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Intellectualization of Industrial Production as a Factor in Achieving Technological Sovereignty: Essence and Principles

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ABSTRACT

Relevance. In the context of the industry's rapid digital transformation, Intellectualization is becoming a key factor in improving enterprises' competitiveness and technological sovereignty. **Purpose.** This article unveils the essence of Intellectualization, which involves transitioning from the mere mechanical use of information to the intelligent, creative management of production processes through artificial intelligence and big data analysis. The eight principles of Intellectualization, which are based on national strategies and the practical experience of AI implementation in the Russian industry, are presented. **Methods.** These principles form the methodological and strategic basis for the standardisation, safety, and effective application of intellectual technologies. Particular focus is given to intelligent information systems and smart manufacturing technologies, which promote the flexibility, efficiency, and sustainable development of enterprises in the Industry 4.0. **The scientific novelty** of the research lies in its complex approach to developing intellectualization principles that take into account the specific characteristics of individual industries. **The results** of this study lay the groundwork for further research and practical solutions aimed at modernising industrial production and achieving national digital economy goals. This article will be of interest to specialists in industrial management, digital technologies, and innovative development.

Keywords: industrial Intellectualization; artificial intelligence; digital transformation; technological sovereignty; smart manufacturing

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INTRODUCTION

Intellectualization is becoming a defining condition and driving force for the development of modern industrial enterprises. Its necessity is the cause of globalization processes that transform the economic environment and the requirements for the competitiveness of enterprises. There are the following principal factors, which stimulate the Intellectualization of industry: accelerated innovative progress, the growth of the share of intellectual labor in generation of economic products, predominance of information flows in production processes, and strengthening of the role of intellectual resources, which determine the innovative potential at the national and regional levels. These tendencies are the result of the information revolution due to the shift in priority in favor of human capital [1].

Intellectualization of industry is closely related to developing information technologies, particularly, to building self-learning and self-reproducing systems that use knowledge bases to generate algorithms for solving applied problems, in view of specific needs.

The industrial sector has a range of advantages that enables to implement intelligent technologies, including high stability of technological processes, a significant amount of data for machine learning and systematic modernisation of production systems. A number of companies operate by means of determining its organizational principle of continuous upgrading at the institutional level [2].

Intellectual industrial production represents an automated system integrating physical, digital and biological components and this is regarded a national priority. Its development is aimed at modernising enterprises in accordance with the concept of Industry 4.0, improving the quality and innovation of products, which ensures sustainable competitive advantages.

The revised “Strategy for the Digital Transformation of the Manufacturing Industry until 2030”¹ has singled out the following priority ar-

eas: “Smart Production”, “Digital Engineering”, “Products of the Future”, “Technological Independence” and “Governmental Backing of Intellectual Activities”. In 2024–2026, the financing for the implementation the “Smart Production” project amounted to 8.5 billion Rubles primarily from extra-budgetary sources. Its key objectives include optimising resource productivity, introducing predictive analytics and the Industrial Internet of Things, developing domestic software and platforms, and professional retraining of personnel.

Smart production technologies ensure flexible and efficient production processes and they allow for personalised management based on real-time data analysis.

The current stage of digital transformation in industry is defined by proactive introduction of artificial intelligence technologies, which requires the simultaneous involvement of all industries for a well-balanced economic advancement [3]. This will enable to radically improve the quality of products, reduce costs and ensure rapid adaptation to market changes, and concurrently strengthening the positions of enterprises in the domestic and foreign markets and contributing to the achievement of technological sovereignty [4, 5].

Currently, the nature of practical study of the Intellectualization of industrial production is of transdisciplinary character, as it requires a combination of engineering sciences, economics, information technology and management. Thus, this field opens up vast opportunities for a new research. Consequently, R. V. Morozov and I. S. Belyasov in their article contemplate Intellectualization as a comprehensive upgrading of production processes, including technology, personnel, equipment and products [1]. Concurrently, it indicates that Intellectualization leads to the establishing an intellectual space and an increase in product quality, and it also provides sustainable competitive advantages. M. D. Fufaev points out the influence of digital technologies on the improvement of innovation activities in industry, in particular in Russia, and emphasises that digital transformation contributes to the optimisation of processes and an increase in productivity [6].

¹ URL: <http://publication.pravo.gov.ru/document/0001202311090050>

A few other scientific studies indicate that the key areas of Intellectualization of industrial production lead to the introduction of digital technologies, artificial intelligence, predictive analysis systems and intelligent algorithms. All of them contribute to increasing the efficiency, safety and competitiveness of industrial enterprises, especially in the oil and gas sector. The article by O.I. Shiryaeva and N.S. Sarsenbaev gives a methodology for the Intellectualization of oil and gas production. As a case in point, the article provides the examples of employment of a CENTUM VP distributed system and global search optimisation algorithms for the synthesis of regulators, which reduces costs and improves the quality of process control. [7]

The need to solve problems related to the achievement of technological sovereignty requires specifying the essence of Intellectualization and developing principles for the use of artificial intelligence in industry, which is determined by some of the following factors identified by means of analysis of modern scientific literature:

- intellectualization of industrial production is a comprehensive renewal of production processes (including technologies, personnel, equipment and products), which enables to establish a single intellectual space and an increase in product quality, ensuring sustainable competitive advantages;
- understanding the essence of Intellectualization allows to shift from traditional mechanistic systems to those integrating digital technologies and artificial intelligence, which significantly increases the efficiency, safety and innovative potential of enterprises;
- intellectualization is not just the introduction of new technologies, but a special work method of activities, where the key role is played by the cognitive use of information, which contributes to the development of a new, dynamic-and-sustainable knowledge-based economy.

Thus, the given research is focused on defining the essence of Intellectualization in terms of minimising or counteracting threats to the technological development of industrial production,

as well as to identifying the principles of using artificial intelligence in industry as one of the factors of technological sovereignty.

THE CONCEPT AND ESSENCE OF INTELLECTUALIZATION OF INDUSTRIAL PRODUCTION

The conceptualisation of Intellectualization of industrial production plays an important role in assessing the achievement of technological sovereignty. Critical analysis of strategic documents reveal that, despite their importance for the national economy, insufficient attention is rendered to the development of industrial sectors: the latter is characterised by disproportion and pronounced structural disparity. Therefore, it is necessary to take a differentiated approach for deployment of artificial intelligence in this sector, which is also necessary to take into account the industry specifics and, in this regard, envisage the differences in the levels and types of technological threats.

Intellectualization of industrial production is the process of introducing AI and digital technologies, such as a set of solutions that imitate human cognitive functions, into manufacturing sectors to ensure technological independence and increase the competitiveness of the national economy.

The essence of Intellectualization lies in the transition from the mechanical use of information to intelligent and creative production management, which allows establishing a single space for making management decisions based on artificial intelligence and big data analysis. Intellectualization transforms industry and makes it more autonomous and efficient. This is not just a trend. It is an essential requirement in the context of global digitalisation and growing competition: companies implementing these technologies gain a strategic advantage.

However, in order to ensure the Intellectualization process effectively, it is necessary to define the principles of using artificial intelligence in industrial production: namely, the rules, approaches and limitations.

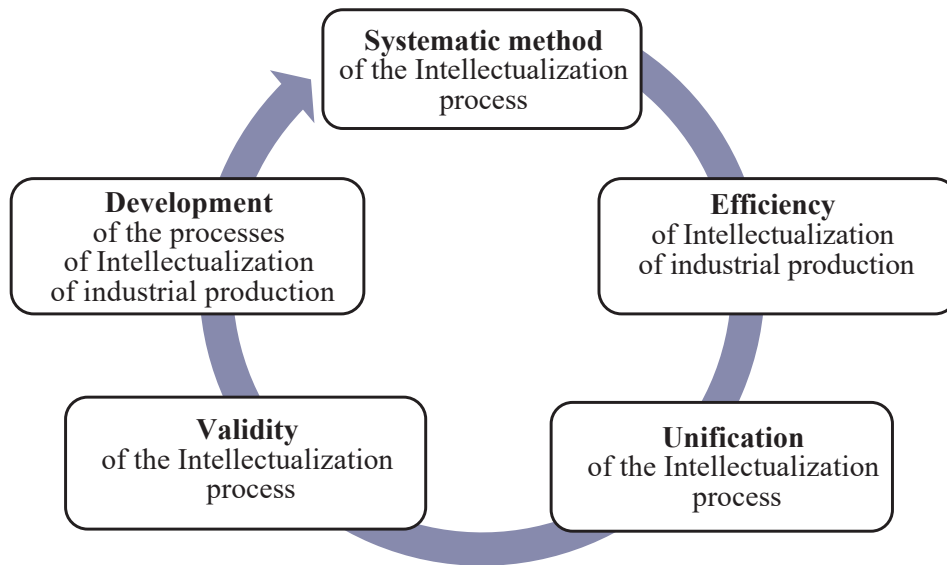


Fig. 1. Prerequisites for Determining the Principles of Intellectualization of Industrial Production

Source: compiled by the authors.

BASIC PRINCIPLES OF USING ARTIFICIAL INTELLIGENCE

Defining the principles of Intellectualization of production processes will contribute to the systematization of knowledge on AI technologies in industrial production, their unification for different industries, as well as progress in achievement of technological sovereignty (Fig. 1).

The development of principles for the utilisation of AI in industry as a factor in Russia's technological sovereignty is based on key documents which formulate the regulatory and conceptual basis for its ethical and secure use: the Strategy for Scientific and Technological Development of the Russian Federation,² the State Program "Development of Industry and Increasing its Competitiveness",³ as well as the National Strategy for the Development of Artificial Intelligence for the Period up to 2030.⁴

The last of these documents defines eleven basic principles for the use of AI (illustrated in the Fig. 2), which should be regarded as basic ones.

Back in 2019, seven initial principles were formulated, and the rest were included in the text of Strategy in 2024. They are all based on the idea that such technologies should make people's lives easier and better, rather than create new threats.

The first principle concerns ensuring the citizens' rights and freedoms in accordance with Russian and international legislation, as well as obtaining their ability to successfully adapt to digital technologies. The second principle ensures the prohibition of the use of AI for the purpose of bringing harm for people and companies and minimising the risks regarding the leakage of personal data or disclosure of classified information. The third one implies the openness and accessibility of AI, equal access for users to the algorithms used in its work. The fourth, quite a separate principle, deals with technological sovereignty, which can be achieved by relying on domestic artificial intelligence technologies. The fifth one assumes a close relationship between developments in the field of artificial intelligence and their implementation in the real sector of the Russian economy. The sixth principle focuses on the use of AI technologies primarily in the scientific and technical sphere and other key sectors for the development of the state. The seventh principle stipulates preventing monopolization in the field

² URL: <http://www.kremlin.ru/acts/bank/50358>

³ URL: <http://government.ru/rugovclassifier/862/events/>

⁴ URL: <http://www.kremlin.ru/acts/bank/44731>

1. Protection of human rights and freedoms
2. Security
3. Transparency
4. Technological sovereignty
5. Integrity of the innovation cycle
6. Most effective use of AI technologies
7. Support for competition
8. Openness and accessibility
9. Continuity
10. Safety
11. Reliability of source data

Fig. 2. Principles of Development and Implementation of AI in Accordance With the Strategy

Source: compiled by the authors.

of AI, ensuring fair competition between organizations using such technologies.

Finally, four more principles, which were introduced into the National Strategy last year. The eighth principle determines a ban to restrict access of industry organizations to AI technologies. The ninth principle implies a gradual incorporating of these technologies for government bodies. The tenth one is their legal protection, and the eleventh principle ensures the reliability of AI-generated data used in model training.

These principles are close to international approaches, however, unlike the latter, they place greater emphasis on sovereignty, and their advantages include the fact that they are aimed at:

- strengthening national security, increasing the competitiveness of the economy and improving the quality of life of the population;
- stimulating domestic AI technologies, which contributes to the country's sovereignty in this area and reducing dependence on foreign digital solutions;
- increasing the level of digital literacy and informing the population about the specifics of artificial intelligence in order to train qualified AI specialists and users;
- creating a foundation for a regulatory framework of documents governing relations which arise in the process of using AI.

However, the mentioned principles have their shortcomings too. Thus, the scientific community has developed a perception, that by the time these principles were defined, Russia's position was not fully reckoned with the global digital space, which may complicate the implementation of the Strategy [8]. However, one of the disadvantages stems from the advantages: despite the fact that the principles facilitate increasing the level of digital literacy of the population and its awareness of the benefits of artificial intelligence, open accessibility to these technologies can also lead to an increasing digital gap as well as to social and economic differentiation.⁵

In addition, scientific researchers raise the issue of the lack of special legislation, which comprehensively regulate AI technologies [9]. Furthermore, although the security principle envisages that violation of confidentiality of personal data is inadmissible, in reality, artificial intelligence can also provide false information, which poses a threat to information security and reduces confidence among AI users [10].

Potential challenges are innate in the principle, which formulates the technological sovereignty and competitiveness of the country should depend on the development of domestic software and

⁵ URL: https://unesdoc.unesco.org/ark:/48223/pf0000380455_rus



hardware systems. This is absolutely a fair statement, but so far, Russia faces sanction limitations related to resources and competencies, which makes its implementation complicated.

Some other disadvantages also include the abstract formulations of some principles, which sound unspecified, without clarifying existing problems and apt measures to solve them. This applies, for example, to the principle of transparency, which provides for equal access of users to AI algorithms, which criteria still do not exist yet.

Thus, the National Strategy can be implemented as a core for developing principles for the Intellectualization of industrial production, however, at the same time it is necessary to take into account the aforementioned potential challenges.

AI technologies display immense potential for their application in industrial production and encompass a broad spectrum of tasks, including:

- automation of production lines, which allow for acceleration and simplification of routine operations;

- projection of demand and optimisation of logistics chains;
- improving product quality by means of analyzing Big Data and preliminarily identifying defects in manufactured products;
- maintenance of equipment, which contributes to preventing malfunctions and reducing downtime.

The principal spheres of AI application in industrial production are illustrated in the Fig. 3.

AI technologies contribute to the following areas:

- Improving the processes of planning, projecting and management decision-making in production. For example, it can be used to forecast failures of equipment and carry out preventive maintenance, consequently reducing the risk of downtime.
- Automating routine operations, which helps employees of manufacturing enterprises to avoid monotonous work. The application of autonomous smart machines, robotic systems

Manufacturing	Mining	Supply of electric power, gas and steam
• Improving product quality and reducing production costs by means of modeling parameters of product • Automating and optimizing of production processes by means of reducing production errors • Minimizing the influence of the human factor • Effective projection of demand	• Optimizing exploration and recovery of reserves based on geophysical data analysis • Enhancing the efficiency and safety of the production process • Preventing downtime of equipment and repairing by means of preventive maintenance	• Reduction of time and costs for design and construction of facilities by means of analyzing data related to conditions of construction sites and experience of previous projects history • Optimization of repairing by means of predictive maintenance of equipment • Optimization of operations management of energy system

Fig. 3. Directions for the Use of AI Technologies in Industrial Production

Source: compiled by the authors on the basis of the following: URL: <https://apr.moscow/content/data>; <https://ivo.garant.ru/#/document/72892976/paragraph/1:0>

and logistics management systems enhances labor productivity.

- Ensuring the safety of workers. AI-based systems can forecast potential risks and prevent emergency situations, reducing human involvement in hazardous processes and mitigating threats to life and health.
- Interacting with customers, increasing their loyalty by means of personalised offers and recommendations.

Thus, AI technologies become a universal instrument that becomes valuable in all areas of activity for enterprises; they create conditions

for enhanced efficiency and broaden the soil for new opportunities. This is particularly essential for the industrial sector, where AI can radically transform key industrial processes.

PRINCIPLES OF INTELLECTUALIZATION OF INDUSTRIAL PRODUCTION AS A FACTOR IN ACHIEVING TECHNOLOGICAL SOVEREIGNTY

During the developing principles of Intellectualization of industrial production one should take into account the specifics of the implementation of artificial intelligence technologies in industry,

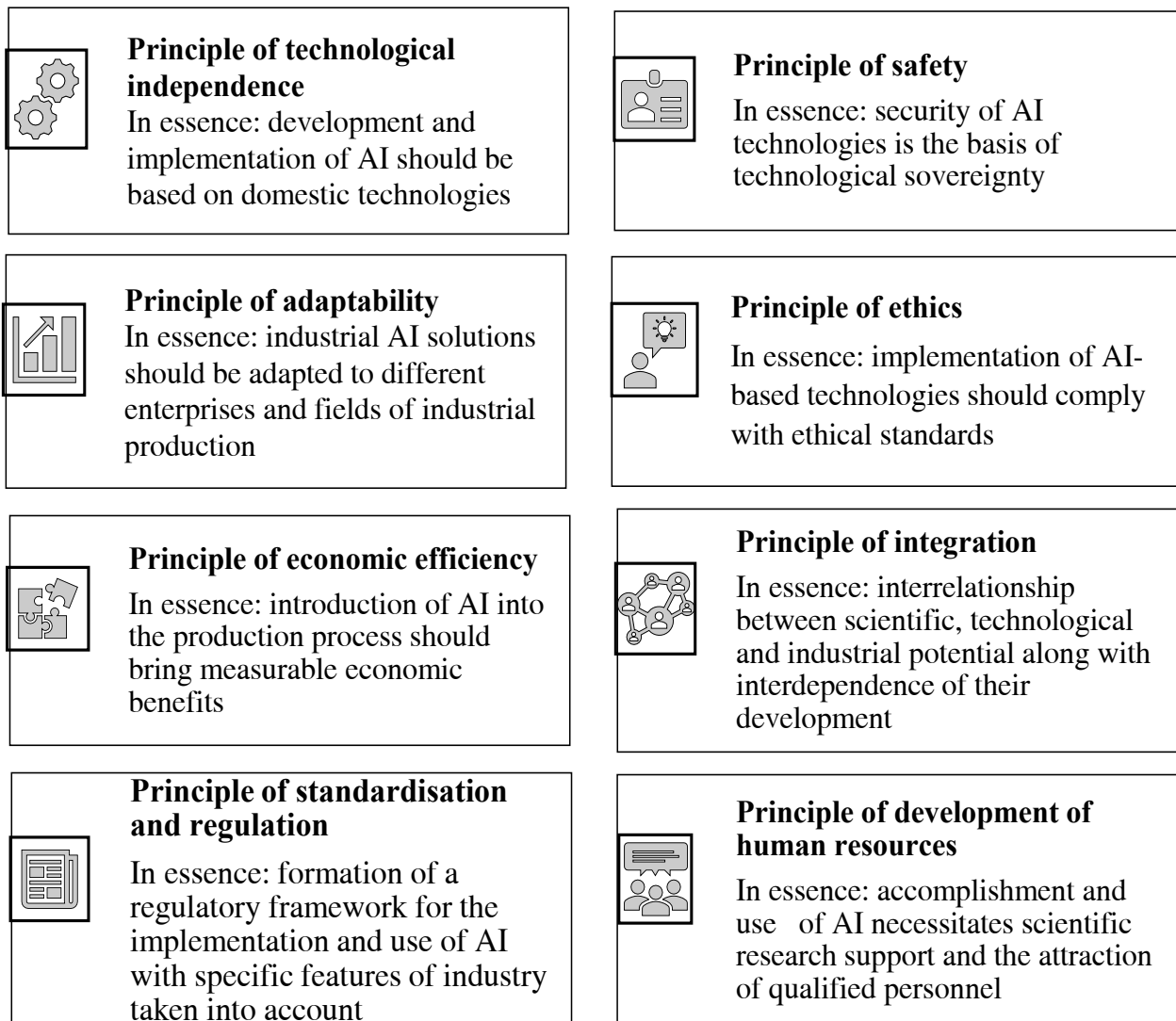


Fig. 4. Principles of Intellectualization of Industrial Production as a Factor in Ensuring Technological Sovereignty

Source: compiled by the authors.



as well as the characteristics of different industries. In essence, an integrated approach should be used, including eight principles (Fig. 4).

The principle of technological independence is established in the Concept for the Development of Regulation of Relations in the Sphere of Artificial Intelligence and Robotics Technologies for the Time Period up to Year of 2024.⁶ It is also in compliance with the Strategy for Scientific and Technological Development of the Russian Federation and the State Program “Development of Industry and Enhancing its Competitiveness”.

It has become a key element of technological sovereignty and it implies the introduction and control of AI technologies in the industrial sector without indispensable dependence on foreign solutions, platforms or data.

Adherence to **the Principle of Security** implies protection of AI technologies from external interference by monitoring stability of industrial systems.

The implementation of **the Principle of Adaptability** in practice includes the design of AI systems in view of the specific aspects of various enterprises and industries, as well as their technological, organizational and economic features. This is particularly essential in the context of structural disparity in industry, when fields of industry are at different levels of digitalization, automation, and readiness for the implementation of AI (according to 2020 data, the share of AI is 5.5 per cent in the manufacturing industry and only 3.4 per cent in the extractive industry [11].

This principle is in conformity with the National Strategy for the Development of Artificial Intelligence for the Period up to 2030, as well as with the Strategy for Scientific and Technological Development of the Russian Federation. It can be implemented by means of differentiated regulation of AI technologies in industries with different levels of development. Adaptability ensures scalability, integration into existing processes (compatibility with various production systems),

flexibility of tuning systems (the ability to meet certain technological requirements) and resistance to changes (adaptability to new circumstances, for example, to a change of suppliers or restrictions related to introduction of sanctions).

The principle of ethics rests on a human-centered approach to the use of Artificial Intelligence, laid down in the National Strategy for the Development of Artificial Intelligence for the Period up to the year of 2030. It guarantees that AI technologies do not bring any harm for human being, society or environment, protect the rights and freedoms of citizens, contribute to the development of the national economy, and it ensures not only compliance with moral standards in industrial AI solutions, but also strengthens technological sovereignty by building trust in national developments.

The principle of economic efficiency implies ensuring measurable economic benefits: reducing costs, increasing productivity, improving quality of product, reducing risks, which altogether contribute to growing profit and competitiveness of enterprises. This is not only related to technological independence, but also economic justification of investments in digitalisation and innovations.

In Russia, practically, unified methodology still does not exist for assessing the economic efficiency of AI in industry, despite the fact, that several regulatory and strategic documents highlight the requirement to put such methodology into effect.

This indicator can be regarded as one of the criteria in the decision-making process of the implementation of artificial intelligence in production processes. Firstly, since investments in AI technologies require considerable costs, so logically, they will be inappropriate without confirmation of economic benefits. Secondly, justification of economic effectiveness allows minimising risks and enhancing returns, which is also important for industrial safety and competitiveness. Thirdly, it contributes to the efficient resource management and the achievement of the state's strategic objectives aimed at the digitalization of

⁶ URL: <https://www.garant.ru/products/ipo/prime/doc/74460628/#review>

production and technological independence. Consequently, the principle of economic efficiency of introducing AI into industry requires that each project should be supported by an assessment of economic benefits.

The principle of integration rests on a close relationship and interdependence of scientific, technological and industrial potentials, which is particularly essential in the context of the Intellectualization of industrial production. Its substance lies in ensuring a single integrated innovation cycle that involves all stages: starting from fundamental scientific research and development up to their effective implementation in the real sector of the economy.

The given principle implies effective interaction and coordination between the scientific community, developers and enterprises. It also takes into account the provisions of the Concept for the Development of Regulation of Relations in the Sphere of Artificial Intelligence and Robotics Technologies for the Time-Period up to the Year of 2024 and the National Strategy for the Development of Artificial Intelligence for the Time-Period up to the Year of 2030.

The integration of scientific, technological and industrial potentials in the implementation of artificial intelligence makes it possible to reduce the time-period between development and implementation. This contributes to the acceleration of technological progress, enhances the competitiveness of enterprises and the efficiency of production thanks to its Intellectualization. Regulatory documents accentuate this principle as a strategic priority, with an emphasis on the coordinated development of all three components, the interrelation of which contributes to achieving independence in the field of high-priority technologies.

The principle of standardisation and regulation in the context of the Intellectualization of industrial production is based on the necessity to build a regulatory framework that would take into account the specific features of various industries. Thus, the Prospective Standardisation Program for the Priority Area of “Artificial

Intelligence” for the years of 2021–2024⁷ included the development of more than 100 national standards covering general and industry-specific requirements for AI technologies.

There exist some standards in the areas of “Artificial Intelligence” and “Technological Readiness”. They have been developed and upgraded for taking into account some specific features of various industries. For example, the standards in the machine tool industry imply the discrete nature of production, dependence on component suppliers and a relatively low level of digital development of enterprises. Thus, the principle of standardisation and regulation of AI in industry presupposes a comprehensive approach to the foundation of a regulatory framework in view of industry specifics.

The principle of development of human resources in the Intellectualization of industrial production is based on the need for comprehensive scientific and research support and training of qualified personnel in view of the industrial specifics of the industry. Specialists who obtain skills in this area are in demand for a successful implementation of AI technologies.

A model of competencies in the field of AI has been developed in Russia. It is implemented in universities and enterprises, and this allows training human resources, that will meet the requirements of digital transformation. All industries have their own specific characteristics, so scientific and educational programs must be tailored to their requirements, which increase the efficiency of the implementation of artificial intelligence.

The development of principles for Intellectualization in industrial production is indispensably important for ensuring technological sovereignty and sustainable economic development. They lay the basis for standardisation, security and effective implementation of AI, which directly influences the competitiveness of enterprises and the national economy as a whole.

⁷ URL: <https://www.economy.gov.ru/material/file/28a4b183b4aee34051e85ddb3da87625/20201222.pdf>



Thus, AI technologies in industry are becoming a strategic tool that guarantees not only a growing, but also prospective economic security.

CONCLUSION

The fundamental core of Intellectualization resides within the transition from the mechanical use of information to intelligent, creative management of production processes, which allows generating a unique intellectual domain of the enterprise and adopting management solutions based on artificial intelligence and big data analysis. Such a transition contributes to the transformation towards more autonomous, efficient and competitive industry in the context of global digitalisation.

The eight principles of Intellectualization implied in industrial production are based on strategic documents, as well as on the analysis of the practice of implementing AI in various fields

of industry. An integrated approach that takes into consideration the basic principles of the National Strategy for the Development of Artificial Intelligence for the period up to the year of 2030 contributes to the formation of a methodological basis for standardisation, security and effective implementation of AI in enterprises and makes up a criterion-oriented base for assessing and managing this process.

Thus, the Intellectualization of industrial production is not a mere technological trend, but also a strategic necessity that ensures sustainable development and competitiveness of enterprises in the epoch of the digital economy. The development and implementation of clearly formulated principles of Intellectualization builds a solid foundation for the effective and safe application of AI in industry, which ultimately contributes to the achievement of national objectives of technological development and sovereignty.

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