

Smart Manufacturing: essential features and development opportunities in Russia

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Abstract - This article discusses the institutional conditions, the essential characteristics and prerequisites for the development of "smart" manufacturing in the transition to a new industrial revolution. Analysis of the literature, as well as government programs and initiatives in Germany, the United States and Russia allowed to highlight the essential features of the development of smart manufacturing such as the convergence of key technologies, integrated engineering integration, interorganizational integration along value chains, vertical intra-organizational cooperation, providing flexibility and adaptability.

To determine the possibilities of practical implementation of the concept of smart manufacturing, an analysis of the development of information and communication technologies in the context of entrepreneurial activities was carried out. In addition to intersectoral comparison, a comparison was made with the level of developed countries. It was revealed that the majority of the business areas of Russia are below the level of developed countries, but this difference is not so significant at present.

Keywords – *smart manufacturing; smart factory; Industry 4.0; digital economy*

I. INTRODUCTION

The transition of developed countries to Industry 4.0 has a far-reaching impact on the economy and society as a whole. The quintessence of transformations is the emergence of "smart" factories, which define a new way to create customer value, and possibly due to the development of digital technologies.

The selection of the essential features of "smart" factories and consideration of their development opportunities are an actual research task.

Composition of Analysis Process

This study includes several stages: first, state strategies and initiatives related to "smart" production were investigated, then, based on them and on the basis of a critical literature review, the essential features of smart manufacturing were identified. Then, using the state statistics data, an analysis was made of the dynamics of the development of information and communication technologies in the context of business sectors to assess the prospects for the development of smart manufacturing.

II. LITERATURE REVIEW

Despite the fact that the term "Industry 4.0" was first publicly uttered at the "Hannover Fair" 2011, yet in 2013 the first report appeared with recommendations for the development of this strategic initiative in Germany.

The report notes that Germany should adopt a dual development strategy in the face of modern challenges: maintaining the leadership of the manufacturing industry through the consistent integration of information and communication technologies; the creation and maintenance of new markets for technologies and products of cyber-physical systems (CPS). All this will require large-scale research and development and will have to be accompanied by appropriate decisions in the field of industrial policy [1, p. 6].

The US is actively developing and funding Smart Manufacturing development initiatives. Thus, the Smart Manufacturing Leadership Coalition, created in 2012, already by 2015 includes 25 companies, 7 universities, 8 consortia, and 1 research institute engaged in creating the concept and roadmaps for the development of technologies of the new industrial revolution.

China, one of the leaders of the digital economy [2], according to the five-year strategic plan “China Manufacturing 2025”, intends to make a transition to smart manufacturing in 13 key industries and new sectors of the digital economy by 2025.

In Russia, the state support of the digital economy is carried out in accordance with the Digital Economy Program¹, which defines it as “economic activity, in which the key factor in the production is digital data”. This program is aimed at the formation of key institutions and basic infrastructure elements of the digital economy, which include the creation of information infrastructure, provision of innovative security, regulation, education and staffing, as well as the formation of relevant competencies and capabilities.

It is expected that as a result of the implementation of the program, by no less than ten national companies will be established by 2024, working with “through” digital economy technologies in the global market; the proportion of people with digital skills will increase; the quality of Internet access and coverage of 5G networks will improve; the number of university graduates in areas related to information technology will increase. The achievement of the results of the program is promoted by the Decree of the President of the Russian Federation of 07.05.2018 No. 204², in which the most important national development goals of Russia are formulated, to which the “Digital Economy” also applies.

The works of O. Romanova are devoted to the formation of industrial policy as the main tool for supporting the development of the digital economy. [3, 4]. The development of a roadmap for the implementation of the program is devoted to the study of A. Babkin. et al. [5]. The works of [6, 7] are devoted to domestic features of digitalization and the possibilities of implementing the state program.

A review of research devoted to the transformation of organizations, government programs and strategic initiatives mentioned earlier revealed the following essential features of Smart Manufacturing:

1. Key Technology Convergence

Research on key technologies (other names - “end-to-end”, “megatrends”) Smart Manufacturing began to appear in large numbers starting in 2013. [8].

The key technologies for the development of Smart Manufacturing are listed below:

Cyber Physical Systems (CPS) – technological solutions that combine virtual and physical reality to create a space in which objects can interact with each other, creating a single network. In the CPS, sensors, drives, and hardware constitute at the physical level, data, communications, and software are at the cyber level [9]. Currently, the focus of attention of researchers is a description of processes and conceptual models. [10].

Internet of things (IoT) - technology of data exchange between devices using the Internet. According to analysts, by 2021 the market for software and infrastructure support for the Internet of things will be the largest in the field of information technology [11, c.74].

Today, IoT technological solutions are most prevalent in the housing and utilities sector, logistics and transport. Thus, the use of smart sensors IoT technology in the port of Hamburg made it possible to increase its throughput by 178% [12, p. 1345]. Promising areas of development of the Internet of Things are medicine, industry, energy and agriculture.

Big data – technological solutions, processing of large, complexly structured data files, including technical and methodological aspects [13].

Cloud Manufacturing (CM) – a common name for solutions that allow the use of cloud technologies to the manufacturing process, which will allow creating temporary and reconfigurable production lines upon a client request by accessing a common set of diverse and distributed production resources.

Smart sensors which devices are equipped with in production systems.

Additive (layered) production and 3D printing – a way to transform a 3D model into a physical object by connecting thin layers of various materials (plastic, metal, composite materials and even cells of the human body) by means of a laser, ultrasonic vibration, etc.

Virtual Reality (VR) and Augmented Reality (AR) Technologies

Under augmented reality is usually understood as an environment in which the physical world in real-time mode is complemented by digital data using various devices.

Virtual reality technology allows using computer graphics to construct an artificial world, elements of which are transmitted to human senses using special devices — helmets, glasses, gloves, etc. Today it is mainly used in the field of entertainment.

An important feature of key technologies is their interpenetration - convergence. For example, the creation of cyber-physical systems is impossible without smart sensors that exchange data using the technology of the industrial Internet and are analyzed by tools of big data.

2. Complex engineering integration (End-To-End)

This type of integration is the use of common platforms. Unlike traditional enterprises for which their assets are the basis for the creation of value, for Smart Manufacturing, the digital and / or technology platform becomes the basis for value creation.

For example, Uber does not have its own car fleet, Booking does not own hotels, Alibaba does not produce goods, they are all examples of successful digital platforms.

Integrated engineering integration is the use of a consistent model of a customized product at all stages of its development - from idea to implementation and to service the manufactured product and its final processing, which becomes possible when using a chain of compatible software tools, thereby creating opportunities for fine-tuning the manufactured products, repetition and scaling of the production process, the use of distributed power [14].

3. Cross-organizational value chain integration

Most of the studies on Smart Manufacturing highlight the importance of deep inter-organizational collaboration, which goes far beyond sales and promotion agreements.

¹ Approved Decree of the Government of the Russian Federation No. 1632 – r of July 28, 2017

² <http://kremlin.ru/acts/bank/43027/page/1>

The vision of an organization's competitive advantages is viewed from the perspective of full cooperation with other organizations, including joint planning, coordination, cooperation in joint projects, the exchange of necessary information and knowledge that will lead to the creation of new business models [15-17]. The monograph of the founder and president of the World Economic Forum in Geneva, K. Schwab, notes the importance of collaborative innovation in building business platforms. [18].

In this regard, the creation of smart enterprises affects not only industry, but all areas of entrepreneurial activity. Obviously, the effectiveness of the entire network depends on the effectiveness of the weakest link, so in the future we will analyze the maturity of information and communication technologies in all areas of business.

4. Vertical intra-organizational cooperation, providing flexibility and adaptability

It implies the integration of all subsystems of an organization at different hierarchical levels from individual sensors to high-level planning systems at the company level (ERP), including a combination of hardware, software and mechanical devices.

One particular case of vertical integration is the creation of a multi-agent system (MAS), in which production resources are defined as intelligent agents who negotiate with each other to coordinate and dynamically reconfigure production, providing the necessary flexibility.

Vertical integration provides smart enterprise qualities such as dynamic configuration — when switching to different

types of products, the necessary resources and production scheme can be reconfigured automatically

online and self-organizing, meaning that the control function is distributed between several objects that communicate with each other, providing flexibility and agility of the system.

It is expected that the transition to smart production will allow to introduce more innovations, reduce their time to market, diversify the portfolio of products and services provided, and ensure deeper compliance with customer needs. [19].

Analysis

The development of information and communication technologies is an indicator of the possibility of developing "smart" manufacturing. In this connection, it seems appropriate to analyze the dynamics of changes in ICT usage indicators by business areas. The information base for the analysis is state statistics. In addition to intersectoral comparison, a comparison is made with the level of developed countries to assess compliance of the degree of ICT development with the world level.

The basis for the development of cyber-physical systems is the use of global networks and, first of all, the Internet. The data on the use of the Internet (Table 1) show that the use of the Internet has decreased in most business activities, which is a negative factor. By this indicator, Russia lags far behind European countries. For example, in Germany, Spain and Italy, the same indicator - 98%, in the UK - 95% [20]. The reduction is probably a consequence of the awareness of threats related to information security, since the greatest decrease is shown by those areas of activity in which this indicator is quite high.

TABLE I. SHARE OF ORGANIZATIONS THAT USED THE INTERNET AND HAVE THEIR OWN WEBSITE, BY TYPE OF ECONOMIC ACTIVITY (AS A PERCENTAGE OF THE TOTAL NUMBER OF SURVEYED ORGANIZATIONS OF THE CORRESPONDING TYPE OF ECONOMIC ACTIVITY)

Indicator	2014	2015	2016	2017	Change 2017 to 2014	2014	2015	2016	2017	Change 2017 to 2014
Mining of minerals	93,5	91,0	92,4	88,1	-5,4	34,5	37,2	41,0	39,7	5,2
Manufacturing industries	95,9	95,7	95,6	94,2	-1,7	55,9	57,5	62,3	63,8	7,9
Production and distribution of electricity, gas and water	87,6	87,8	88,7	н/д*	1,1**	34,2	38,6	41,8	н/д	7,5**
Construction	91,5	90,5	90,4	86,5	-5,0	37,1	40,1	41,0	38,7	1,6
Wholesale and retail trade; repair of motor vehicles, motorcycles, household goods and personal items	92,8	92,5	94,4	92,6	-0,2	48,5	53,3	53,5	52,9	4,4
Hotels and restaurants	86,8	87,0	83,3	85,7	-1,1	38,2	42,2	44,4	45,4	7,2
Transport and communication	83,8	82,3	80,7	н/д	-3,1**	35,5	36,9	37,7	н/д	2,1**
from them communication	94,2	92,5	92,9	н/д	-1,3**	63,6	62,1	60,9	н/д	-2,7**
Financial activities	93,6	92,0	91,7	92,2	-1,4	60,7	61,6	64,7	66,7	6,0
Real estate transactions, rental and provision of services	79,3	75,8	76,5	н/д	-2,8**	29,9	29,7	31,7	н/д	1,8**
In total	89,0	88,1	88,7	88,9	-0,1	40,3	42,6	45,9	47,4	7,1

Source: Goskomstat * the lack of data for 2017 is explained by the change in the classification of organizations by areas of activity, which does not allow them to be correctly compared ** change in 2016 to 2014

Despite the fact that the number of websites in Russian companies is still less than half in most areas of business, it is increasing every year, becoming a kind of business standard.

Directions of Internet use (figure 1) are an indicator of the digital maturity of companies. The greatest differentiation is observed in the areas of "Telephone

calls" and "recruitment". Thus, the Internet in these areas is used by more than half of trade and communication organizations, and less than a quarter of organizations in the areas of real estate and transport.

Industrial enterprises are leading in the use of the Internet to communicate with contractors and subscribe

to databases and electronic libraries. This indicates a higher readiness for digital integration with contractors, as well as the use of digital Analytics. At the same time, the rate of Internet use by industrial organizations in internal business processes is lower than in service areas such as trade and communications.

The opportunities for the development of key Smart Manufacturing technologies are shown in figure 2. Broadband Internet access is a basic prerequisite for the development of the Internet of Things (IoT). According to this indicator, all industries lag behind European countries, where the development rate exceeds 95%.

At the same time, the use of "cloud" services is quite high in all areas of business, and on average corresponds to the level of developed countries. The use of "cloud" technologies can improve the mobility of the organization's personnel, reduce the cost of maintenance of virtual infrastructure, but at the same time imposes increased

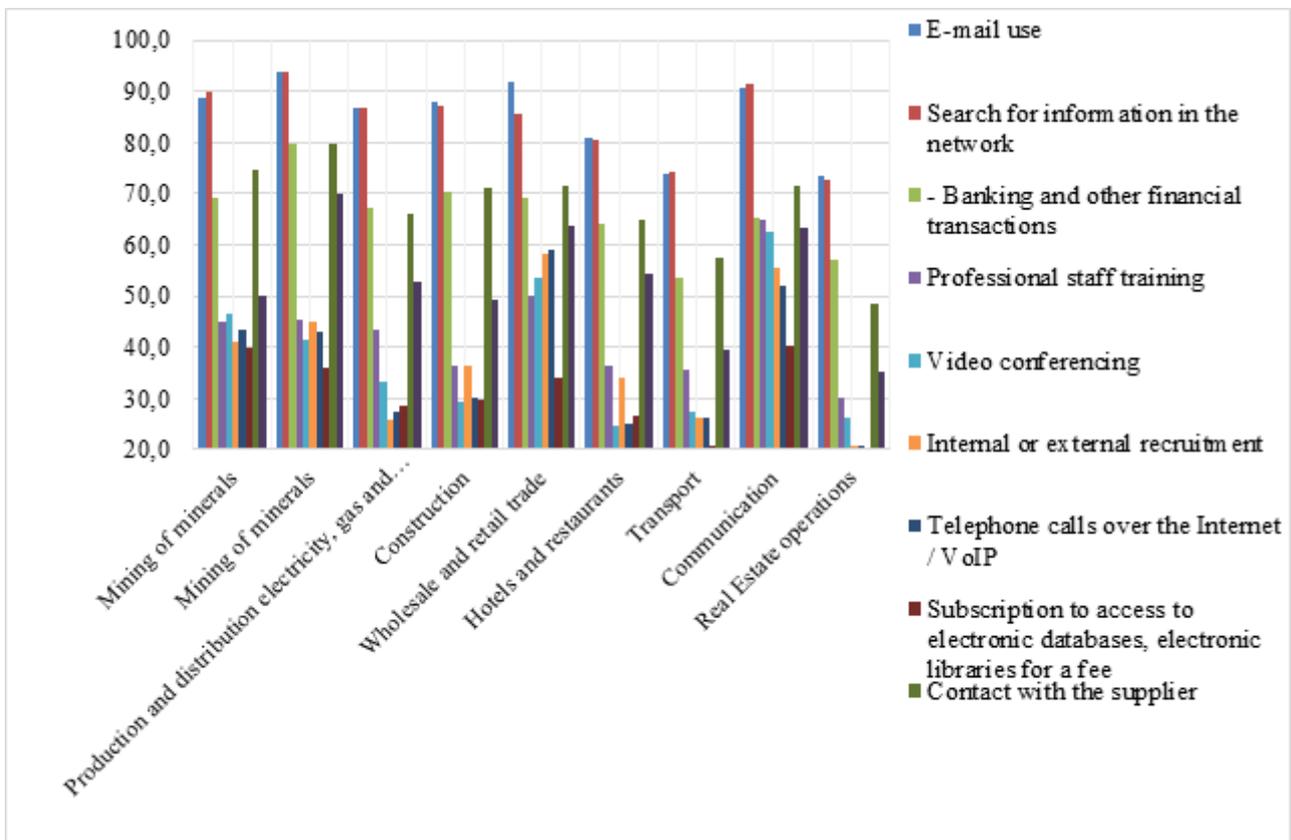
demands on information networks and increases the risks of unauthorized access to confidential information.

RFID technologies are automatic identification technologies that allow to read or write data of objects by means of radio signals. They are an indicator of the development of Smart Sensors and the possibility of creating cyber-physical systems.

For this indicator, Russia lags behind all European countries, but the value for industrial enterprises exceeds the average value for the business sector as a whole.

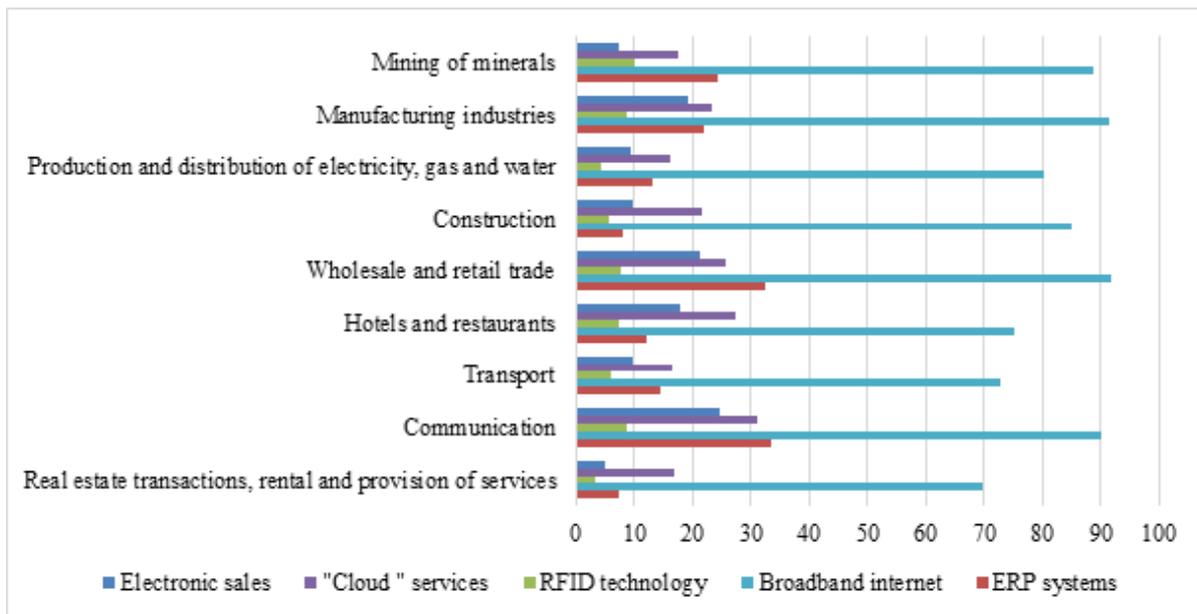
The use of resource planning systems of the organization allows to evaluate the intra-organizational integration of the main functional systems of the organization and to evaluate the automation of business processes.

The average for all organizations is 17 per cent, well below the average of developed countries. So the same figure in Germany is 38%, Spain – 46%, the Republic of Korea – 36%.



Source: Digital Economy Indicators in the Russian Federation: 2018 : Data Book / G. Abdrakhmanova, K. Vishnevskiy, G. Volkova, L. Gokhberg et al.; National Research University Higher School of Economics. – Moscow: HSE, 2018.

Fig. 1. Directions of Internet use in organizations by economic activity in 2016 (as a percentage of the total number of organizations in the business sector)



Source: ibid

Fig. 2. The intensity of the use of advanced digital technologies in 2016 (as a percentage of the total number of organizations in the business sector)

The electronic sales index shows the degree of digitalization in inter-organizational cooperation. Electronic sales are carried out by filling out special forms on the company's website or on Extranet distributed corporate networks using automated messaging (EDI-systems).

The scatter of data values for this indicator is the most significant. Thus, the indicator values in manufacturing enterprises, in trade organizations, communications and restaurants correspond to the average European level, whereas in the mining industry enterprises it is almost three times lower. This suggests that digital maturity of counterparties, in this case, consumers, has a significant impact on the digital maturity of suppliers.

III. DISCUSSION

Today, smart manufacturing is a new paradigm for business development. The rapid development of smart manufacturing technologies is leading to a widening digital divide between developed and developing countries.

At the present stage, many areas of development of smart industries are at the level of conceptual models, which suggests that the digital divide is just beginning to form.

Under these conditions, state support for the development of "digital" technologies is of great importance, which, in addition to financing individual events, should provide mechanisms that enable entrepreneurship development in key industries related to smart technologies.

At present, in most indicators of the development of information and communication technologies, Russia lags somewhat behind the level of developed countries, and in a number of business areas, negative trends are increasing.

At the same time, the protectionist policy of import substitution in the field of software during the development of the domestic market and the declared

increase in the level of information security also contributes to a certain lag in the development of technological solutions of smart industries.

Promising research tasks, in our opinion, are the development of models of transition from traditional to smart industries, the adaptation of business models to interorganizational cooperation, the identification of key success factors for this transition.

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