to be adapted in technological and environmental terms to the harsh conditions of the Arctic region and have already been proven to be effective. However, we must not neglect the fact that development of alternative energy technologies requires quite significant investment, and can face high risks and substantial expenses to facilitate sustainable operations.

4. Discussion

In the course of this study, we have examined digital technology applications in the Arctic industries. The results are given below.

Due to the current revolutionary transfer of the operational business model and widely used digital technologies, the oil and gas sector is now on the threshold of a new technological era. Digital technologies in the oil and gas industry are commonly used in all segments: in exploration and production, processing, supply management, logistics (warehousing and transportation), as well as in business, marketing and logistic forecasts and planning practices. For example, the digitization of 4D seismic to forecast oil fields in real time is the most advanced innovation being implemented currently.

Networking and digitization provide for new possibilities for intelligent wells and oil fields to be exploited. The extensive adoption and spread of digital intellectual complexes throughout Arctic oil and gas regions are to boost productivity and efficiency of ‘Digital Oil Fields’ and ‘Intelligent Wells’ (‘Smart wells’) [18]. Improvement and extensive introduction of digital mining technologies should lead to a more dynamic development of oil and gas resources of Siberia and the Arctic zone [19].

The development of an intelligent platform, based on artificial intelligence and neural networks, is a promising option which can help monitor, model and predict different exploration scenarios to develop Arctic oil and gas resources, contributing to increased possibilities of choosing the best management solutions. For example, the digitization of oil and gas 4D seismic in real time is an innovative and highly efficient practice.

The most important trend of digitization of oil, gas and energy industries is designing digital twins and digital shadows of energy companies connected to integrated national and global digital platforms. A digital twin is a real image of all components and functions in a product’s life cycle applying big data (physical data, virtual data, and data on interaction between these). A digital twin creates a virtual prototype of a real object, which makes it possible to conduct experiments, test properties, predict behaviour of a real object and deal with its life cycle control [20].

Digital Shadows are systems of relationships and dependencies describing an approximate behavior of a real product in normal operating conditions, and being part of redundant Big Data, this information is obtained from a real object via a large number of sensors and industrial Internet technologies. A digital shadow can only predict the behaviour of a real object under the conditions in
which such big data were collected, but they do not allow modelling possible future situations in which a real product has not yet been used [21].

Today the time to launch new products onto the market has to be reduced in order to meet specific needs of customers. Digital twins allow companies to design and roll out highly competitive innovative products, services and technologies in the world markets within a short time. Therefore, there should be paid special attention to the research and assessment of the future economic effect of digitization of oil and gas industry on governments, regions, companies and population.

Big Data is an integral part of digital platforms (digital ecosystems). These are obtained from various detectors, sensors and meters. In such conditions, with a large amount of data, it is possible to create a digital twin of a unit of an object, product, equipment, process or system (a city, a region, etc.). According to «Navigant Research» and «Bloomberg New Energy Finance» the size of the digital technology market in the world energy industry in 2019 will amount to US $54bln, and it is expected to increase by 3-5% [21] every year.

5. Conclusion
The research we conducted can lead to a conclusion that the current trend in technology development is to elaborate integrated digital ecosystems based on self-learning artificial intelligence (via deep machine learning) and neural networks.

Digital ecosystems allow for convergence of natural, technological, productive, socio-economic and business processes and thus generate synergies [22]. Ufa State Petroleum Technological University carried out a research into the petrochemical quality management system applying neural networks (that is three-layer neural network by means of a mathematical backpropagation algorithm). The system was introduced at production facilities in the petrochemical cluster of the Republic of Bashkortostan [23].

The break-through trend now is to apply the concept of creation and development of the smart settlement, or the smart city (or smart region) in the Arctic. ‘The Strategy for the Development of the Russian Arctic Zone and National Security by the year 2035’ outlines implementing and scaling-up a programme for integrated development of settlements serving as national security instrument and a base for development of mineral resource centres, as well as facilitating Arctic economic and infrastructure initiatives. The most important section of the Strategy is the summary on key development trends of the Arctic zone territories which provide for further research and development of the region.

The concept of the smart Arctic city (the smart region) includes a number of essential components: information and geographic information systems in cities and areas of the Arctic North; energy-saving materials for Arctic construction projects, providing a better quality of urban amenities and residential areas; game-changing new road infrastructure and road surfaces in volatile climatic conditions of the Arctic and building up a logistics network, energy-efficient transport and management systems of “the smart city” (the smart region) of the Arctic through digitization and optimization of both consumption and transportation, while a civil engineering infrastructure is being generated for production and housing sectors; digitization of the accounting system and the system of energy demand and supply regulation; development of urban smart grids and smart energy-saving houses (smart buildings, digital factories); development of advanced technology and shaping an electronic component base, setting up a digital infrastructure and equipment to boost social and economic growth of Arctic settlements and towns; new technologies for air, water and soil treatment; and the introduction of digital sensors to provide ongoing monitoring of the environmental conditions in Arctic settlements and cities.

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