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Problems of digitalization of the Russian industry

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Abstract

The article is devoted to the substantiation of the model of the formation of an industrial development ecosystem based on modern digital technologies in industry.

The article deals with the problems of technological sovereignty of the Russian economy. It is shown that the solution of this problem is possible only on the basis of an industrial development ecosystem – a system of production chains of the most important types of industrial products, a technological development platform, interaction of subjects of industrial production with consumers of its products in the domestic and foreign markets. The necessity of concentration of industrial potential, resources of technological development, qualified personnel potential and direction to create conditions for providing the Russian economy with products corresponding to the world technological level is shown. The article analyzes the main existing and promising models of the functioning of an industrial enterprise. A detailed description of the barriers and difficulties on the way of digitalization of industrial enterprises in the Russian Federation is given.

In order to form the ecosystem of industrial development of the Russian Federation, the directions of identifying and assessing the state of production and technological personnel potential, its compliance with the needs of the domestic market are formulated. Recommendations are given on the creation of an ecosystem structure, mechanisms for the interaction of its various elements, a management and coordination system based on digital technologies for creating a system of individual elements that form information and analytical centers in various functional areas of the ecosystem.

A model of the ecosystem of industrial and technological development of the Russian economy based on digital technologies is proposed.

A set of mechanisms that contribute to reducing the level of uncertainty is proposed, and a design method of interaction within the framework of the digital industrial enterprise technology platform model is described.

The article formulates recommendations for the digitalization of an industrial enterprise in the new technological conditions of economic and social development, in the so-called new technological paradigm “Industry 4.0”, the characteristic features of which are minimal use of manual and mechanized labor, as well as a low level of transaction costs.

A new approach is proposed, on the basis of which industrial enterprises will interact on the basis of shared access to information and digital resources and the ability to combine the development of innovative projects and value chains necessary to create competitive products in order to increase the operational efficiency of enterprises.

Keywords: digital technologies, Industry 4.0, global value chains, regional value chains, industrial policy, industrial revolution, digitalization levels, smart manufacturing, advanced technologies, ADP, industry ecosystem.

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Introduction

The key task of the Russian economy is to ensure its technological sovereignty. World practice shows that digital technologies (hereinafter - DT) are effective tools for solving this problem, since they are widely used in leading countries to implement the industrial revolution 4.0 with the transition to a new technological order. It should be noted that DT has been used in industrial production for more than 70 years. Currently, the classification of production systems by the level of use of digital technologies is as follows [Delera et al., 2022]:

- 1st level - inflexible production. For this type of production DT are aimed at organising the solution of a specific problem (production or development);
- 2nd level - lean manufacturing. For this type of production DT organise, regulate and control the quality of various production functions (automation of the production process, interaction between production and development);
- 3rd level - integrated production. For this type of production DT facilitate the integration of different activities and functions (e.g. production management system);
- 4th level - smart production. For this type of production DT provide a fully integrated production process. In this case, not only individual processes are regulated, but feedback is provided in real time. The quality management system for production processes is built on the basis of the application of the Internet of Things and artificial intelligence [Industrial Development Report.., 2020].

1. Description of the research methodology

This study draws on a review of leading research on the application of digital technologies in today's industry. Also, based on the research tools of the United Nation Industrial Development Organiation (UNIDO) in the field of industrial development of countries, they analyse the level of the development of digital technologies in the industry of the Russian Federation by technological levels (from 1 to 4). The results of this study were prepared as part of a fundamental research paper on the topic "The concept of a single digital space for the effective functioning of the Russian industry."

At present all countries use DT at various levels of production development from the 1st to 4th. In the conditions of Russia the 1st and 2nd levels are widely used in production processes. In rare cases the 3rd level is applied (military-industrial complex enterprises). On the whole, Russian industry is characterised by a fragmented production process for complex products (consisting of a number of large units). In addition, to solve the key problem of technological sovereignty, it is necessary to integrate the scientific potential of the Russian Federation. The analysis shows that in all areas of the development of science and technology in the Russian Federation there are teams that work at the world level, but there is no system for organising the work. So, for example, the development of microelectronics is carried out separately in various departments. This reduces development efficiency and contributes to excess costs. Thus, the solution of the problem is possible only on the basis of the integration of scientific, technological, human, financial and other organisational resources with the widespread use of digital transformation of the 3rd-4th levels. It should be noted that in the world, even in the leading countries, a small number of companies operate in the 4.0 standard. This standard is met by technologies such as: electrical energy based on smart power plants, energy from renewable sources, software platforms, industrial Internet of Things, big data analysis, artificial intelligence, industrial and collaborative robots, additive manufacturing, smart manufacturing, the use of which leads to a fully integrated stand-alone manufacturing process. In fact, many of these technologies evolved and emerged based on the same engineering and organisational principles that operated during previous industrial revolutions, which suggests an “evolutionary transition” rather than a “revolutionary breakthrough” [Kupfer et al., 2020].

It should be noted that, despite the widespread introduction of modern technologies in the production process, 70% of companies in the world use "analogue production", in which the level of technology corresponds to the 1.0 standard: manual labor and mechanical devices (mechanisation) are used in most of the production processes. A characteristic feature of "analogue manufacturing" is the lack of use of digital technologies throughout the entire production process (for example, interacting with suppliers in person or by phone, using equipment that is not based on microelectronics) [Industrial Development Report.., 2020].

No more than 15-30% of companies in the world use the latest technological advances that form the next wave of progress (industry 4.0). The process of introducing level 4.0 DT is defined in the literature as the fourth industrial revolution. Within its framework, the convergence of new technological areas is carried out - digital production, nanotechnology, biotechnology and the development of new materials (NBIC convergence). NBIC convergence refers to the acceleration of scientific and technological progress due to the mutual influence of various fields of science - nanotechnologies, biotechnologies, information and cognitive technologies [Schummer, 2009].

2. Theoretical and calculated parts

Modern production requires a high degree of cooperation based on unified technologies and a strict system of control over the production process. Enterprises connected to the ecosystem through cooperation links within the smart industry system access and apply these technologies in production and fall under the classification of advanced manufacturing enterprises, or enterprises with advanced manufacturing technologies (hereinafter referred to as ADP technologies) [Industrial Development Report.. , 2020].

Enterprises that use ADP technologies receive the status of smart factories / plants due to the presence of production systems of industry 4.0, or smart industry. The main features of smart manufacturing are the control over the production process using sensors and equipment connected to digital networks, as well as the use of artificial intelligence to support managerial decision-making. Another characteristic feature of smart manufacturing is manifested in the use of cyber-physical systems (CPS) [Albrieu et al., 2019]. In such a system, sensors, equipment and information systems are connected throughout the entire value chain that goes beyond a single enterprise or business. These systems communicate with each other using standard Internet protocols to predict, self-adjust and adapt to change. Cyber-physical systems cover entire industries and countries at different speeds and in different directions. Equipped with sensors, processors and actuators, these smart network systems are designed to recognise and interact with the physical world and support in real time [Industrial Development Report.., 2018; Readiness for the Future.., 2018].

Industries with a wide product line, such as automotive, food, benefit from the flexibility of cyber-physical systems and productivity growth. Industries that require high quality, such as electronics and pharmaceuticals, benefit from the use of big data and analytics, continuous improvement in product quality and functionality.

Developed countries with a high cost of skilled labor can take advantage of the growing demand for skilled workers. Developing countries with young people who have skills in IT and mechatronics can jump over several technological stages and create completely new production concepts [Challenges for industry.., 2018].

Mechatronics, first introduced into production based on electric drive technology, has become the core of robotics development and determined the level of production automation based on the use of three important components: hardware, software and communications. Thanks to new smart manufacturing technologies, the industrial landscape of the global industry will change significantly [Graetz, Michaels, 2018].

The introduction of digital heating into the production management system is aimed at solving several main tasks:

1. Development, implementation and management of production processes based on the use of digital heating in specific equipment.
2. Ensuring the control of the technical and economic characteristics obtained as a result of a specific production process, the requirements for the characteristics of the entrance to the system (for example, based on the SIPOC principle) for the next production process.
3. Receiving feedback in the form of decision-making and its implementation based on the output of the system.

Researchers and developers of ADP technologies, managing modern manufacturing enterprises, investors of the new industrial landscape, predict quite significant socio-economic results from the introduction of new technologies [Industrial Development Report.., 2020] (Table 1).

It should be noted that when implementing advanced technologies, the main costs are associated with the use of equipment rather than resources, components and assemblies. Therefore, the economic feasibility of using technology is possible only if there is a large-scale production. In this regard, the global economy has formed several centers for the production of nanoelectronics - Taiwan, Japan, South Korea, China [China Manufacturing.., 2017]. These countries account for more than 70% of the industrial production of the global electronics industry. Currently, there is a drop in the production of automotive industry products in the world due to the lack of some microelectronic elements. Modern production, due to its concentration, is sensitive to various kinds of non-economic influences: sanctions, protectionist policies, pandemic measures, and everything else that disrupts global value chains. Therefore, attempts by a number of leading countries to carry out "reshoring" and the creation of appropriate production are facing economic problems associated with profitability: the demand for products at the national level does not cover the costs of production equipment. There is a problem of creating a model of industrial production that ensures the harmonisation of supply and demand under these conditions. Thus, high-tech development of production processes based on cyber-physical technologies is not enough - a fundamentally new systematic approach to organising modern production based on digital heating is needed. When developing such a model, the following should be taken into account:

1. According to UNIDO statistics, the share of ten national economies is about 90% in the segment of advanced industrial and new technologies (ADP) [Kupfer et al., 2019].
2. A high degree of technology concentration used in production is a characteristic feature of advanced digital production.
3. The leading countries - the USA, Japan, Germany, China, Taiwan, France, Switzerland, Great Britain, South Korea and the Netherlands account for most of the innovative activity in the industry. Moreover, even in these countries, only a few corporations have a full deployment of ADP technologies. In

Table 1
Results obtained from the application of advanced digital manufacturing (ADP)

Focus areas	Solutions	Rresults
Development of new competitive production	New solutions for low-income population	Medical devices at affordable prices
	New more adapted to the market business models	• Personalised products, mass customisation • New services and services based on data processing • New pricing models
	Release of goods that meet environmental standards of operation	• Products made from environmentally friendly materials • Improved product energy efficiency
Increasing the efficiency of production capacities	Reducing economic costs and improving energy efficiency	• Reduction of emissions and waste • Accelerating the transition to a circular economy
	Minimisation of operational expenses	• Flexible and decentralised production • Supply chain connectivity, delivery, efficiency and logistics • Flexible, adaptive organisation
	More efficient use of capital	• Diagnostic and automatic maintenance, reduced downtime • Reduced inventory quota, shortenedcash conversion cycle
	Attracting more qualified personnel from the labor market and strengthening cooperation with the service sector	• Improved working conditions, safety • Gender balance in the structure of personnel in production • New skills, task performance efficiency

Source: Compiled by the authors based on UNIDO data.

other countries, no more than 5% of companies have access to the technologies of the fourth industrial revolution.

A characteristic problem of involving the industry of developing countries in a new technological paradigm is an attempt to integrate the technologies of previous industrial revolutions into modern industrial management systems, while the level of mastering the technologies of the previous generation is low (low level of automation and ICT in industry) [Hathaway et al., 2016] (Fig. 1).

The main direction of solving the problems of ADP technology deployment in developing countries is the gradual integration of new technologies into the existing production systems of the previous generation, as well as the modernisation of existing production systems.

Global value chains (hereinafter referred to as GVCs) concentrate the best competencies of various types of production process. In this regard, they are the flagships of the technological development of the world economy.

Currently, there is a process of disintegration of GVCs and their reorganisation at the regional level within partner trade unions. However, it is necessary to solve a number of economic and technological problems and create profitable production [Digital Russia.., 2017].

As a result of the sanctions regime for the Russian economy, there is a need to meet domestic needs in the production of industrial products. The need arose not only for the production of high-tech sector products, but also for the production of automobiles (components, metallurgy). In all these types of production, there are different types of technologies. In this regard, in order to organise a system for the use of digital technologies in Russian industrial production, it is necessary to determine their key areas, which should meet the strategic needs of the Russian economy. In this regard, it is necessary to create an ecosystem for the introduction of digital technologies in industry. One of its sectors should be an information system that can monitor the structure of the domestic market by type of product based on its existing classification. This determines the volume of products, their export-import structure and quality level, as well as the level of novelty (no more than 3, no more than 6 years).

As world experience shows, electronics and mechanical engineering are manufacturing industries that are most susceptible to the transition to advanced technologies. Indeed, these industries are already experiencing large-scale adoption of digital technologies based on cloud computing and 3D printing. And in the field of transport engineering, robotisation of production capacities is widely carried out. Thus, the variety of DT tools used in industrial production is due to the peculiarities of the production process. Therefore, in different countries with different production profiles, different digital technology tools will be used. For example, in Japan and Germany, where the automotive industry is developed, production robotisation processes are being intensively carried out.

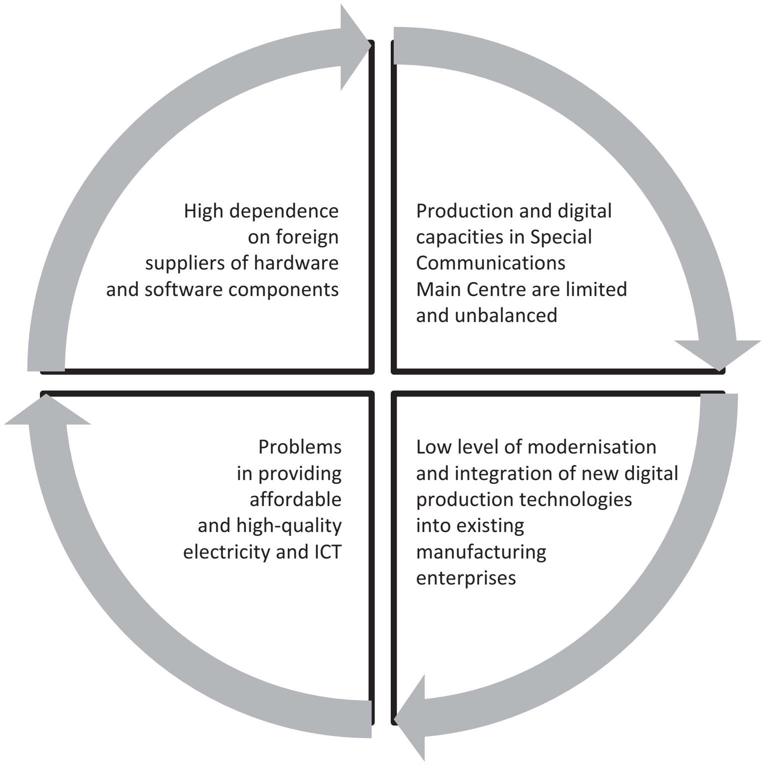
With the help of the existing register of enterprises of the Ministry of Industry and Trade of the Russian Federation, enterprises that participate in the production chain for the creation of these types of products are determined. Further monitoring of production and technological levels, as well as human resources is carried out.

Technological level is the level of novelty of the technologies used (from 3 to 6 years). In each of these age periods the share of imported products is determined.

In this case, the production potential will be determined using the following indicators:

- share of production assets (industrial equipment) up to 3, up to 6 years;
- share of imported and domestic equipment;
- average age of equipment;
- share of export potential;
- labor productivity (GVA / number of employees);
- profitability of production;
- profitability of export products to domestic profitability;
- personnel potential;

Fig. 1. The main problems of ADP technology deployment in developing countries



- share of specialists with higher technical education (in general and up to 50 years old);
- average age of specialists with higher technical education;
- share of workers with secondary technical education (in general and up to 50 years old);
- average age of specialists with secondary technical education;
- share of qualified specialists with a working specialty;
- the proportion of specialists with skills in the use of digital technologies;
- share of technologies that use digital technologies and by types of levels;
- financial efficiency of production;
- financial effect of production capacities.

Based on the results of monitoring, a set of industrial enterprises is formed - participants in the technological chain that produces a certain type of end product.

Based on the technological production potential, the engineering of the technological chain is carried out. According to the results of engineering, bottlenecks that require the purchase of a certain type of equipment and technologies are identified.

Further, a program for the implementation of tasks is being developed, which provides for the introduction of DT at various levels.

The personnel potential for such a system will be determined as follows: the formation of a register of jobs in the technological chain, which indicates the necessary competence and level of education and prescribes the level of competence and its relevance, working conditions and wages. Based on this, a register of all technological chains and jobs is created. Requirements for the competence of the workplaces of specialists graduating from higher schools and institutions of secondary technical education. The organiser must have a register of competencies. The most important requirement in the personnel management system will be the ability to use these competencies in practice and solve non-standard tasks.

The second sector of the new ecosystem will be the sector that forms the production site for the production line. A consortium of enterprises included in a certain production and technological chain is formed.

Stages of work to build this sector:

1. Formation of the production process - preparation of the production site and placement of production equipment, organisation of the system of production processes within the frames.
2. Creation of a system for the selection and development of qualifications of personnel with the necessary competencies to work with digital heating.
3. Establishing the work of production and technological chains of product management.
   The production and technological chain involves control over the technical characteristics of products manufactured at the previous stage, control over production at this stage, control over the result. Such a chain is a set of production sites. At present, the practice of introducing DT has shown that the most effective form of industrial organisation is the organisation of a system of technological chains based on enterprises that perform only production functions.
4. Implementation of a quality management system at all stages of the life cycle: from project management to service maintenance.

A good example of such work is the organisation of a quality management system in the enterprise system of the leading corporation in the global nanoindustry TSCMS (Taiwan). The need to implement this approach in a Taiwanese company arose due to the case of a large manufacturing defect (100,000 microcircuits), which led to economic losses and claims from customers [China Manufacturing.., 2017].

It should be noted that the development of the technological level of production requires certain costs. In this case, the cost of equipment and workplace exceeds the cost of material resources. Therefore, large orders are required and, as a result, such enterprises work around the clock (in several shifts).

For example, most industrial companies need to revise the standards of competitiveness and decentralisation of suppliers. Intel tried to expand the number of suppliers to obtain its nanoplates for electronics, but faced the problem of poor product quality. As a result, Intel was forced to return to the scheme of a single mono-supplier (from Taiwan).

3. Results and discussion

Indeed, in the global economy, the production of high-tech products is present in a limited number of countries - Taiwan, Japan, South Korea, China.

Since the cost of creating smart production is high, it is assumed that the competencies of the production process of certain types of products are concentrated. In this regard, it is necessary to form a federal program for the development of the technological level and structure of industrial production in the Russian Federation.

This program will make it possible to differentiate the focus areas of technological chain production, taking into account the needs of the state's economydevelopment. This approach will allow to concentrate the efforts of the development priorities of the state. For example, the Government of the Russian Federation has determined that pharmaceuticals and electronics are the priority areas for development. The main drawback of the leading Russian industrial development programs is the inefficient methodology for their implementation. It was supposed to support individual enterprises with export potential (metallurgy, production of semi-finished products and fertilisers, food).

As a result - a low technological level and labor productivity, which differs many times from the similar indicator in advanced countries; dependence of the domestic market on foreign supplies in a wide range of industrial products, especially in its high-tech sector. We propose the concept of a program for organising a technological chain, within which the final product is produced, which makes it possible to ensure the technological development of manufacturing industries (means of production, including equipment for the digitalisation of control systems). At the same time, the program is aimed at the formation of sustainable inter-industry relations and the core of industrial development based on the outstripping economic growth of high-tech industries that create complexes of modern equipment for various sectors of the economy.

Due to the fact that the technological level in the Russian Federation is insufficient, it is necessary to organise stable relations with friendly countries that are able to supplement the necessary competencies of domestic technological chains.

In the Russian Federation, there are examples of the effective use of scientific potential in a wide range of scientific problems of production development. For example, the development of the nuclear industry, solving the problems of the aviation industry for defense purposes, the creation of a high-tech military-industrial complex, etc. In these industries, a system of technological chains for the production of a wide range of products has been created. The nuclear industry of the Russian Federation is the only one in the world that produces the entire range of products using nuclear technologies.

It is necessary to create a high-tech sector in the Russian economy, within which, on the basis of the existing technological potential, programs for the modernisation and breakthrough development of production potential are being developed. To do this, the developments of scientists over the past 5-10 years are monitored with their comparison and compliance with the requirements of world science and scientific and technical progress. According to his results:

- scientific teams are determined, the scientific potential of which corresponds to the world level
- a register is formed in which research teams are distributed according to state priorities.
- teams within each direction form development programs with technical specifications for the technical and economic characteristics of products.

To organise the management of the solution of tasks on the technological sovereignty of the Russian economy, a control and coordination center is formed, which consists of departments for each priority area. Each department defines a system of tasks for scientific and technological development. To coordinate their solution, a core is formed [Digital Russia., 2017]. Each core has the following structure:

- management committee, headed by the Deputy Prime Minister of the Government of the Russian Federation, who oversees the relevant direction of the technological development of the Russian economy, and heads of enterprises that determine the technological chain and aggregate product development plans.
- an advisory body under the committee, consisting of leading specialists, developers and technologists who create programs for industrial and technological development in priority areas.
- a group of economists who determine the mechanism and amount of financial support for the development of each priority area. This group is also developing systems of indicators that characterise the effectiveness of its implementation.

The Committee elaborates a development program based on the agreed proposals of the advisory body and a group of economists, and then submits the program for approval to the Federation Council and the State Duma.

Thus, the introduction of DT is a tool for solving the problems of technological sovereignty of the Russian economy. For the comprehensive systemic implementation of digital transformation in the industry of the Russian Federation, it is necessary to create an institute of digital technologies in industry, within which to form a target methodological center for each level of digital transformation. The functions of the methodological center are the development of software, methods for organising the use and training of personnel, a system for monitoring the effectiveness of digital heating use at the appropriate level.

The main directions of the development institute are:

- elaboration of a program-targeted set of directions for the development of the domestic industry;
- formation of the production process based on modern digital technologies;
- selection and advanced training of personnel with the competencies of digital transformation.

Conclusion

It should be noted that the current industrial revolution is the last element in the evolutionary and technological development of the world society, the goal of which, according to a number of experts, is an all-encompassing sustainable industrial development. Development is possible subject to the application of two groups of new technologies based on:

- bringing new products to the market (products that meet the standards of the modern environmental agenda, products of new industries, new jobs and income opportunities);
- growth of production efficiency due to the consumption of energy from renewable sources and raw materials from the latest materials, the development of industrial competitiveness, close ties with related activities (complementary approach).

For the effective functioning of the ecosystem of technological development of the industry of the Russian Federation, it is necessary to form fundamentally new competencies. These competencies can be divided into three groups:

- ability to analyse data and information in the system of production processes;
- professional skills in the use of a certain type of technology;
- engineering and mathematical skills to use relevant knowledge to solve non-standard problems of practical activity.

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