Digital transformation of mining enterprises contributes to the rational use of resources

S A Shvedina

Irkutsk National Research Technical University, Russia

E-mail: shvedsv@istu.edu

Abstract. Today, the digitalization of industrial enterprises means the use of the latest technologies: robotic or remotely controlled equipment, visualization of technological processes in inaccessible areas, remote centralized control rooms, high-precision positioning of drilling rigs and excavators, portable devices for monitoring the health status of personnel, electronic shift-based risk cards of workers, three-dimensional field models in design and management, predictive methods for analyzing geological and production data. The aim of this work is to demonstrate how the digital transformation of mining enterprises will allow for rational use of resources, including natural resources, while maximizing the economic effect. The objects of the study were enterprises of the oil and gas industry and the coal industry in the Siberian Federal District of the Russian Federation. In the work, we analyzed the need for digitalization of production and business processes of these enterprises. It was proposed to combine robust control, cloud and IoT technologies. Based on the survey results, it was possible to identify implemented digital technologies. Based on the assessments of enterprises, we made a rating of the feasibility of their implementation and development. The paper described the functions of digital infrastructure. It was recommended to create digital infrastructure at mining enterprises. The study proved the feasibility of its implementation.

1. Introduction

The priorities of scientific and technological development in the field of geological study of subsurface, prospecting, assessment and exploration of mineral deposits are: creation of effective software tools and algorithms for the analysis of large amounts of geological information and its visualization with high resolution, transition to advanced digital, intelligent and robotic technologies for the production and interpretation of geological data. The Unified Fund of Geological Information on Subsurface Resources provides a transition to digital technologies for collecting, processing, accumulating and making available primary and interpreted geological information; online access to geological information resources of various levels; transition to digital subsoil use management in accordance with the requirements of the digital economy [1].

The opportunities offered by the digital economy are attracting more and more participants in the economic system all over the world every day, and each of them seeks to take advantage of these opportunities. As a result of this process, there arise a lot of diverse ideas, initiatives, and potential development paths [2 – 5]. A traditional company is turning into a company with “digital thinking” by embarking on a course of digital transformation. The product itself, offered by such an enterprise to the market, also becomes digital [6]. Accenture believes a digital enterprise offers the opportunity for new operating models and business processes, platforms of connected products, analytics and
collaboration to increase productivity [7]. PwC connects the term “digital enterprise” with the concept of “Industry 4.0”, focusing primarily on changing the scope of industrial production [8]. It can be summarized that the term “digital enterprise” refers to the integration of industrial-level automation systems with business applications. Such a combination allows for creating a single cycle of planning, execution, accounting and analysis of the enterprise, thereby increasing the flexibility of the management system and radically reducing the time of reaction to changes in the external and internal environment [9].

2. Study Objects and Methods

The leading mining enterprises were selected as objects of the study: NK Rosneft PJSC, INK LLC, Vostsibugol LLC, SUEK-Kuzbass PJSC, Gazprom Neft PJSC, NK Russneft PJSC, Polymetal JSC, etc.

Currently, in order to optimize the development of fields and save financial, labor and technological resources, Russian and foreign mining companies are increasing interest in geological digital models of fields. By definition, this is a representation of productive formations and the surrounding geological environment as a set of digital maps (two-dimensional grids) or three-dimensional networks of cells [10]. Its construction is necessary for the study and refinement of the geological structure of the field, a more detailed analysis and assessment of the current state of exploitation. A qualitative and detailed geological model allows for increasing the reliability and adequacy of forecast calculations of exploitation indicators, increasing the rationality of the use of natural and technological resources, and developing deposits on depletion [11]. As a result of the study, it has been found that the use of a digital model is economically feasible not only for exploration, but also for the exploitation of the field. Here, it is a single electronic repository of engineering and financial information on each production asset. Any employee with access can obtain relevant data on any technological process and make the necessary decision in a timely manner (Figure 1).

![Figure 1](image)

Information modeling made it possible to shorten the implementation period of the Novoportovskoye field development by Gazprom Neft from design and construction to commissioning of the field by 30-40% [13]. INK LLC also notes that the use of a digital model can increase the efficiency of management decisions, prevent critical situations, technological accidents, reduce costs and time for repair work, and increase the safety of production activities. Therefore, it is one of the priority areas of technological development of an enterprise. The high development cost (~$ 40,000) pays off with significant savings in operating costs.
The purpose of managing the exploitation of a mineral deposit is to bring the actual production and activities in the field as close as possible to the plan with minimal cost and time expenditures, i.e. to optimize the planning, production, transportation, etc. To achieve it, in the last ten years, many of the world’s leading mining companies are actively using robust control, cloud and IoT technologies, machine learning to optimize production processes [14]. While projects in the field exploitation have a high degree of uncertainty, the determination of target indicators and solutions helps to achieve these indicators with a given probability and allows for increasing the economic efficiency of companies’ activities. Robust control allows for predicting the level of risk and choosing a strategy for investing and implementing projects according to targets, taking into account the existing geological, technological and economic uncertainties. And open access to data improves operational efficiency. This approach is relatively easily interpreted into the current production and management tasks and KPI indicators of production and other activities of the company; it forms a decision support system for the entire personnel of the company, including technical specialists, geologists, developers, and technologists. It allows for not exceeding the permissible level of risk for each type of work and is necessary when developing specific technological solutions and various scenarios of the company development. Monitoring of production operations will help transfer operational local management solutions to the cloud (Fig. 2), which will provide the greatest savings due to speed, innovation, flexibility and simplicity. Thus, a company adapts better to changing operating conditions.

Using the decision tree algorithm as the main planning tool allows for calculating several possible scenarios, which reduces the uncertainty and risk of making wrong management decisions. The flexibility and variability of cloud solutions makes it possible to quickly respond to rapidly changing market needs and cost-effectively implement transformation projects of an enterprise. Thus, robust control coupled with digital transformation undoubtedly increases the investment attractiveness of an enterprise.
3. Results and Discussion

The economic feasibility of digital transformation of the mining industry is obvious. The successful implementation of digital technologies requires not only the desire of owners and shareholders, but also the introduction of digital standards that envisage mass digitalization of fields and enterprises; the availability of equipment, turnkey solutions, experienced contractors for the implementation of digital systems; the presence of personnel with competencies in digital technology. Existing knowledge in the field of digital technology in the oil and gas market is quite limited. Rapid prototyping of new digital technologies is carried out in many industries [2], but capital-intensive enterprises in the mining industry have no option of operating by trial and error or using a multi-technology approach.

Digitalization of an enterprise is not limited to robotic automation of production and sensorization of equipment. Enterprises need a digital infrastructure that connects all production processes online and makes it possible to:

- visualize and dispatch production processes even in areas inaccessible to humans (wells, towers, mines, oil and gas pipelines, etc.);
- transmit current data and effectively use the current conditions;
- carry out remote control and management of any production operations;
- promptly identify deviations and reasons for failure to achieve planned production indicators;
- promptly improve the accuracy of technological operations;
- promptly and remotely diagnose and monitor the operation of the equipment, the quality of the extracted natural resources and the quality of their transportation;
- learn from failures;
- increase employees’ mobility;
- monitor and ensure compliance with labor protection and safety standards;
- monitor and ensure compliance with environmental standards (control of greenhouse gas emissions, dust emissions and other pollutants);
- increase labor productivity;
- increase the rational use of various types of enterprise resources.

However, the smallest risks and greatest benefits can only be achieved by creating digital twins that combine a simulated physical model of a field or other facilities of an enterprise and analytics based on data [16]. A digital twin will help to take the necessary measures in a timely manner in order to prevent and eliminate deficiencies, create new prototypes and virtual ecosystems [11]. The latter will enable the transition in remote access and provide high efficiency of production management.

The practical and economic importance of digital transformation is confirmed by the results of a survey concerning the extent of implementation of digital technologies among the studied enterprises. To date, they have implemented and are actively using:

- system of wireless communication with workers, video broadcasting – 93% of respondents;
- process dispatching based on cloud and IoT technologies – 88%;
- automated system for management, accounting and control of pollutant emissions – 79%;
- digital field models in design and operational management – 56%;
- remotely controlled equipment, unmanned production and transportation technologies – 37%;
- robotic production – 35%;
- monitoring of the location and well-being of employees at hazardous production facilities - 24%;
- predictive maintenance and real-time analysis of the technical condition of equipment – 11%;
- BigData, neurotechnology and artificial intelligence in data processing, machine learning – 7%;
- electronic shift-based risk cards of workers – 3%.

4. Conclusion

As a result of the assessment, we confirmed that digital transformation in the mining industry will lead to a more rational use of natural, labor and financial resources due to the high speed and quality of
managerial decision-making, prompt and clear monitoring of the decisions made being implemented at the mining sites and sites of other activities at the fields. It will prevent and reduce environmental and man-made risks, and the level of injuries. The digitalization of fields guarantees an increase in the efficiency of the extraction of in-place reserves through the maximum development of reservoirs.

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