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Production's digital transformation analysis using Industry 4.0 technologies

Анализ цифровой трансформации промышленности при помощи технологий «индустрия 4.0»

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Abstract

The article is devoted to a detailed analysis of the industry's digital transformation processes based on the use of Industry 4.0 technologies. The theoretical analysis made it possible to establish that technological trends are often in the spotlight, however, the need for transformation is not posed by technology as such, but by deep shifts in the enterprise's external environment caused by digitalization. The study of industry transformation global mechanisms allowed the article's authors to identify eight key levers necessary for creating value due to the Industry 4.0 technologies implementation at a high-tech production. In conclusion, the authors consider the technological transformation process in Russia, as well as the main directions that can effectively accelerate it.

Keywords: economic trends, Industry 4.0 technological components implementation, industry's digital transformation, modern business models, production processes efficiency increase, production's digital transformation, technological modernization.

Аннотация

Статья посвящена подробному анализу протекания процессов цифровой трансформации промышленности на основе использования технологий «Индустрия 4.0». Проведенный теоретический анализ позволил установить, что в центре внимания в настоящее время зачастую оказываются технологические тренды, однако необходимость трансформации задается не технологией, как таковой, а глубокими сдвигами во внешней среде предприятия, вызванными цифровизацией. Исследование общемировых механизмов трансформации промышленности позволило авторам данной статьи выделить восемь основных рычагов необходимых для создания стоимости вследствие внедрения технологий «Индустрии 4.0» на высокотехнологичном производстве. В заключение статьи авторами рассматривается процесс технологической трансформации в России, а также приводятся основные направления способные эффективным образом его ускорить.

Ключевые слова: внедрение технологических компонентов «Индустрия 4.0», повышение эффективности производственных процессов, современные бизнес-модели, технологическая модернизация, цифровая трансформация производства, цифровое преобразование промышленности, экономические тренды.

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Introduction

Digital transformation within the framework of Industry 4.0 technologies is rapidly changing the current business environment. Creating various numerous opportunities for growth, improving the quality and efficiency of running a business, reducing and optimizing costs, improving customer experience and developing innovative business models, this phenomenon at the same time poses a number of rather serious business threats. Success-oriented enterprises simply cannot afford to ignore the prevailing new trend, and there is only one correct reaction way to such changes, which is a complete rethinking of format everyday activity. Nowadays, to achieve weighty and significant results, enterprises need a complete integrated strategy (Korrespondent, 2017). It should be flexible enough to allow enterprises' development in accordance with current technological trends and at the same time take into account a number of associated risks. Creating such an integrated strategy is impossible without an in-depth analysis and understanding of the digital transformation phenomenon. In the digital economy, growth depends directly on the technology development speed, but exclusively humans can often achieve such growth.

Theoretical analysis

Digital transformation means a gradual transition from a high-tech enterprise's traditional IT service (focused on solving individual problems, formalized, controlled, manageable and costly) to a new world of people-oriented, informal, spontaneous, empathic and accessible by price open systems. As a result, technologies cease to be internal resources and assets that are completely controlled by the company's management, and turn into powerful natural factors that shape and develop markets. This instability of the business environment almost always leads to a new type of managerial risk: the inability to cope with the digital transformation's nature and make it work in the enterprise's interests. Therefore, in order to maintain the current competitiveness level and minimize possible risks (including new type risks), high-tech enterprises need to stop experimenting with digital technologies and try to switch to a fully digital business (European Commission, 2019). Digital transformation is increasingly perceived as a strategic success unique key in almost any commercial activity area. Numerous technology providers and business consultants are looking for all kinds of ways to convey this point of view not only to functional specialists, but also to enterprises' top managers. Digital transformation in the Industry 4.0 implementation concept framework will be carried out in nine main areas (Figure 1) (Bughin, Hazan, Labaye, Manyika, Dahlstrom, Ramaswamy, Cochin de Billy, 2016).

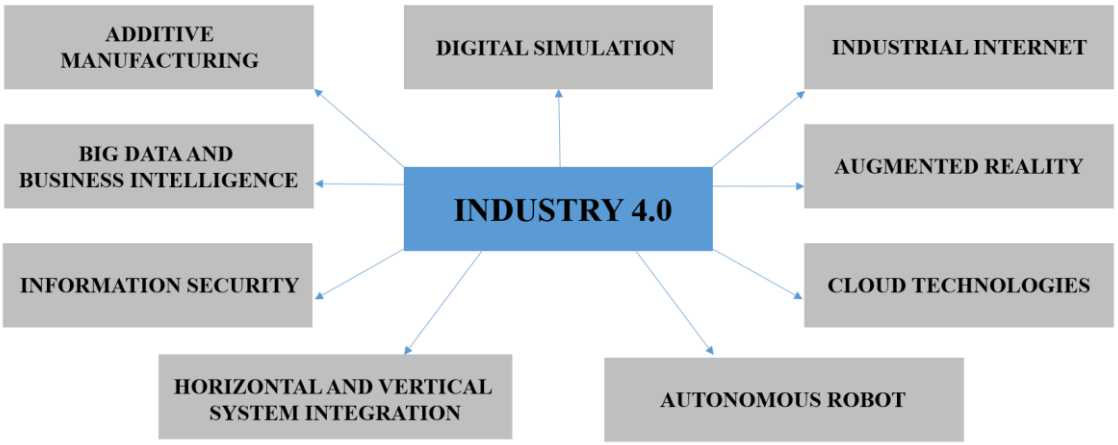

Figure 1. The main areas of technological concept Industry 4.0 implementation

The transformation process as a whole should begin with the top managers' vision, which implementation, in turn, requires the constant active and informed CEO's participation and the board of directors. The enterprise's top management should realize that it requires continuous participation in the workflow over the next few years. The basis for this approach was the leading experts' study, in the framework of which fairly convincing evidence was obtained that effective digital transformation management should be carried out at the directors' level. Let's consider the study's key findings (Yashin, Grigoryan, 2015):

- technological transformation speed determines its final result's quality. If the transformation does not have enough momentum, then it cannot lead to the creation of the desired value. The technological transformation development speed largely depends on the required amount of resources allocation, which is possible only with the full senior managers' support;
- it is necessary to correctly understand the digital transformation essence, since it is often associated only with the innovative technologies implementation, and it significantly changes the enterprise itself, allowing it to take full advantage of all the innovative technologies' privileges. Organizational changes can be associated with areas such as the new consumer experience creation, new production processes or completely new business models, which means that they can only be initiated at the senior management level;
- carrying out technological transformation requires high-quality tools and effective process control. Among other issues, almost any change in the existing situation causes the enterprise's employees a sense of personal insecurity. Therefore, in such a way there should be taken actions that enable all employees feel and understand that the management really knows what it is doing;
- successful digital transformation takes place not only due to the fundamentally new organization's creation, but also due to the qualitative reassembly of the existing one, which allows it to use the new valuable strategic assets. Businesses can receive significant new benefits from previous investments.

Experts in their study concluded that successful digital transformation does not occur on a bottom-up basis, it has to be managed from the top. It is necessary to clarify the first part of this statement: successful digital transformation requires a lot of activity, participation and enthusiasm of the "bottom". Nevertheless, the top management should be the initiator and constant driving force of this process.

Methodology

Analytical assessment of technological transformation forecasts from the concept of Industry 4.0 is used as research method. The study is based on a comprehensive analysis and subsequent assessment of the main results of the implementation of industrial technological transformation processes, with the subsequent identification of key areas and directions of transformation in Russia. The analysis is based on the study of the main provisions of the Industry 4.0, the program "Digital Economy of the Russian Federation", as well as the decree of the President of the Russian Federation "On national goals and strategic objectives of the development of the Russian Federation for the period until 2024". The first program focuses on the "Development Strategy of the Information Society of the Russian Federation for 2017–2030" and assumes that the digital economy is an economic activity in which the data presented in digital form is a key factor in production. The processing of large volumes and the use of the results of the analysis of digital data in comparison with traditional forms of management can significantly increase the efficiency of various types of production, technologies, equipment, storage, sale, delivery of goods and services.

The use of basic tools within the Industry 4.0 technological concept will require high-tech enterprises to deploy an industrial Internet of things at their facilities, combining a set of necessary software solutions, as well as introducing new equipment types (for example, 3D printing machines, automated drones). The potential annual effect of the industrial Internet of things technologies implementation on industrial and construction sites is estimated to be in the range of 1.5 to 4.7 trillion. US dollars (Figure 2) (Eurostat, 2019). The deployment effect's reliable assessment of the Industry 4.0 concept remaining elements has not yet been carried out, but it is obvious that they will significantly enhance the positive impact on the industry provided by digitalization.

By the analysis of the global digital transformation, the article's authors identified eight key levers necessary for creating value due to the Industry 4.0 technologies implementation at high-tech production (Ditkovsky, Fridlyanova, Gokhberg, Gorodnikova, Kuznetsova, Lukinova, Martynova, Ratay, Rosovetskaya, 2017; Plakitkin, Plakitkina, 2018):

- existing equipment operating modes optimization;
- equipment loading schedules optimization;
- increase in general productivity and labor safety indicators;
- logistic optimization;
- products' quality comprehensive improvement;
- demand dynamics forecasting mechanisms improvement;
- products' market launch time optimization;
- after-sales service quality improvement.

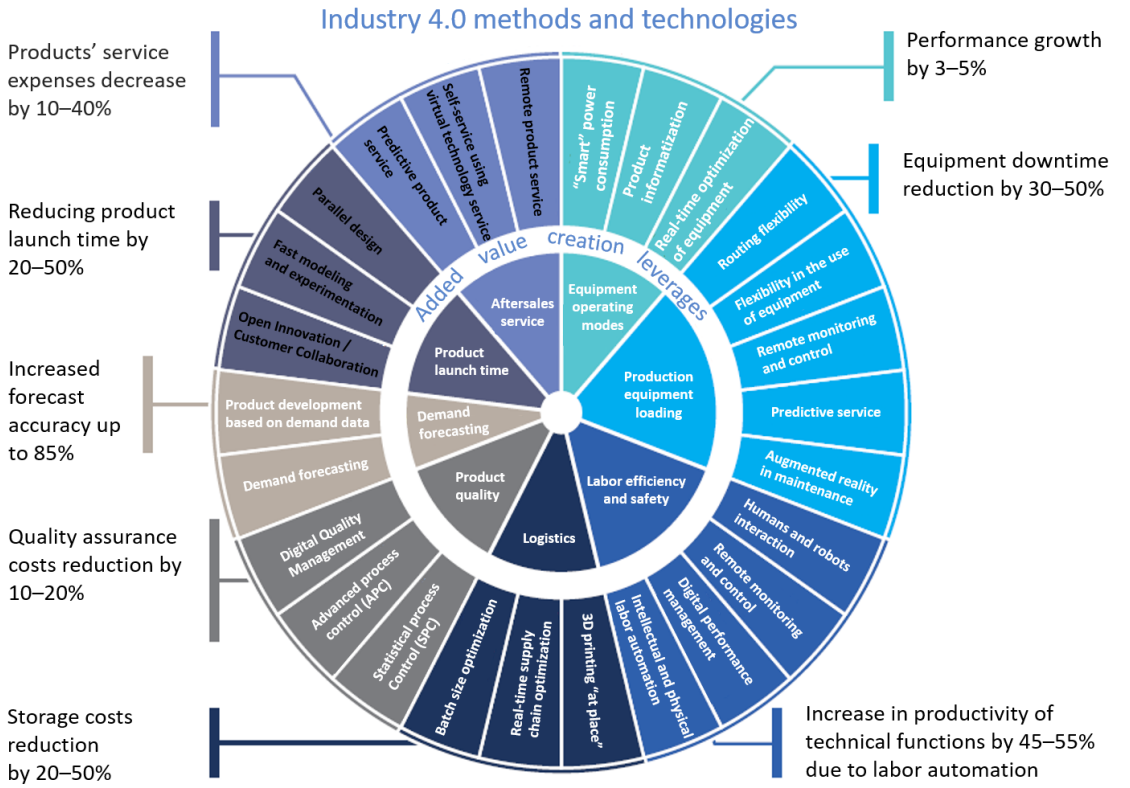

Figure 2. Potential benefits of using Industry 4.0 technologies

1. Enterprises' existing equipment operating modes optimization.

Using the tools included in the Industry 4.0 concept allows high-tech enterprises to flexibly and efficiently optimize the production equipment operating modes in order to improve the quality of the final product. The proposed optimization mechanisms are based on a comprehensive analysis of data obtained from installed sensors of an automated enterprise management system (ACS) and an automated process control system (APCS). The process of collecting information necessary for subsequent analysis is carried out in real time (Tadviser, 2019). The analysis is based on the machine learning methods use and allows identifying existing patterns that increase the overall production efficiency, but which were difficult to establish when using classical analytical methods. High-tech enterprises can significantly reduce the resources use, such as raw materials or electricity, by implementing innovative systems that automatically control costs using data from sensors (for example, motion sensors). For example, the use of an integrated digital system for fine-tuning the stamping production

in real time has reduced operating costs by about 14%.

2. Equipment loading schedules optimization.

The use of a preventive approach to repair and maintenance at the enterprise significantly improves the equipment technical readiness coefficient by reducing equipment downtime. Using in the analysis the data obtained from sensors at the wells, the history of equipment types maintenance and repairs, as well as the wells' operating modes information and using a self-learning model, the oil production enterprise was able to significantly optimize the geological and technical measures. The carried out optimization allowed increasing production by about 12%. Through the use of an almost similar efficiency increasing program, built on the use of similar technologies, the coal-chemical enterprise was able to achieve a profit growth of about 45%.

3. Increase in general productivity and labor safety indicators.

A different complexity set of tasks, performed by highly skilled and low-skilled workers, can be carried out more efficiently, if all the digitalization mechanisms and elements are used correctly. Modern innovative technologies help significantly increase the current industrial safety level, which is extremely important and relevant for industrial enterprises. An additional tool capable of increasing the safety level and production processes controllability is the use by enterprise's workers of portable devices and sensors connected to a single network that automatically track their movements. Sensors installed at the enterprise will also signal the risk of dangerous emergency situations. Such funds are now actively used, for example, in mining and metallurgical industries.

4. Logistic optimization.

The procedures' organization aimed at developing the automatic exchange of information between various supply chain elements qualitatively accelerates logistics and reduces the goods' inventory, raw materials and spare parts stored in the company's warehouses to the necessary minimum. An example of such optimization in the logistics field is the synchronization of the chain from the place of direct mining to loading at the port, which allows, for example, a copper mine to increase overall productivity by 18%.

5. Products' quality comprehensive improvement.

Digitalization of the enterprise's high-tech equipment, as well as the active innovative technology implementation, for example, 3D printers, enables enterprises to manufacture products that cannot be produced on an industrial scale in the traditional way. Boeing plans to use in its new manned spacecraft more than 650 different unique parts made using 3D printing technology (Decree of the President of the Russian Federation, 2017). Due to the special "digital" skills accumulation and data on the work of their own products, manufacturers that timely implemented modern IT tools, it becomes possible to earn not only by selling and after-sales service, but also by providing additional services to their customers.

6. Demand forecasting mechanisms improvement.

The use of advanced analytics mechanisms, carried out using automated digital systems, provides an opportunity for high-tech enterprises to achieve more accurate indicators when forecasting demand, taking into account the analysis of the already formed statistical base, which contains information about production and sales, as well as current data on current sales figures, arriving in real time. This type of information can be effectively used by enterprise management as an effective tool for organizing production and sales planning.

7. Products' market launch time optimization.

Advanced digital technologies make it possible to significantly reduce the amount of time required to develop and market innovative and modernized products. Consider an example from the aircraft industry: parallel computer-aided design and virtual testing systems in the aircraft engine industry contributed to the product development optimization time by 25–55%, which contributed to the market launch acceleration. In the satellite parts manufacture using computer-aided design and industrial three-dimensional printing systems, the American aerospace corporation reduced development time by 75% and reduced production costs by 50%, reducing production waste by 70%.

8. After-sales service quality improvement.

The technologies used in the concept of Industry 4.0 provide a full range of tools and opportunities for manufacturers to significantly improve the quality of after-sales services: information on the products' use by customers is collected through a single sensor system and then analyzed automatically. One of the leading enterprises of aircraft engine manufacturers began to install additional tools for their operation and maintenance remote monitoring according to their actual state, which made it possible to increase reliability indicators and save for aircraft operators equipped with such additional tools more than 2% of the aviation fuel allocated funds.

The technological aspects application degree analysis of the Industry 4.0 concept in Russia

Technological aspects of the Industry 4.0 concept in various capital-intensive industries, for example, such as mining, energy, etc. can significantly increase efficiency, but do not set themselves the goal of fully modifying the current business model. The optimization process in labor-intensive industries is based on the performance indicators growth of the enterprise's current production process, using multicomponent automation systems that are connected to the Internet of things (industrial Internet) (Decree of the President of the Russian Federation, 2018; Yashin, Grigoryan, 2015). The optimization process is also influenced by additional sensors installed at the enterprise, which collect real time data and after use the obtained information in multi-level analytical processes. A rather tangible result from the digitalization components use can be achieved in the manufacturing industry, as it is characterized by a fairly high complexity. To date, Russia's technological lag from other countries is increasing every year, so the digitalization of this industry should qualitatively contribute to the gap narrowing. The lag reduction is achieved due to the work of mechanisms aimed at increasing additional efficiency on all segments of the chain used to create value added components. The creation of added value starts from the process of developing a new product and bringing it to the market, followed by the logistic mechanisms use directly aimed at synchronizing this production chain to a qualitative increase in the overall performance indicators of planning, control and after-sales service. Due to the engineering industry renewal in Russia on the basis of the Industry 4.0 concept elements, the overall industry's labor productivity has qualitatively increased, which has had a beneficial effect on technological gap reducing from more developed countries.

For now, advanced technologies in the industrial production field are actively being implemented into the activities of the most Russian high-tech enterprises. In the aviation industry, the advanced innovative technologies implementation made it possible to modernize the enterprises' systems existing, which are used to organize product life cycle management processes. (Product Lifecycle Management (PLM)). For example, the domestic United Aircraft Corporation (UAC) has successfully implemented a unique innovative concept aimed at creating a virtual design and technology bureau, where leading specialists and engineers from several design bureaus and design sites work together to design a fundamentally new aircraft model in a single independent digital environment (Tadviser, 2019).

The PLM systems' modernized structure consists of the following set of sequential works implemented on the basis of combining various components within the framework of the created universal data warehouse in the structure of a high-tech enterprise:

- enterprise's electronic technical document management process organization, the key feature of which is the design unity and technical data, including various supporting information;
- clerical and office workflow in conjunction with a single document management, i.e. the possibility of organizing a single access to the enterprise's documents, as well as the business processes effective management through the timely approval of documents;
- optimization of management technology in the field of customer relationship management at all stages of the life cycle (it is necessary not only to attract new and retain old customers, but also to increase loyalty), with the aim of creating a sustainable and efficient business based on mutually beneficial relationships;
- modernized complex of operational and calendar planning, which is based on MES systems, is necessary not only for the production and technological process control systems effective

organization, but also for simplifying the providing initial design and technological documentation mechanisms, as well as obtaining real-time work schedules and equipment loading.

The digital modernization of Russian enterprises has to be carried out immediately at several levels: in terms of industrial equipment, IT systems and internal business processes.

Industrial equipment. According to the report of the Center for Strategic Research "Analysis of the most important structural characteristics of the Russian manufacturing industry production capacities", the average age of capacities in oil refining is 18 years, in metallurgy is 16 years, in chemical production is 17 years. Russian enterprises use a small number of industrial robots in order to automate production; according to statistics from the International Federation of Robotics, there are only 3 industrial robots for 10 thousand workers in Russia, while the average around the world is 70, and in countries leading in digitalization, it is more than 100. The Russian market share of industrial robots is only 0.27% of the global total, and the main consumers are China (29%), South Korea (17%), Japan (16%) and North America (about 15%). Also, the lag is observed in the proportion of machines with numerical control (CNC):

- in Germany and the USA it is more than 65%;
- in China it is about 35%;
- in Russia in 2016, the share of CNC machines was only 10% with a forecast of growth to 35% by 2020.

IT systems. Russia's share in the total use of product lifecycle management (PLM) systems approximately corresponds to its share in world industrial production and is approximately 3%. This indicator is significantly lower than that of the leading industrial countries, where the share of PLM use, as a rule, exceeds their share in world industrial production by 1.6–5.5 times.

Business processes. Despite the significant amount of investments aimed at modernizing and updating the equipment fleet made over the past 14 years, domestic high-tech industrial enterprises show a rather low level of processes digitalization. Even when Russian manufacturers use innovative equipment equipped with sensors connected to the industrial Internet of things, they often don't know how to fully use the data generated by this equipment necessary for efficiency growth, as a rule, about 1-2% collected in this way are applied on average data (Decree of the President of the Russian Federation, 2018; Tadviser, 2019).

The Russian economy digital transformation will have an ever-increasing impact on various industries. According to our estimate, the additional growth from the new digital technologies implementation will average up to 2025 from 0.4 to 0.9% of GDP per year. A comparison of this growth with the forecast growth rates of the Russian economy allows estimating the digitalization's contribution at the level of 19 to 34% of real GDP growth from 2015 to 2025 (Figure 3) (Eurostat, 2019).

Let's note Russia's key transformation areas and directions recommended by specialists and experts for long-term economic development as part of the technological Industry 4.0 concept's mechanisms successful development:

1. The business model and digital strategy renewal:

- overall digital enterprise concept renewal;
- strategy and business model rethinking;
- digital product portfolio optimization;
- new business thinking development.

2. The digital operating model components change (structure, culture and various processes):

- new unique digital structure development;
- digital control model creation;
- identification of the place of digital business in the enterprise structure;
- digital business management model reorganization;
- digital transformation mechanisms optimization.

3. The technological infrastructure and digital production processes change:

- bionic (toponymic) design use in order to reduce weight and improve the products' strength qualitatively, as well as the "smart" products use;
- production transformation and service support carrying out;
- organization of work with augmented reality technologies;

"cloud" technologies inclusion in the production process.

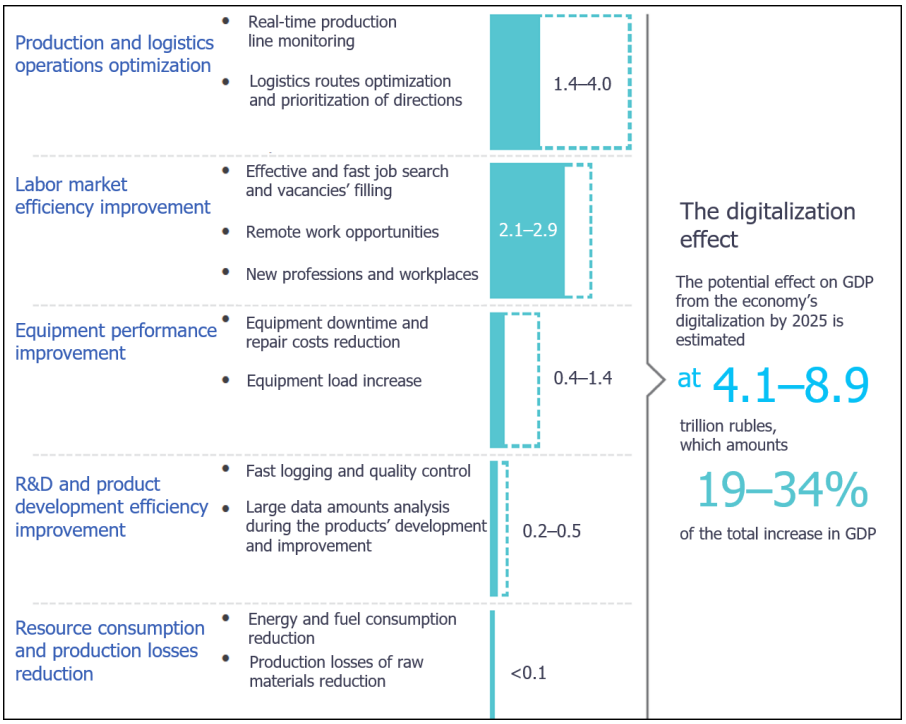

Figure 3. The source of GDP growth by 2025 due to the technological digitalization within the framework of the Industry 4.0 concept (trillion rubles)

Discussion

The single digital space of industry will allow domestic enterprises to become more transparent, faster and more efficient, which will provide competitive advantages both in the domestic and international markets. In addition, the introduction of the system will give the Ministry of Industry and Trade an effective tool for monitoring the state of the country's industry and will allow responding promptly and targetedly to changes in market conditions, offering targeted incentive measures for precisely the industries that need support a lot. Of course, all stages and levels of such interaction should be covered by adequate means of ensuring information security. The current landscape of cyber threats is becoming a new type of business risk (protection of intellectual property, human factor, complex integration scenarios of individual components of a solution, etc.). The presence of the information protection subsystem as part of the presented concept will strengthen the innovative character and contribute to its promotion in the Russian and international markets.

We single out the main aspects considered in the article that are related to the implementation of digital transformation and the development of the Industry 4.0:

1) digital economy is a unique part of the currently implemented Industry 4.0 program;
2) digital economy will develop at the expense of digital enterprises;
3) "Digital Economy of the Russian Federation" determines the development of the economy until 2024;
4) Industry 4.0 and "Digital Economy" programs began to be implemented in many countries of the world: United States of America, Germany, Netherlands, Great Britain, South Korea, Japan, China, Sweden, etc.;
5) leader in the implementation of the Industry 4.0 program is Germany, in the economy of which the share of digital technologies by 2020 can be up to 90%;
6) digital transformation allows achieving almost complete transparency of the product life cycle and provides the ability to actively manage changes from the design stage to the delivery of finished products to the customer and their service;
7) basis for building a single digital space in Russia is the integrated implementation of digital technologies at all stages and levels of industrial production.

Conclusion

The survival strategy in the era of digital transformation includes the transition of numerous partnerships creation with various independent third parties in order to build a held ecosystem around a digital platform (marketplace). In order to do this, it is usually required to completely rebuild the classic corporate model of the 20th century. During this process, it is important to use the creative abilities and energy of the company's employees who go through digital transformation as individuals. Modern workers under constant pressure of rapidly increasing automation are looking for ways to secure their future by participating in the company's final result. Revealing their potential by providing them with the opportunity to experiment, make strategic decisions and become de facto entrepreneurs directly involved in creating a value proposition for customers is a key approach to the corporation's digital transformation.

Digital technologies create a new consumer value level through a previously unattainable accessibility and customization combination, with the delivery of analytically customized goods and services at once on demand and often at a much more attractive price compared to the already existing traditional offer. Consumers transformed by numbers are well informed, have tools for cost-free switching between suppliers and therefore have market power, so that they transform market competition. In many segments, especially in segments with the digital technology maximum penetration, the current situation has come close to what the classical economy calls "perfect competition" with many suppliers and rational customers. As predicted by economic theory, the rate of return in such a situation tends to zero. The main conclusions from the materials considered in the article are the following:

1) economic growth is possible if a healthy production system exists in the country (products, equipment, machines are manufactured), which ensures the creation of physical goods with high added value, which are the basis for the development of various services;
2) industrial sector generates demand for various professions, highly qualified specialists, increasing productivity and reducing costs, developing science and technology in the country;
3) maximum effect of digitalization will be given to those countries where real sectors are highly developed;
4) Russia needs serious efforts to protect its own industrial sector and engineering, existing players and young innovative industries, which is no less revolutionary task to build economic priorities than the industrial revolution of the 4.0 era;
5) it is important to study the most advanced world experience, cooperate with foreign partners at all stages of joint production, research and projects, and build effective work schemes.

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