

Sustainable development of the mining industry in the context of digital transformation

Angela Mottaeva^{1*} and Yelena Gordeyeva²

¹Financial University under the Government of the Russian Federation, 49, Leningradsky Prospekt, 125167, Moscow, Russian Federation

²Buketov Karagandy University, 28, Universitetskaya str., 100024, Karaganda, Kazakhstan

Abstract. The article considers the processes and prospects of the mining industry sustainable development. The main results of the study include the substantiation of the introduction of digital transformation processes as the main global trend of the mining enterprises sustainable development, along with the use of high-tech innovative approaches. The presented study considers the impact of the digital technological revolution "Industry 4.0" on the prospects for the of the mining industry development. The comprehensive analysis of the state, problems, advantages and disadvantages of the mining enterprises functioning in the context of constantly changing external and internal factors of economic and foreign policy development of modern Russia has been carried out. The factors determining the relevance of the digital transformation of mining enterprises, promising directions for the development of geotechnology in the 21st century, are considered, using the example of the introduction of intelligent Mining 4.0. (Mining 4.0.) and the construction of intelligent digital mines. The mechanisms and digital solutions, which implementation will solve the key tasks, are considered. The practical application of the research results will allow mining enterprises to reach a new sustainable level of the development as well as to increase the competitiveness in the global market.

1 Introduction

It is planned to achieve the maximum growth in production efficiency in the next five years in the context of the era of Industry 4.0, due to the transition of about 80-85% of enterprises' production processes to a digital model.

Mining companies made significant strides in promoting innovation and integrating technology into their operations. There is a significant shift towards the so-called "smart mines".

It is worth noting that a rather low level of implementation of digital technologies and innovative methods of the mining industry is due to some negative factors:

- ✓ the scale and complexity of production processes;
- ✓ territorial and geographical remoteness of production areas;

* Corresponding author: doptaganka@yandex.ru

- ✓ outdated equipment and management technologies;
- ✓ the need for global investments to modernize production;
- ✓ conservative methods of the production process management.

Within the framework of the Sustainable Development Goals of the mining industry, significant growth in energy consumption and the level of negative impact on the environment are seriously considered and taken into account.

Nowadays some problems can be identified, that reduce the pace and negatively affect the development of mining enterprises: low cost of products, fluctuations in price levels, increased costs, environmental challenges, suspension of projects, declining global demand and growing risks of occupational safety and health [1, 2].

The concept of modernizing the mining industry became relevant due to the necessities of sustainable mining, as well as environmental, social and management requirements. That is not surprising, taking into account the important role of modernization in the current context of the fourth and expected fifth industrial revolutions.

Thus, the indicators of the development of mining enterprises, in the context of constantly changing external and internal factors of the economic and foreign policy development of modern Russia, determined the urgent need to revise the existing strategy of the mining industry.

2 Review of literature and research

The topic of digital transformation of mining enterprises is actively discussed in the scientific literature. The works of leading Russian and foreign scientists in the field of theory and practice of digitalization of the mining industry were used within this research.

Such authors as Nagovitsyn O.V., Babkin A.V., Isaichenkova V.V. [1, 3, 4], Osipova R. G. , Aleksashina T.V., Gileva T.A. , Kuzin D.V. [5, 6, 7, 8], A. I. Piskunov and V. B. Glavatsky [9], Izyumtseva A.A., Klebanova D.A. [10], A Matsko N.A., Kharitonova M.Yu. [11], Lukicheva S.V. [12, 13, 14], Zholmagambetov T. [15], Petrenko I. E. [16], Plakitkin Yu.A.[17], Rozhkov A. A. [18] consider the need to introduce digital technologies in key industries, the concept of digital transformation of the mining industry, criteria for assessing the readiness of enterprises to actively implement innovative technologies; the level of competitiveness of enterprises in the mining industry; updating digital strategies of multinational companies; the issue of organizing deserted mines. The analysis of the problems of implementing digital transformation in the mining industry, trends and challenges, their impact on the sustainable development of industry, on socio-economic development, is reflected in the works of foreign authors, such as Yue Zhou [19], Qamar Uz Zaman, Yuhuan Zhao, Shah Zaman, Kiran Batool, Rabiya Nasir [20], Lars Barnewold, Bernd G. Lottermoser [21], Keith Storey, Greg Halseth, Laura Murphy, Sean Markey [22], Deepak Kumar, Dilip Kumar, Chapter Four [23], Arman Hazrathosseini, Ali Moradi Afrapoli [24], Jiacheng Xie, Suhua Li, Xuewen Wang [25], et al., [26-27].

Despite a lot of scientific research and works, the topic of digital transformation of the mining industry remains relevant and requires updating modern innovative methods and approaches as well as more scientific research.

3 Materials and methods

The authors of this work use scientific materials from Russian and foreign researchers, open statistical data and analytical reports on the topic of digital transformation of the mining industry. The methodological framework is based on the scientific approach to the study of objective patterns of the mining industry development in the context of digital

transformation, systematic analysis of the industry as a complex social-and-economic system interacting with the digital economy. During the study, tabular and graphical methods of visualization of calculations were used.

4 Results and discussion

This research considers the possibilities of implementing digital transformation as a global trend in the sustainable development of the mining industry.

The mining industry is the main mineral resource and fuel base of the entire national economy of Russia. At the global level, Russia holds a leading position, being one of the 166 mining industry countries. For comparison, 48 kinds of minerals are extracted in our country, while the same indicator for other countries is 10 kinds of minerals.

Figure 1 graphically shows the share of Russian mining during the period 2021-2023 in the structure of the global mining industry, which amounted to 10.1%. (Fig.1).

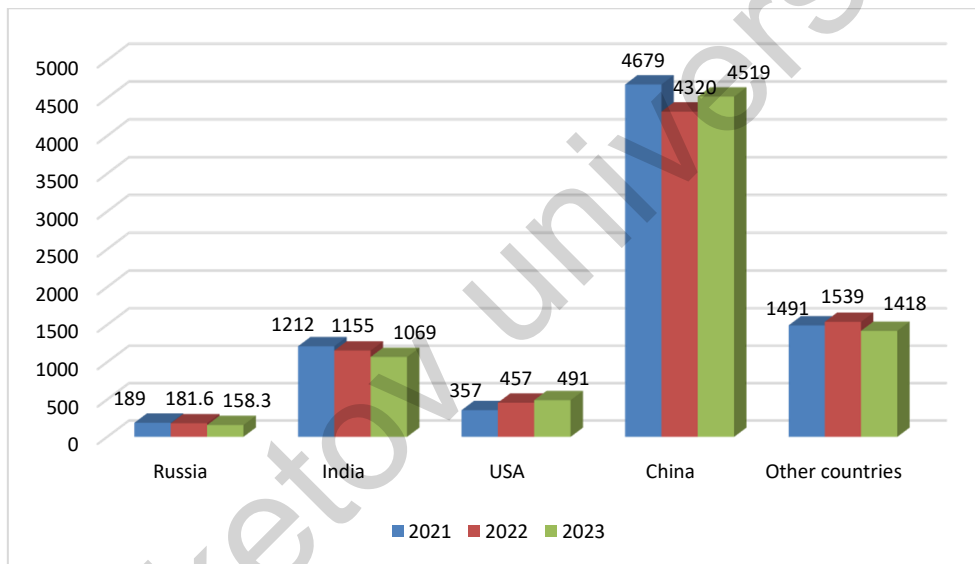


Fig.1 Global coal consumption — the main consumer countries, 2021-2023, mln. Ton (*Developed by the author*)

In world practice, including the practice in Russia, there are objective factors affecting the production activities of mining enterprises. The most relevant of them are the following:

- production and operating costs;
- costs of industrial and environmental safety of mining operations.

It is worth noting that during over 20 years of reforms, the mining industry, along with the others, faced large-scale problems such as the protracted transition to green energy, reduction of natural resources and global environmental changes [14].

The current foreign policy concerning Russia, the Armed Forces of Ukraine, and sanctions pressure from European states and the United States affected the development of the economy as whole, affecting the mining industry as well. As a result, some problems have arisen that require special attention to [15]:

- reduction of investments,
- restrictions on exports and foreign trade,
- restrictions on external financial transactions, etc.

The consequences of the above-mentioned problems include disruptions of supply chains, more complicated access to modern technologies, increased overhead costs, and lower incomes of enterprises.

However, Russia has great potential to raise the level of the economy, including at the expense of the mining industry [15]. Nowadays, the urgent tasks, the mining enterprises face should include:

- accelerated process of searching for new mining tools,
- global digital transformation,
- increasing the pace of modernization of production.

At the same time, the development of science and innovative technologies prove that digital transformation is the main trend of modernization and accelerated development of the mining industry. The introduction of digital technologies "Industry 4.0" and "Digital Economy of the Russian Federation" have the maximum impact on the development potential of mining companies in Russia. It should be noted, that more than 50% of Russia's GDP is created in the extractive and manufacturing industries [15].

In order to implement the national policy, the processes of digital transformation in the mining industry have been identified:

- implementation of artificial intelligence technologies;
- technological sovereignty of enterprises.

Today, only 20-30% of mining enterprises have the opportunity and are able to implement digital transformation actively.

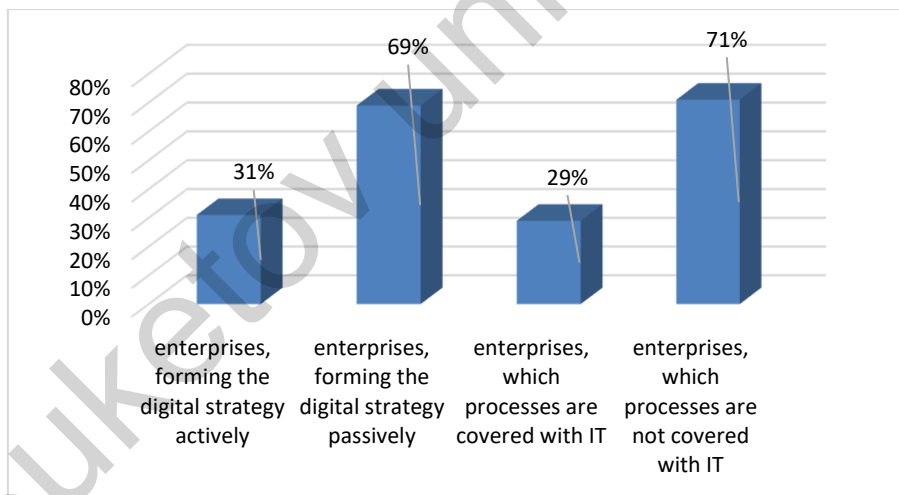


Fig. 2 Indicator of the involvement of mining enterprises in the processes of digital transformation, % (Developed by the author)

In Fig. 2 the indicator of the level of involvement of mining enterprises in the processes of digital transformation is schematically presented. According to the research conducted by Reksoft in May 2023, only 31% of 100% of enterprises are actively forming a digital strategy, 29% of enterprises use digital technologies for most of their processes, while the rest of enterprises are at an early stage of digital transformation or cover only key processes [14].

Russian large holdings EVRAZ, Mechel, PJSC Norilsk Nickel, PJSC Alrosa are trying their best to introduce digital technologies to improve the efficiency of production and business processes, quality and safety [14].

At the moment the main trend in the development of large mining enterprises is digital transformation and the automation of all production processes on its basis [14].

In the world practice, mining enterprises apply the principle of "smart production" in the planning and management process [14].

The traditional mining industry is the industry with maximum production risks, a labour-intensive industry, and it needs a reliable and efficient information collection and transmission system to facilitate the comprehensive interconnection of people, machines and objects in mines. The advantages of 4G and 5G technology with high bandwidth and low latency allow remote control of the equipment. This innovation significantly reduces the costs of operation and maintenance, as well as the construction risks of mining enterprises, reduces the number of people in mines and improves intelligent decision-making, intellectual perception and executive capabilities of mines.

Intelligent mines are not only an advanced area of scientific-and-technological innovation in the Russian mining industry, but also a reliable guarantee of the sustainable development of the mining industry. In recent years, in the context of the continuous integration and development of domestic IT technologies, such as the transition to 4G, 5G, cloud computing and big data processing using mining, the process of building domestic smart mines should accelerate. At this stage, they already have good results and prospects for development.

With the advent of the Fourth Industrial Revolution, mining enterprises began to widely practice the process of intelligent construction. Depending on the direction of application of the technology, it can be divided into automated mines and intelligent (smart) mines.

Currently, it is considered that the functions of modern intelligent mines include planning, design, automated operation, the possibility of implementing unmanned operation and intelligent control processes.

The digitalization of mines is the main trend and the basis for the intelligent construction of coal mines. The concept of digital transformation of coal mines is aimed at bringing all processes together on the basis of specialized digital platforms – Connected Mine's class solutions ("digital mine").

Connected Mine's main digital platform contains the main production system and an auxiliary production system. The main production system includes the intelligence of the coal mining face and the intelligence of the dredging face. For coal mines, this is an intelligent integrated excavation face and an unmanned excavation face, represented by automatic coal mining technology. For non-coal mines, this may be an unmanned treatment face and an unmanned face system represented by intelligent explosive development or automatic mechanical mining technology.

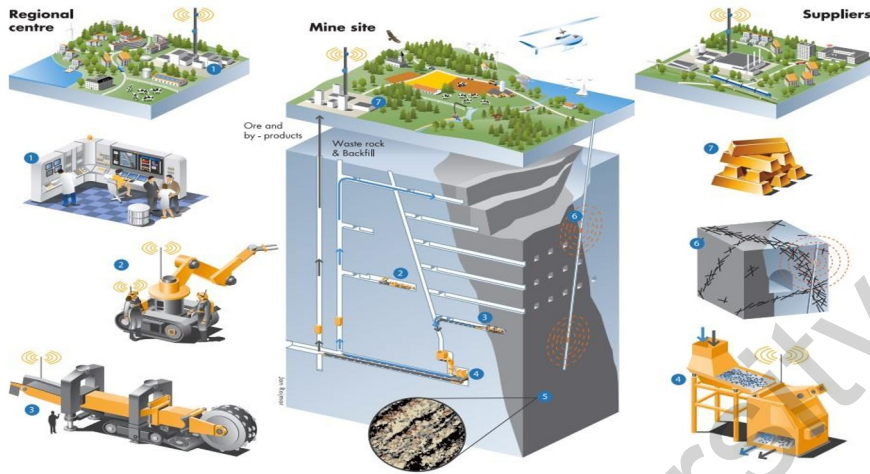


Fig.3 The project of an intelligent digital mine (*Developed by the author*)

An intelligent auxiliary production system is the intelligent operation of an auxiliary system [26]. It is mainly characterized by the automatic intelligent transportation system (including belt transportation and auxiliary transportation), intelligent lifting system, intelligent power supply system, intelligent drainage system, intelligent pressurized air supply system, intelligent ventilation system, intelligent dispatch and control system, intelligent communication systems, etc., which have developed rapidly recently (Fig.3).

This article states that the construction of smart mines should be supported by the communication system platform with advanced technologies, integrated business, powerful functions and stable performance. 4G communication technology, and in the future 5G, has the characteristics of high bandwidth, low latency and large-scale equipment connectivity. It provides a channel for the “Internet of Everything” of the mining equipment group, which can realize the full range of mine communication network coverage, comprehensive collection and transmission of data on underground equipment and the environment, as well as accurate and reliable implementation of equipment management to meet the needs of various types of mines, business systems requirements for network data transmission.

The main objective of the process of building intelligent digital mines in Russia is to create an advanced digital infrastructure, with a system of applications for mining, focused on people.

Intelligent coal mining (Mining 4.0) is the vertical application of the industrial Internet system to maximize the efficiency of mining operations, ensure safe mining and reduce the number of accidents related to personnel safety. The possible results of the introduction of artificial intelligence in Mining 4.0 are discussed in the table in Fig. 4:

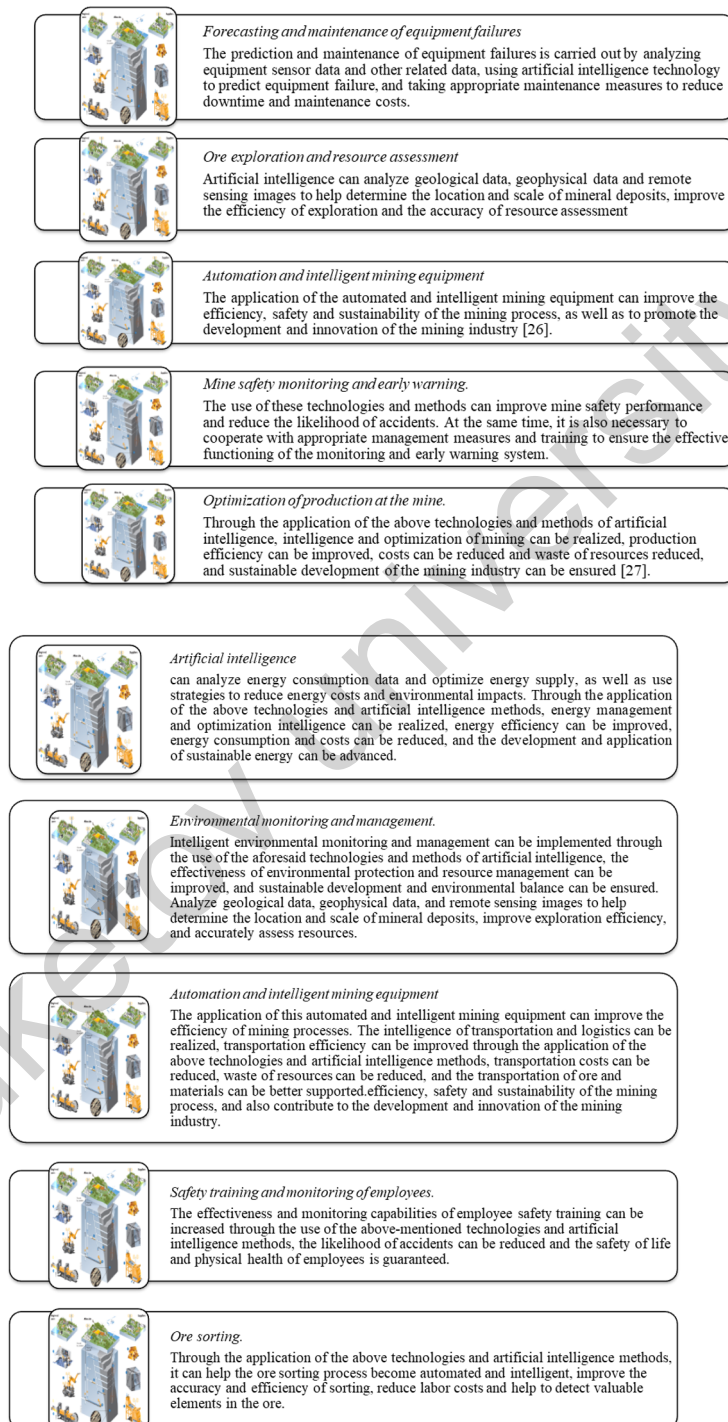


Fig.4 Possible results of the use of artificial intelligence in Mining 4.0. (Developed by the author)

The company creates an intelligent information infrastructure basing on the two-way interaction of business and the platform, a basic software platform and a data integration platform for the implementation of production intelligence, security intelligence and support system intelligence, thereby stimulating industrial potential, comprehensive promotion of digital mine construction.

Unfortunately, it is not uncommon to receive reports of accidents at coal mines. However, with the development of 4G technology, this situation may change. On the one hand, the introduction of sensors and networks will make mining more controlled, on the other hand, thanks to a seemingly indirect indicator such as safety in the development of smart mines, production efficiency in general will also increase.

Certainly, such an important way to ensure the safe, efficient, economical and environmentally friendly development of the coal industry as intelligent coal mining will be highly appreciated by the state and relevant departments. It will be necessary to formulate a regulatory framework and appropriate strategies to support, standardize and promote the intellectual mining industry step by step.

Figure 5 clearly shows the performance indicators at mining enterprises that have implemented digital technologies (Fig.5).

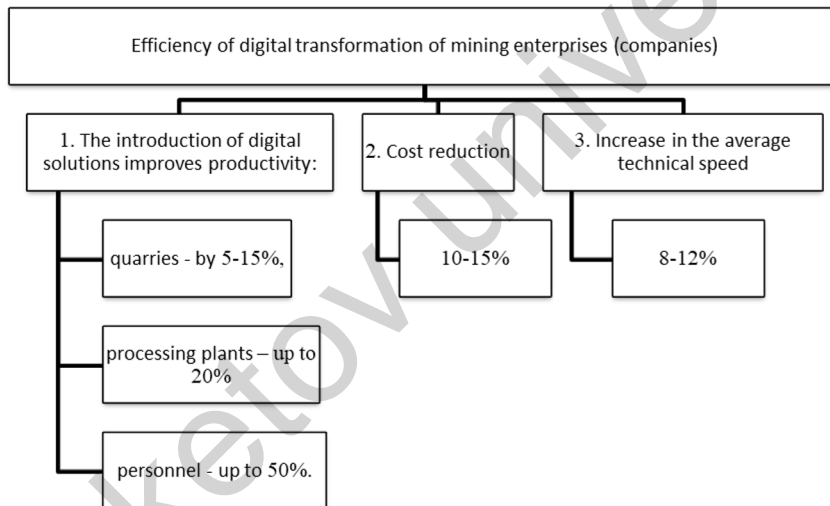


Fig.5 Indicators of the effectiveness of digital transformation in the mining industry (Developed by the author)

Further plans for the construction and digital transformation of intelligent (smart) mines include the formation of new functional units aimed at the efficiency of production processes and improving safety, such as:

- "digital (smart) quarry",
- "digital (smart) transport"
- "digital (smart) control centres".

In the short term, the efficiency of the production equipment of mining enterprises will increase by about 1.9 times, the productivity of the main production staff by 4-5 times, and finally, it is planned to increase safety, which will help reduce the number of workers affected by coal mining by 3-4 times.

5 Conclusions

The results of the research can be stated as follows:

1. The digital transformation of the mining industry is a global strategic important process. In order to support and develop the mining industry, the Russian Government approved a strategy for the development of the coal industry until 2035 in February 2020.

2. Today, along with all industries, mining enterprises have actively joined the processes of digital transformation of the Russian economy.

3. In the complex, digital transformation contains scientific and innovative technologies that include automation, digitalization and intelligent technologies of all the production processes, the purpose of which is to maximize production costs, increase production, economic efficiency and enhance safety at all sites of mining enterprises.

Thus, digital transformation is indeed the main global trend in the sustainable development of mining enterprises, which contributes to the improvement of efficiency indicators at all production levels and, in general, the growth of industry indicators.

References

1. Nagovitsyn O.V. Digital technologies in mining / O.V. Nagovitsyn, O.G. Zhuravleva, A.A. Gilyarova, E.B. Zhidkevich // Collection of abstracts of the conference of the All-Russian scientific and technical conference "Digital technologies in mining". Doi: 10.37614/978.5.91137.491.4
2. Hilson G., Murck B., Sustainable development in the mining industry: clarifying the corporate perspective // Resources Policy, Volume **26**, Issue 4, 2000, pp. 227-238
3. Babkin A.V. Digital economy and its impact on the competitiveness of entrepreneurial structures /A.V. Babkin, O.V. Chistyakova. - Text : direct // Russian entrepreneurship. - 2017. No.24. - pp. 4087-4101. Doi: 10.18334/rp.18.24.38670.
4. Isaichenkova V.V. Ensuring an increase in the competitiveness of an industrial enterprise in the digital economy // Electronic scientific journal "Century of quality". 2019. No.2. pp. 91-105. Access mode: <http://www.agequal.ru/pdf/2019/219007.pdf>
5. Osipova R. G. Digitalization as a competitive advantage of Russian organizations / R.G. Osipova. - Text: direct // Bulletin of the Academy of Knowledge. - 2020. - №2 (37). - Pp.258-262. Doi: 10.24411/2304-6139-2020-10174.
6. Aleksashin T.V. Modern research in the field of digital maturity of HR business processes in support of corporate digital transformation / T.V. Aleksashina, V.I. Smagina, V.V., Smagina. - Text: direct // Scientific works of the Free Economic Society of Russia. - 2020. - No.4. -pp. 86-102. Doi:10.38197/2072-2060-2020-224-4-86-102
7. Gileva T.A. Digital maturity of the enterprise: methods of assessment and management / T.A. Gileva. - Text: direct // Bulletin of the USPTU. Science, education, economics. Series: Economics. - 2019. - №1 (27). - Pp. 38-52. Doi: 10.17122/2541-8904-2019-1-27-38-52
8. Kuzin D.V. Problems of digital maturity in modern business / D.V. Kuzin. - Text: direct // The world of the new economy. - 2019. - No. 3. - pp. 89-99. <https://doi.org/10.26794/2220-6469-2019-13-3-89-99>
9. Piskunov A.I., Glavatsky V.B. New industrialization of Russia: ways to overcome the backlog // Issues of innovative economics. – 2019. – Volume 9. – No. 2. – pp. 287-300. doi: 10.18334/vinec.9.2.40579

10. Izyumtsev A.A., Klebanov D.A. Open software – the key to improving the efficiency of digital transformation of the mining industry // Rational development of the subsoil. – 2022. – No. 5. – pp. 68-71. Doi: 10.26121/RON.2022.92.56.007
11. Matsko N.A., Kharitonova M.Yu. Digitalization of the mining industry and the state of the mineral resource base // Izvestiya Far Eastern Federal University. Economics and management. – 2022. – № 3. – c. 37-47. Doi: <https://dx.doi.org/10.24866/2311-2271/2022-3/37-47>
12. Lukichev S.V., Nagovitsyn O.V. Digital transformation and technological independence of the mining industry. Mining industry. 2022;(5):74–78.
13. Lukichev S.V. Digital transformation of the mining industry / Mining information and analytical bulletin. - No. S37. – 2019. – pp. 7-20. Doi: 10.25018/0236-1493-2019-11-37-7-20
14. Lukichev S.V. Digital mining technologies – import substitution and technological independence. Mining industry. 2023; (5S):04–09. <https://doi.org/10.30686/1609-9192-2023-5S-04-09>
15. Zholmagambetov T. Digitalization of production is the next stage of increasing the productivity of the mining industry // Mining and metallurgical industry. 2018. No.2. URL: <http://metal.mininginfo.kz/archives/5578>
16. Petrenko I. E. The results of the work of the Russian coal industry in January–December 2022 // Coal. 2023. No. 3. pp. 21-33. Doi: 10.18796/0041-5790-2023-3-21-33.
17. Plakitkin Yu. A., Plakitkina L. S., Dyachenko K. I. The main trends in the development of the coal industry in the world and Russia in the conditions of low-carbon energy. Part II. Low-carbon development as a factor in reducing demand for coal and its impact on the prospects of coal generation // Mining Journal. 2022. No. 8. pp. 17-23. doi: 10.17580/gzh.2022.07.01
18. Rozhkov A. A. Structural analysis of import substitution in the coal industry of Russia: reality and forecast // Mining industry. 2017. No. 6. pp. 4-13. <https://bik.sfu-kras.ru/elib/view?id=PRSV-gorp/2017/6-245908320>
19. Yue Zhou, Natural resources and green economic growth: A pathway to innovation and digital transformation in the mining industry, Resources Policy, Volume 90, 2024, 104667, <https://doi.org/10.1016/j.resourpol.2024.104667>
20. Qamar Uz Zaman, Yuhuan Zhao, Shah Zaman, Kiran Batool, Rabiya Nasir, Reviewing energy efficiency and environmental consciousness in the minerals industry Amidst digital transition: A comprehensive review, Resources Policy, Volume 91, 2024, 104851, <https://doi.org/10.1016/j.resourpol.2024.104851>
21. Lars Barnewold, Bernd G. Lottermoser, Identification of digital technologies and digitalisation trends in the mining industry, International Journal of Mining Science and Technology, Volume 30, Issue 6, 2020, Pages 747-757, <https://doi.org/10.1016/j.ijmst.2020.07.003>.
22. Keith Storey, Greg Halseth, Laura Murphy, Sean Markey, Digitalization and changing value propositions for mining regions: Options for action, Resources Policy, Volume 91, 2024, 104861, <https://doi.org/10.1016/j.resourpol.2024.104861>
23. Deepak Kumar, Dilip Kumar, Chapter Four, Digitalization of mining industry, Phosphate Rock, Elsevier, 2023, P. 61-93, <https://doi.org/10.1016/B978-0-323-95984-1.00001-9>.

24. Arman Hazrathosseini, Ali Moradi Afrapoli, The advent of digital twins in surface mining: Its time has finally arrived, *Resources Policy*, Volume 80, 2023, 103155, <https://doi.org/10.1016/j.resourpol.2022.103155>
25. Jiacheng Xie, Suhua Li, Xuewen Wang, Digital Intelligent Product Service System and Mining Industry Case Study: MSPSS, *Advanced Engineering Informatics*, Volume 53, 2022, 101694, <https://doi.org/10.1016/j.aei.2022.101694>
26. Bataev A.V., Mottaeva A.B., Vasilyeva E.Y., Digital Transformation of Industry: A Model of Economic Efficiency of Introduction of Industrial Robots in Russia, *Proceedings of the 34th International Business Information Management Association Conference (IBIMA). Vision 2025: Education Excellence and Management of Innovations through Sustainable Economic Competitive Advantage*. Madrid, Spain, 2019, pp. 277-287
27. Makhosheva, S., Vasilyeva, E. Development of business processes in the innovatively active organizations // *E3S Web of Conferences* Эта ссылка отключена., 2021, Vol. 244, Art. num. 10027