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Digital Transformation of Mining Enterprises

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Abstract. The level of competitiveness of the mining industry is determined primarily by productivity and operational excellence. Digitalization is becoming a determining factor that will enable companies in this field to remain competitive in the future. In the mining industry, the transition to new, more advanced working methods is usually slower due to the scale and complexity of production processes, as well as due to the significant volumes of technological modernization costs. Therefore, some enterprises in this area are not actively using digital technologies. Nevertheless, the world's leading mining companies are investing heavily in the development of modern energy and automation technologies in order to increase production and environmental efficiency, reduce the use of manual labor and energy expences. It is becoming clear that digital technology is opening up new opportunities to dramatically increase productivity and profit margins. The article examines the main directions of digital transformation of mining enterprises, reveals the main opportunities and threats.

1 Introduction

As one of the oldest industries, mining continues to be the main focus of global production. It includes the extraction, processing and beneficiation of mineral raw materials. Its active development began in the late 18th – early 19th centuries during the period of massive construction of factories and plants. In the 20th century, the pace of exploration and extraction of raw materials grew. Now, when the reserves of the mining industry are depleted, and humanity is seriously thinking about replacing traditional energy resources.

The mining industry belongs to the primary sector of the economy, and therefore is not characterized by the highest degree of innovation in comparison with enterprises of the processing industry or the service sector. However, despite the initially established conservatism, the mining industry could not avoid changes. Now digital technologies with the use of advanced enterprise management systems and its business processes are being introduced to varying degrees in the activities of all enterprises in the industry without exception.

Despite the fact that the share of the mining industry takes only about 10% in the structure of the world economy, it is the main source of income for many countries.

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Without its primary materials and energy resources, other industries, including science-intensive and high-tech ones, could not exist. The leaders in the mining industry, which account for 70% of the world's resources, include the United States, Canada, Australia, China and Russia.

2 Materials and Methods

N. Amirova [1], S. Zhironkin [2], A. Voloshin [3], T. Skryl [4], V. Frolova [5], N. Kazitskaya [6], L. Khayrulina [7], I. Politkovskaya [8], N. Rebrowa [9], E. Shavina [10], V. Prokofev [11] and others. Issues of digital transformation of enterprises are considered in the works of P. Weill [12], K. Dery [13], J. Gertner [14], E. Dotsenko [15].

According to various estimates, the population of our planet will reach 9 billion people by the middle of the 21st century. The rapid population growth, enhanced by the urbanization factor, makes it possible to predict an increase in demand for energy and metallurgical products. Despite the trends in "green energy", coal consumption is growing by 0.6% every year, and for the implementation of projects on renewable energy sources, for example, several times more metals are required than for traditional energy. In addition, new emerging markets are forming, such as the production of electric vehicles and high-power batteries.

However, despite the optimistic outlook, the mining industry faces a very serious problem – a critical increase in costs. Thus, capital expenditures have increased by more than 30%, and the increase in operating expenses sometimes reaches 90%. This is due to reasons such as an increase in labor costs, a decrease in the quality of ores, pressure from new markets, depletion of reserves of some types of ore raw materials, the location of new mines in geographically remote areas with extreme weather conditions, etc. All this negatively affects the price of the finished product and its marginality. Therefore, the most important task of the enterprise is to increase productivity and reduce costs. One of the tools for rationalizing production is precisely the use of digital technologies, and digital transformation is becoming a prerequisite for ensuring the company's profitability.

3 Results and Discussion

We are currently witnessing major transformational changes in economic processes. The fourth digital industrial revolution, the concept of which was presented by K. Schwab at the World Economic Forum in 2011, is taking place before our eyes. Every day more and more enterprises are drawn into this process, mastering the methods and tools of Industry 4.0. Its essence lies in the integration of production and digital technologies, which ultimately makes it possible to replace manual labor with robots, create “digital twins” of production facilities, etc. The greatest competitive advantage will come from businesses that create an enabling environment for change and support digital transformation initiatives.

The majority of Russian enterprises are rapidly increasing their digital potential, but the pace of introduction of new technologies still remains insufficient to gain leadership positions. An analysis of the business digitalization index as a whole shows that in Russia the digitalization of business processes is carried out less dynamically compared to most European countries (Fig. 1). This indicator characterizes the degree to which firms use broadband Internet, RFID technologies, cloud services, ERP-, CRM- and CSM-systems, as well as the possibility of e-commerce. The leaders here are Finland – 52, Denmark – 50, Belgium – 49, Sweden – 47. Outsiders are Greece – 31, Bulgaria – 30, Romania – 27. Index values for Russia – 32.

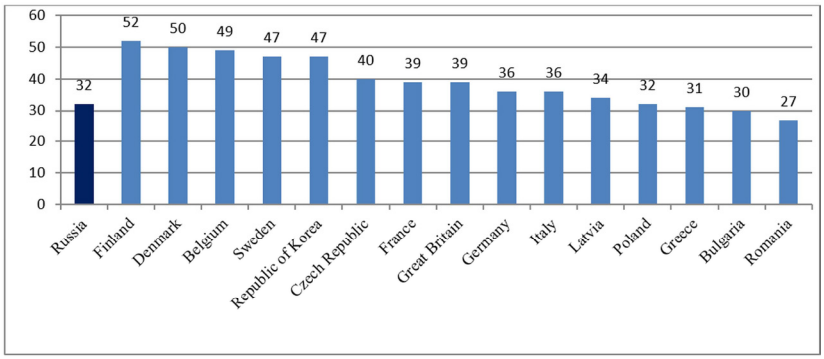

Fig. 1. Business digitalization index by country [16].

If we consider the business digitalization index by type of activity, then the highest values of the indicator are observed in the telecommunications sector – 45.5, wholesale and retail trade – 39.2, the manufacturing industry – 35.8 and the information technology industry – 35.6 (Fig. 2).). The lowest are in construction (25.3), water supply, sewerage and waste disposal (24.9) and in real estate operations (23.8). The digitalization index of the extractive industries is 29.4, which is below the average value for the business sector. This only confirms the aforementioned thesis that the mining industry is a fairly conservative sphere, and the digitalization of processes here is taking place at a much slower pace. The main reasons hindering digital transformation may be: lack of specialists; lack of industry knowledge and competencies to develop a competent digital strategy; insufficient technical equipment of production. However, according to experts, in the near future, digitalization in the mining sector will completely catch up with the technological revolution 4.0.

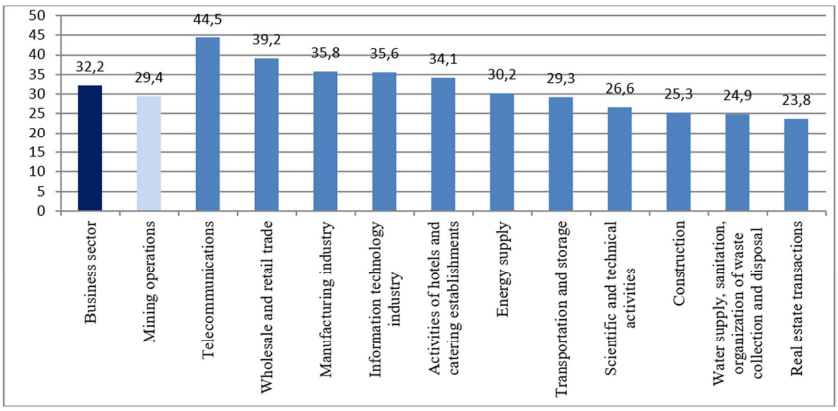

Fig. 2. Business digitalization index by type of activity [16].

Considering the structure of digital transformation, a number of conclusions can be drawn. First, only 1/3 of Russian organizations use systems designed to automate work with data and information that are key for business. The most common of them are ERP systems, they are used by about 23.3% of enterprises on average, while in Korea, France and Finland this figure is 2 times higher. Analysis of data on the use of ERP-, CRM-, SCM-systems in organizations by type of activity allows us to conclude that these systems are not used in the extractive industry in the most active way. However, the rate of use of RFID technologies by mining companies (12.2%) is ahead of the average for the business sector (8.2%), surpassing even manufacturing enterprises (12%) and second only to telecommunications organizations (46.1%).

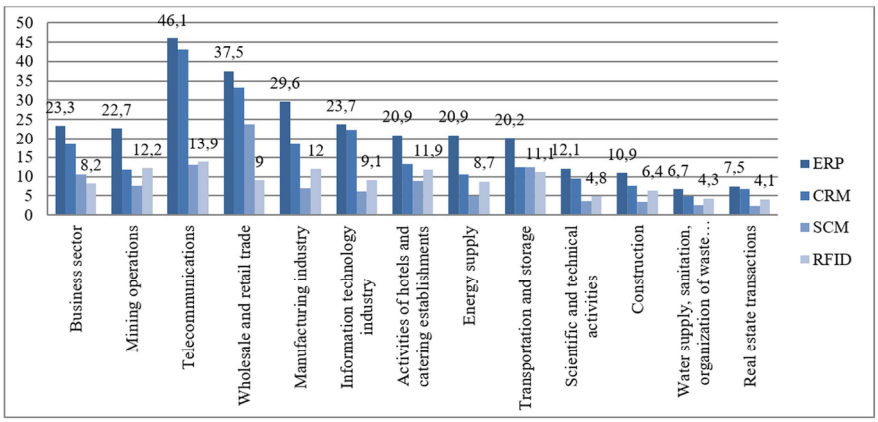

Fig. 3. Use of ERP-, CRM-, SCM-systems and RFID-technologies in organizations, % [14].

Currently, the main challenges faced by the mining industry include price volatility, increased costs, undervalued product estimates, environmental threats, project suspension, declining global demand, and growing health and safety risks. In this regard, the enterprises of the industry need to solve a number of important issues:

• the use of advanced information technologies instead of the optimization of old methods;
• the introduction of innovations based on digital technologies used in other industries;
• increasing production efficiency through a new approach to the collection, analysis and use of information;
• introduction of new technologies that meet modern requirements for environmental protection in the places of extraction and processing of raw materials;
• the use of new ways of managing end-to-end processes, as well as platforms for collecting and using data from various sources.

Traditionally, operations in the mining industry have been divided into separate operational units with minimal interconnections between mining, processing and transportation. The integration of disparate elements into value chains opens up ample opportunities for enterprises both to find new ways to solve production problems and to minimize environmental damage. Digitization of these chains provides a holistic representation of the complex of operations from "entry" to "exit" and is implemented in the following areas:

• obtaining data and providing links. The introduction of a large number of sensors into physical objects is becoming more affordable. This allows you to link them into one network and track changes in real time. For example, the occurrence of problems in hard-to-reach places of the mine is immediately displayed in the control center, which allows you to take certain actions and prevent serious negative consequences.
• analytics and modeling. Advanced analytical capabilities allow using Big Data and machine learning tools to predict certain events with significant accuracy. In the mining industry, this makes it possible to solve the problems of geological modeling, operational planning and preventive maintenance. In addition, digital technologies make it possible to develop a model of a digital twin (digital copy), which is created and developed together with a real object. For example, a simulation of a mine is a virtual 3D model with the entire infrastructure, thanks to which it is possible to analyze options for a mining plan and select the optimal ones, determine the resources required for them, identify bottlenecks, etc.
• the interaction of people and machines. Modern technologies make it possible not only to ensure the interaction of machines with each other, but also to ensure their relationship with

humans. For example, the use of an industrial exoskeleton reduces the load on a person, and also reduces the risk of injury and fatigue when working with heavy hand tools, when lifting and carrying loads, etc.

• digital-and-physical transformation, ensuring the adaptation of digital solutions in the physical world. Over the past 30 years, the cost of industrial robots has almost halved. Artificial intelligence makes it possible to significantly expand the scope of their application, transferring the performance of production and management functions from a person to a robot. The equipment can be either comprehensively automated or involve remote control, and be implemented in the processes of drilling, loading and unloading, transportation, etc. Therefore, the equipment installed on mining dump trucks allows you to control the quality of the road surface in an automatic mode, and not send people to the quarries for completing this task.

Thus, a built-in digitalization system can open up a number of advantages for a mining enterprise:

• improved resource estimation, from exploration to production planning. Digital technologies allow integrating information on production operations for ore mining, as well as optimizing the parameters of drilling and blasting operations;

• reducing the cost of equipment and materials. The combination of modern technologies (mobile technologies, the Internet of Things, etc.) helps to optimize the volumes of resource extraction, traffic, mine planning, equipment loading, etc.;

• predicting equipment failures and carrying out preventive maintenance. Continuous monitoring of processes and complex diagnostics of equipment in real time lead to a reduction in downtime and in case of a deviation from the norm, they allow you to quickly take appropriate measures;

• automation and robotization of processes, allowing to reduce operating costs and ensure the safety of technological processes. The use of automation in the mining industry allows to reduce the number of employees by 50% when performing hazardous work;

• performance monitoring and evaluation. Remote operations centers can see the real picture for each piece of equipment, comparing it to the targets. Thus, the head office is able to quickly make decisions to optimize operations throughout the value chain, not just limited to individual departments and processes.

The possibilities for digitalization are almost endless. However, in addition to its advantages, it can produce the threats. First, large-scale automation and robotization is a potential job loss. Secondly, due to the increasing complexity of systems, the risk of technological failures and man-triggered disasters, as well as the risk of uncontrolled interaction of systems that harm an individual, organization or society as a whole, will grow. Thirdly, digital technologies entail an intensification of production, which, without appropriate safety measures, can lead to a deterioration of the environmental situation, climate disruption, etc. Finally, digitalization increases vulnerability to cyber threats, which can be associated not only with industrial espionage, but also with intrusion of intruders into the technological process. Cyberattacks are often aimed at disabling the power systems of the enterprise, production processes, water supply and transport.

There are a large number of both foreign and Russian examples of effective digital transformation of mining enterprises. For example, the Australian iron ore project Roy Hill at one of its largest mines has completely rebuilt the entire technological process. The transformation efforts involved a processing plant in the Pilbara region, a mine-to-port heavy rail system, new port facilities in Port Hedland and a remote operations center in Perth. As a result, digitalization has allowed the company not only to optimize value chains, but also to improve the operation of complex systems and significantly increase productivity.

Vale Brazil, one of the world's largest mining companies, is another prime example. The old production management system was very different in twenty mines and ten pelletizing factories, as well as railways and ports. Most of the routine operations such as planning, drilling, blasting and material handling were performed separately, with inherent deficiencies in the management and comparison of the various processes. The use of a digital control system made it possible to structure and optimize all operations by ensuring interconnections. The system makes it possible to process up to 1.2 terabytes of data in real time. Thus, this allowed Vale Brazil to achieve a number of advantages, for example, improve the productivity of work procedures, optimize human resources, improve security conditions, reduce the costs associated with IT copyrights, and improve the efficiency of asset management. Saving financial costs through the introduction of digital technologies, reducing the harmful effects of production by increasing labor productivity and reducing downtime will amount to about $50 million.

In addition, you can consider the experience of Russian companies. For example, the structural division of the Ural asbestos mining and processing plant – the enterprise "Promtekhvyzryv" – since 2020 has been conducting pilot industrial explosions using electronic detonators. This allows avoiding deceleration errors during initiation and is reflected in the quality of crushing, reducing seismic impact and eliminating the wellbore undercutting. In addition, the company continues to automate production processes. Thus, the workshop for emulsion explosives received an automated section for the manufacture of an emulsifier. This made it possible to get away from manual control of mixers, pumps, heating elements and fans. Now they are supervised by the controller, the operator only enters the necessary parameters.

Another example of a modern mining enterprise actively pursuing digital transformation is the Mikheevsky mining and processing plant of the Russian Copper Company, located in the Chelyabinsk region. Integration of more than 3,000 controllers, sensors and actuators into a single information network allowed the company to significantly reduce the time for diagnosing equipment and the reasons for deviations in its operation. Now only three people per shift can be used to control technological processes: two operators and a technologist.

The Far Eastern company Primorskugol also boasts a whole range of digital systems. These include a video monitoring system for the operation of transport equipment, which allows managers to observe the processes on monitors in real time, road quality control system, which allows to increase the service life of mining equipment and dump truck tires, an automated system for weighing and video monitoring of loading, etc. All this makes it possible to significantly increase production efficiency in several areas. First, by saving fuel, reduce costs by 10%. Second, reduce nonscheduled downtime by more than 75%. And finally, to achieve a reduction in operating costs of equipment by almost 10%.

Sometimes academic and educational organizations take part in the process of industrial digitalization. Thus, the cooperation of G.I. Nosov Moscow State Technical University and Magnitogorsk Metallurgical Plant led to the creation in 2018 of the innovative enterprise R&D MSTU, engaged in research, development and implementation of high-tech products of Industry 4.0 at Russian industrial enterprises. Its main projects include: industrial passive exoskeletons designed for the most complex processes at an enterprise; automated system of digital twins of turbine units; machine vision, which allows you to control technological processes; gas detection on coke oven batteries; industrial internet of things in industrial water supply systems.

4 Conclusion

Thus, digital transformation is not a long-term perspective, but already actively emerging reality. It allows you to change for the better the ways of forming strategies and models of conducting production and commercial activities of companies. Like most industries, mining industry is also continually developing and evolving, albeit at a slower pace. However, despite all the changes that are already taking place, this is still just the beginning. In the near future, we will witness completely new technical and technological advances that go beyond the use of devices for receiving and processing information and the use of autonomous self-driving technology. All this will ultimately benefit the mining industry, unlocking its colossal potential, and will allow the industry's enterprises to harmoniously integrate into the new economy.

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