«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ
«ХАЛЫҚ» ЖҚ

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ИЗВЕСТИЯ	N E W S
РОО «НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК РЕСПУБЛИКИ КАЗАХСТАН» ЧФ «Халық»	OF THE ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN «Halyk» Private Foundation

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NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

ЧФ «ХАЛЫҚ»

В 2016 году для развития и улучшения качества жизни казахстанцев был создан частный Благотворительный фонд «Халык». За годы своей деятельности на реализацию благотворительных проектов в областях образования и науки, социальной защиты, культуры, здравоохранения и спорта, Фонд выделил более 45 миллиардов тенге.

Особое внимание Благотворительный фонд «Халык» уделяет образовательным программам, считая это направление одним из ключевых в своей деятельности. Оказывая поддержку отечественному образованию, Фонд вносит свой посильный вклад в развитие качественного образования в Казахстане. Тем самым способствуя росту числа людей, способных менять жизнь в стране к лучшему – профессионалов в различных сферах, потенциальных лидеров и «великих умов». Одной из значимых инициатив фонда «Халык» в образовательной сфере стал проект Ozgeris powered by Halyk Fund – первый в стране бизнес-инкубатор для учащихся 9-11 классов, который помогает развивать необходимые в современном мире предпринимательские навыки. Так, на содействие малому бизнесу школьников было выделено более 200 грантов. Для поддержки талантливых и мотивированных детей Фонд неоднократно выделял гранты на обучение в Международной школе «Мирас» и в Astana IT University, а также помог казахстанским школьникам принять участие в престижном конкурсе «USTEM Robotics» в США. Авторские работы в рамках проекта «Тәлімгер», которому Фонд оказал поддержку, легли в основу учебной программы, учебников и учебно-методических книг по предмету «Основы предпринимательства и бизнеса», преподаваемого в 10-11 классах казахстанских школ и колледжей.

Помимо помощи школьникам, учащимся колледжей и студентам Фонд считает важным внести свой вклад в повышение квалификации педагогов, совершенствование их знаний и навыков, поскольку именно они являются проводниками знаний будущих поколений казахстанцев. При поддержке Фонда «Халык» в южной столице был организован ежегодный городской конкурс педагогов «Almaty Digital Ustaz.

Важной инициативой стал реализуемый проект по обучению основам финансовой грамотности преподавателей из восьми областей Казахстана, что должно оказать существенное влияние на воспитание финансовой грамотности и предпринимательского мышления у нового поколения граждан страны.

Необходимую помощь Фонд «Халык» оказывает и тем, кто особенно остро в ней нуждается. В рамках социальной защиты населения активно проводится

работа по поддержке детей, оставшихся без родителей, детей и взрослых из социально уязвимых слоев населения, людей с ограниченными возможностями, а также обеспечению нуждающихся социальным жильем, строительству социально важных объектов, таких как детские сады, детские площадки и физкультурно-оздоровительные комплексы.

В копилку добрых дел Фонда «Халык» можно добавить оказание помощи детскому спорту, куда относится поддержка в развитии детского футбола и карате в нашей стране. Жизненно важную помощь Благотворительный фонд «Халык» оказал нашим соотечественникам во время недавней пандемии COVID-19. Тогда, в разгар тяжелой борьбы с коронавирусной инфекцией Фонд выделил свыше 11 миллиардов тенге на приобретение необходимого медицинского оборудования и дорогостоящих медицинских препаратов, автомобилей скорой медицинской помощи и средств защиты, адресную материальную помощь социально уязвимым слоям населения и денежные выплаты медицинским работникам.

В 2023 году наряду с другими проектами, нацеленными на повышение благосостояния казахстанских граждан Фонд решил уделить особое внимание науке, поскольку она является частью общественной культуры, а уровень ее развития определяет уровень развития государства.

Поддержка Фондом выпуска журналов Национальной Академии наук Республики Казахстан, которые входят в международные фонды Scopus и Wos и в которых публикуются статьи отечественных ученых, докторантов и магистрантов, а также научных сотрудников высших учебных заведений и научно-исследовательских институтов нашей страны является не менее значимым вкладом Фонда в развитие казахстанского общества.

С уважением,
Благотворительный Фонд «Халык»!

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EVALUATION OF THE EFFICIENCY OF DIGITAL SOLUTIONS IN THE MINING SECTOR

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Abstract. The relevance of the study is predetermined by the strategic objectives of the mining sector of Kazakhstan. In the foreseeable future, it is necessary to increase the predictability of the sphere of subsoil use, complete the transition to the international system of reporting standards for mineral reserves, master higher redistribution based on the integrated use of digital solutions. In this study, a generalized assessment of the impact on the results of state regulation of the sphere of subsoil use of the uncertainty of the external environment is given. It is emphasized that in the context of increasing the geological knowledge of the territory of Kazakhstan and attracting investments in the mining sector, the processes of state regulation in the field of subsoil use require the accelerated development of digital technologies, the development of domestic software, and the creation of an information technology infrastructure. It is shown that the lag of mining enterprises in Kazakhstan in the development of digital solutions negatively affects the investment attractiveness of the country, slows down the transition to the international system of reporting standards for solid mineral reserves CRIRSCO.

The importance of digital technologies in increasing the reliability of the geological and economic assessment of deposits characterized by a low degree of exploration is substantiated. The most popular guidelines for the digital transformation of a mining enterprise are indicated in accordance with the chosen strategic trends and positioning features in the international division of labor. New approaches to the use of neural models in the mining sector for making managerial decisions based on up-to-date information about the structure of the resource base and the amount of profitable reserves are discussed. The practical significance of the work lies in the argumentation of the engineering and economic approach to the selection of information and analytical tools for digitalization of mining enterprises. The experience of Kazakhstan can be useful for mining companies in developing countries that are expanding their international positioning and promoting the decarbonization of the national economy.

Keywords: digitalization, Kazakhstan, investment policy, mining sector, KAZRC standard, neural model

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ТАУ ӨНДІРУ СЕКТОРЫНДАҒЫ ЦИФРЛЫҚ ШЕШІМДЕРДІҢ ТИІМДІЛІГІН БАҒАЛАУ

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Аннотация. Зерттеудің өзектілігі Қазақстанның тау-кен секторының стратегиялық міндеттерімен алдын ала анықталған. Жақын болашақта жер қойнауын пайдалану саласының болжамдылығын арттыру, пайдалы қазбалар қорлары бойынша есеп беру стандарттарының халықаралық жүйесіне көшуді аяқтау, цифрлық шешімдерді кешенді пайдалану негізінде жоғарырақ қайта бөлуді игеру қажет. Бұл зерттеуде сыртқы ортаның белгісіздігінің жер қойнауын пайдалану саласын мемлекеттік реттеу нәтижелеріне әсерінің жалпылама бағасы берілген. Қазақстан аумағының геологиялық білімін арттыру және тау-кен саласына инвестиция тарту жағдайында жер қойнауын пайдалану саласындағы мемлекеттік реттеу процестері цифрлық технологияларды жедел дамытуды, отандық бағдарламалық қамтамасыз етуді, және ақпараттық технологиялар инфрақұрылымын құру. Қазақстандағы тау-кен өндіруші кәсіпорындардың цифрлық шешімдерді әзірлеудегі артта қалуы елдің инвестициялық тартымдылығына кері әсерін тигізетіні, қатты пайдалы қазбалардың қорлары бойынша CRIRSCO есеп беру стандарттарының халықаралық жүйесіне өтуді баяулататыны көрсетілген. Барлаудың төмен деңгейімен сипатталатын кен орындарын геологиялық-экономикалық бағалаудың сенімділігін арттыруда цифрлық технологиялардың маңыздылығы дәлелденді. Тау-кен өндіруші кәсіпорынның цифрлық трансформациясының ең танымал нұсқаулары таңдалған стратегиялық үрдістерге және халықаралық еңбек бөлінісіндегі позициялау ерекшеліктеріне сәйкес көрсетілген. Ресурстық базаның құрылымы мен пайдалы қорлардың көлемі туралы өзекті ақпарат негізінде басқару шешімдерін қабылдау үшін тау-кен секторында нейрондық модельдерді қолданудың жаңа тәсілдері талқыланады. Жұмыстың практикалық маңыздылығы тау-кен өнеркәсібі кәсіпорындарын цифрландыру үшін ақпараттық-аналитикалық құралдарды таңдаудағы инженерлік-экономикалық тәсілді дәлелдеуде жатыр. Қазақстанның тәжірибесі халықаралық позицияларын кеңейтіп, ұлттық экономиканы көміртексіздендіруге жәрдемдесетін дамушы елдердің тау-кен компаниялары үшін пайдалы болуы мүмкін.

Түйін сөздер: цифрландыру, Қазақстан, инвестициялық саясат, тау-кен секторы, KAZRC стандарты, нейрондық модель

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ОЦЕНКА ЭФФЕКТИВНОСТИ ЦИФРОВЫХ РЕШЕНИЙ В ГОРНОДОБЫВАЮЩЕМ СЕКТОРЕ

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Аннотация. Актуальность исследования предопределена стратегическими задачами горнодобывающего сектора Казахстана. В обозримом будущем предстоит повысить предсказуемость сферы недропользования, завершить переход на международную систему стандартов отчетности по запасам полезных ископаемых, освоить более высокие переделы, базируясь на комплексном использовании цифровых решений. В настоящем исследовании дана обобщенная оценка влияния на результаты государственного регулирования сферы недропользования неопределенности внешней среды. Подчеркнуто, что в условиях наращивания геологической изученности территории Казахстана и привлечения инвестиций в горнодобывающий сектор, процессы государственного регулирования в сфере недропользования требуют ускоренного освоения цифровых технологий, разработку отечественного программного обеспечения, создания инфраструктуры информационных технологий. Показано, что отставание горнодобывающих предприятий Казахстана в освоении цифровых решений негативно влияет на инвестиционную привлекательность страны, замедляет переход на международную систему стандартов отчетности по запасам твердых полезных ископаемых CRIRSCO. Обоснована значимость цифровых технологий в повышении достоверности геолого-экономической оценки месторождений, характеризующихся низкой степенью изученности. Обозначены наиболее востребованные ориентиры цифрового преобразования горнодобывающего предприятия в соответствии с выбранным стратегическими трендами и особенностями позиционирования в международном разделении труда. Обсуждаются новые подходы к использованию нейронных моделей в горнодобывающей сфере для принятии управленческих решений на основе актуальной информации о структуре ресурсной базы и количестве рентабельных запасов. Практическая значимость работы заключается в аргументации инженерно-экономического подхода к подбору информационно-аналитических инструментов цифровизации горнодобывающих предприятий. Опыт Казахстана может быть полезным горнодобывающим предприятиям развивающихся стран, расширяющих

свое международное позиционирование и продвигающих декарбонизацию национальной экономики.

Ключевые слова: цифровизация, Казахстан, инвестиционная политика, горнодобывающий сектор, стандарт KAZRC, нейронная модель

Introduction

In terms of mineral wealth, Kazakhstan is among the world leaders, ranking 1st in terms of tungsten reserves, second in chromium ore, fifth in lead and zinc, 12th in copper and 15th in gold. In terms of proven reserves of most types of minerals, the country is among the top ten leading countries in the world.

However, the geological industry of Kazakhstan has come to the threshold when previously explored economically attractive deposits are either in development or exhausted, and new deposits have not been discovered for decades. Since the early 2000s, these reserves have been estimated as subcritical. At the moment, 1.2 million square meters. km of Kazakhstan are available for geological study and only a fifth of this territory has been studied in accordance with the requirements. By 2026, the exploration of the territory of Kazakhstan will increase by 680 thousand square meters. km, will reach 2.2 million sq. km. At the same time, the subsoil is underexplored to such an extent that one can talk about the discovery of large deposits on a systematic basis.

The condition of the economy directly depends on reserves in the subsoil, therefore, in recent years, the state has been actively resuming geological exploration: for 2019–2022. state funding for geological exploration of the subsoil has doubled. Work is being stepped up at small deposits discovered almost thirty years ago and suspended due to their small size, facilitated licensing for the search for solid minerals is being introduced, and favorable conditions are being created for small exploration companies.

Kazakhstan expects an increase in investment activity in exploration, the level of capitalization of reserves of local raw materials and their reliability, the discovery of new deposits largely due to joining the international standards for reporting on reserves of solid minerals CRIRSCO (Committee for Mineral Reserves International Reporting Standards) (Code of the Republic of Kazakhstan, 2017). Since the best world experience in the mining industry confirms that over 60 % of investments in exploration and development of solid mineral deposits relate to projects developed according to international CRIRSCO standards.

For Kazakhstan, it is important that almost half of the new deposits in the world were discovered by juniors, whose main activity involves geological exploration and development of new deposits. In the context of the current diminution in the number of large deposits in Kazakhstan, it is critically important to create a favorable environment and ecosystem for the development of the junior market, thereby ensuring the quantitative and qualitative growth of the mining industry, replenishing the country's mineral reserves through new high-quality deposits.

Since the country's mining sector is one of the top three air pollutants, it is

crucial for Kazakhstan to fulfill its obligations to decline greenhouse gas emissions, otherwise positions in the world market will be lost due to non-compliance with "green" standards. For a country that has set a goal of declining industrial carbon emissions by 19 % by 2030 and becoming carbon neutral by 2060, huge investments in new manufacturing and energy technologies are required.

To solve the set tasks, the digital transformation of the mining sector is being updated, which makes it possible to reduce hydrocarbon emissions. The development of digital technologies, the scaling up of modern energy-efficient equipment and technological competencies in the development of complex reserves allow us to optimize unit production costs. Cost reduction in turn improves business efficiency, maximizes free cash flow and amplify.

As Kazakhstan plans to become a central digital hub in a large part of the Eurasian region, the transfer of digital products, the introduction of innovative approaches and environmentally friendly technologies for the transition of industrial production to a low-carbon economy are coming to the fore.

The foregoing actualizes the issue of digital transformation of the mining sector for Kazakhstan. The demand for research and the feasibility of in-depth consideration of these issues predetermines the desire of enterprises for digitalization, as the most important factor in the growing competition in the mineral raw materials market. The situation is complicated by the fact that at the moment, domestic mining enterprises are significantly behind foreign competitors in terms of value created, which is largely due to the low level of digitalization.

The purpose of this study is to assess the effectiveness of the digitalization of the mining sector in Kazakhstan, taking into account international integration and the growing uncertainty of the external environment.

Literature review. Currently, researchers are paying more and more attention to the search for a qualitative geological and economic assessment of objects using digital tools, since the reserves of deposits are not unlimited and non-renewable, which can lead to a sharp deterioration in the quantitative and qualitative indicators of the state of the mineral resource base (Young and Rogers, 2019).

Many studies summarize the results of a thorough study of the implications of digital technologies for the energy value chain (Menzel and Teubner, 2021), show the role of advanced technical solutions in the geological and economic assessment of the enterprise, approach the sustainability of the mining industry and diversify the national economy (Zhironkin and Cehlár, 2021; Breul and Atienza, 2022).

Using a specific example, the authors (Issayeva et al., 2023) are studying a new approach in the methodology of geological studies and ore objects. Research confirms that the solution of the most complex problems is possible only thanks to modern research technologies.

The study (Bazaluk et al., 2022) reveals the role of digital technologies in making investment production decisions. According to a study (Al Rawashdeh and Campbell , 2022), the development of digital approaches in mining has a positive result not only in increasing the investment attractiveness of the country. Positive

shifts are observed in the growth of social responsibility and corporate management. The paper (Kumar Sharma and Rai, 2017) demonstrates the performance of medium size forecasting models in the context of industrial digital solutions.

Of great interest are the issues of using digital technologies in the activities of a mining enterprise from the standpoint of its environmental and socio-economic achievements (Aznar-Sánchez et al., 2019), unlocking the potential of digital technologies in solving health and safety issues is consecrated in the work (Gurina et al., 2020), the specifics of the digital impact on copper production and the corresponding environmental impact (Azadi et al., 2020).

Much research is focusing on natural resource management and resource-saving sustainability (Kashan et al., 2022), based on the emerging long-term demand for minerals that is transforming the mining industry (Lufin and Soto-Díaz, 2022).

The focus of scientists and practitioners is always on the issues of competence and a professional approach to digitalization. Thus, the authors of the study (Tortorella et al., 2020) conclude that enterprises that invest in training and the exchange of relevant knowledge in the field of digitalization on an intra-production scale may subsequently benefit from the introduction of digital solutions into production and management processes.

Discussions about the role of international standards, mastered by industrial enterprises, in increasing the returns from digitalization, strengthening competitive positions both in the domestic and foreign markets do not subside. (Jelisic et al., 2022).

The scientific and practical value for mining enterprises is an integrated approach to systematizing knowledge about digital production solutions based on a large array of initial data (Zhan et al., 2019).

Given the growing importance of juniors for exploration and the relevance of this problem for countries with economies in transition, the results of studies, the authors of which study the experience of using digital technologies in the business environment, are of interest (Zaher et al., 2019).

Numerous publications are devoted to developing countries, summarizing their positive experience in implementing digital technologies in various industries. For example, (Anderson, 2015; Espinoza and Rojo, 2017) show how the growing contribution of the mining sector in developing countries to regional economic growth is taken into account.

Many studies focus on the effectiveness of neural networks in the mining industry and new opportunities for their use in the geological and economic assessment of a deposit (Moody and Darken, 1989; Kulatilake et al., 2010; Sayadi et al., 2013).

Materials and basic methods

The theoretical and methodological base of the study is represented by the concepts and notions traditionally used in the study of state regulation of the real sector of the economy. For the study of information and analytical material, well-known practices of economic, statistical and functional analysis, methods of pattern recognition based on the identification of geological patterns were used. In

preparing the article, the authors faced evidentiary constraints. This is largely due to the fact that for any country, data on mineral reserves is strategic information of a secret nature, sometimes mineral deposits are generally described only by qualitative assessments. A limiting factor in conducting this study is the lack of experienced mining engineers, technologists, IT specialists and financial analysts in Kazakhstan who are able to evaluate statistics on digitalization in the mining sector and compare them with international practice.

Results

Trends in the development of the mining sector in Kazakhstan: an international aspect. Despite the positive dynamics of the key indicators of the mining and metallurgical complex, in the context of growing geopolitical tensions, the dependence of the industry on external conditions remains extremely high, since only insignificant volumes of copper, lead and zinc are processed domestically (tables 1, figure 1).

Table 1 - Dynamics of production in the mining and metallurgical complex

Index	years										
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Volume of production, billion tenge: - in the metallurgical industry	1935.0	1772.1	1915.2	21119.3	3360.7	4089.7	4645.0	4885.4	5677.8	7678.0	9018.8
- in the field of mining of metal ores	691.8	786.2	882.3	700.5	996.3	1211.6	1462.1	1906.0	2188.4	3277.3	3419.2

Source: compiled by the authors based on (Bureau of National Statistics, 2023).
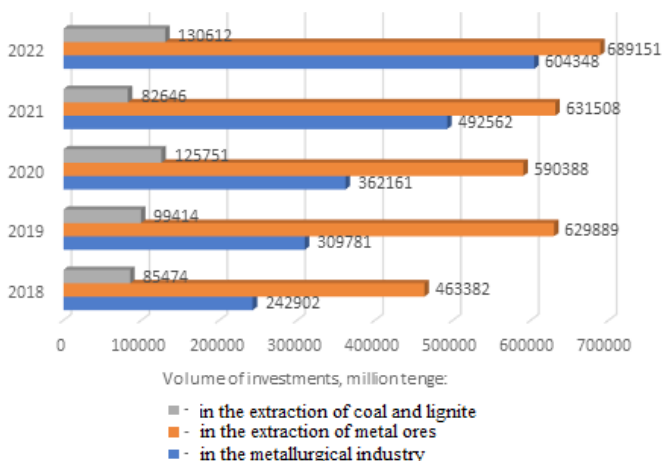
Figure 1 - Dynamics of investments in the mining and metallurgical complex
Source: compiled by the authors based on (Bureau of National Statistics, 2023).

Kazakhstan competes for fourth position of world ranking among copper-production countries, which will be facilitated by the increase in copper output, the development of new copper deposits, and the commissioning of two new copper smelters. In terms of promoting the production of high value-added products (copper, lead, aluminum and other metals), Kazakhstan relies on both its own resources and potential investors.

Among the countries of Central Asia, Kazakhstan and Uzbekistan have the most favorable investment directions. This is due to both the favorable strategic location between Europe and Asia, as well as the huge reserves of natural resources. For long-term sustainable growth, the diversification of the economies of the Central Asian countries, advancement along the value chain, not only the financing of joint international projects, but also the training of national personnel, the introduction of digital solutions in geological exploration, enhancing energy and environmental security, are becoming crucial.

This is evidenced by the directions of attracting foreign direct investment (FDI): in 2019–2021. FDI in Central Asia, despite the potential of the mining and hydrocarbon sectors, has shifted from extractive industries to the service sector (Table 2).

Table 2 - Dynamics of FDI in the economy of Central Asia (2019–2021)

Direction	Projects	Number of jobs created (thousand)	Capital investments in projects to create new facilities and new jobs (US$ billion)	Weighted FDI score
Services	103	22.6	5.5	37.6
Industry	76	13.9	7.8	28.1
Extractable Resources	13	1.2	4.7	5.4
Total	192	37.7	18.0	71.1

Source: compiled by the authors based on (Investment attractiveness of Central Asian countries, 2022)

Kazakhstan has a huge long-term mining potential as a source of metals necessary for the production of vehicles and renewable energy sources. The country has enormous potential for the development of the mineral resource base of gold and the copper ore industry, there are prospects for discovering new deposits of tungsten, molybdenum, aluminum, and tin. However, the discovery of new deposits is constantly becoming more complicated and more expensive, which makes it necessary to develop geological science to justify the risks and justify the increasing.

8,000 deposits discovered during the Soviet period have been put on the state balance of mineral resources of the country. Of these, 317 are hydrocarbons, 910 are solid minerals, more than 3,000 common minerals and about 4,000 groundwater deposits. Calculation of reserves of solid minerals is carried out for 37 types of metallic minerals and 65 types of non-metals, 4 thousand deposits have approved reserves of 43 million m³ / day.

Near depletion of lead, copper and a number of rare metals in 10–15 years' time. The technically complex and costly process of closing deposits, requiring the solution of socio-economic problems, began in Kazakhstan relatively recently, and practical experience in solving it is critical to ensure the sustainable development of the mining industry. After the depletion of mineral and metal deposits, mining enterprises are responsible for the conservation of biodiversity and the restoration of pre-existing ecosystems.

Notwithstanding that the volume of state investments in exploration are constantly growing up, only in 2020–2022, 30 billion tenge was invested, the investment rate in the industry is considered low: per sq. km accounts for only 11 dollars, which is 15 times less than in Australia and 18 times less than in Canada.

Moreover, the country has an extremely low level of reserves replacement (Figure 2).
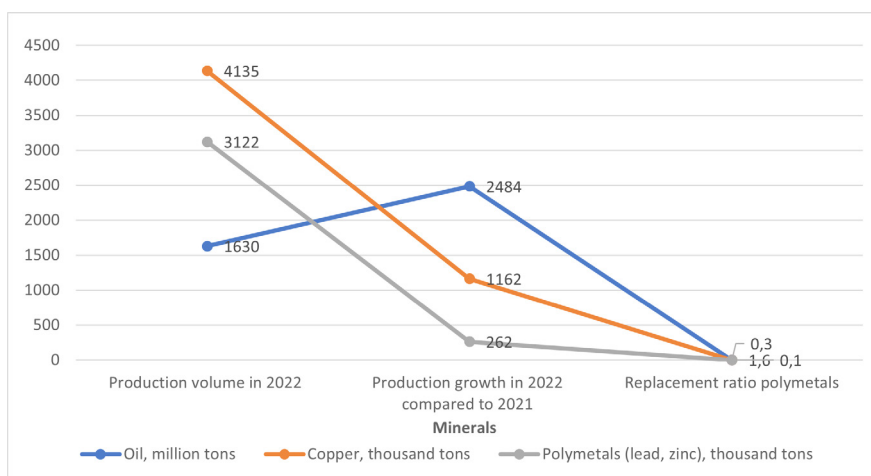
Figure 2 – Mineral recovery level

Source: compiled by the authors based on (Concepts for the development of the geological industry of the Republic of Kazakhstan for 2023–2027, 2022).

The lack of real results in geological exploration has a negative impact on the investment attractiveness of the industry, since foreign investors are interested in more explored areas and blocks, for which a decision has already been made to involve them in the development of deposits. Investors invest in exploration of deposits in those countries where the early stages of work have already been or are being carried out, a database of promising areas with predicted resources has been formed, there is no disorder in the coordination of procedures in the field of subsoil use, imperfections in the system of taxation of subsoil users and interdepartmental barriers.

In the last decade, deposits of Kazakhstan with foreign participation have been evaluated in parallel both according to the standards of the State Commission for

Approved Reserves of the Republic of Kazakhstan (GKZ RK) that have existed since Soviet times, and the standards of the Australasian Code for the preparation of reporting on the results of geological exploration, Mineral Resources and Ore Reserves ("JORC Code, 2012). This was necessary for internal use (providing an understanding of the current potential of the field) and entering the stock exchange. Therefore, these local subsoil users are practically ready for a complete transition to international standards.

Regarding the goals pursued by the JORC Code and the GKZ RK system. The internationally recognized JORC Code is aimed at public reporting to investors, the reporting format is governed by the rules of the exchange / financial institution. The GKZ RK system was originally created for state regulation and accounting of the mineral resource base in a planned economy. Reports are prepared for all local deposits and without their protection in the state commission, it is impossible to design and build an enterprise. The system proceeds from the fact that the state is independently engaged in exploration, evaluation, design and development of deposits.

The implementation of the Kazakhstani Code of Public Reporting on Exploration Results, Mineral Resources and Mineral Reserves (KAZRC Code) - essentially equivalent to JORC / NI 43-101, started in 2016 from the moment Kazakhstan joined the International Committee for Public Reporting Standards on Mineral Resources and CRIRSCO reserves and adoption of the Western Australian Mining Code. Since 2022, Kazakhstan has introduced the practice of checking KAZRC reports, similar to how it is done in most countries: RPO - SAMREC - South Africa, JORC - Australia, CIM - Canada. KAZRC reports inform government agencies, stock exchanges, banks, investors about the results of exploration work, assessment of mineral resources and mineral reserves for a particular object. Investors are provided with access to almost all sites, except for those already occupied (contractual and licensed), environmental zones and objects of the Ministry of Defense.

While in 1996–2018 years, 551 solid minerals subsoil use contracts were drown up, about 2000 solid mineral exploration certificates were issued in 2018, of which 1995 were for exploration and 58 for mining. The share of junior companies was more than 90 %. In 2019, the first 7 reports under the KAZRC code were tested, which were accepted with the state balance sheet. In 2020, 14 reports were developed, in 2021. - 23 reports. This is more than the number of reports according to the GKZ standard, which were adopted by the Committee of Geology for the same period. In 2019–2021 more than 800 licenses were issued for the exploration of solid minerals with exploration periods from 3 to 6 years, and 1,400 new licenses were issued mainly for prospecting and exploration. Exploration licenses are presented mainly at the level of new, young deposits. Prospecting works have brought an effect: identification and delineation of promising areas and ore occurrences of minerals, assessment of mineral resources, scientific and technical justification of exploration work.

The first reports according to international standards submitted by domestic

enterprises had fundamental remarks: distortions of geological information and insufficiency of exploration data (low confirmation of historical exploration results, insufficient verification work, technical studies covering hydrogeology, geotechnics and technology), unsatisfactory (or insufficient) data quality control and reliability of sampling and analytical data.

Please note that when switching from GKZ to KAZRC, the enterprise will need to conduct exploration work for concealed deposits that do not have obvious signs on the surface, requiring business risks to be taken into account when exploring new deposits that may have a high degree of cost of recovering reserves. The foregoing will have a particularly negative impact on medium and small subsoil users, since significant financial investments will be required.

The implementation of standards concerns not only the system of counting reserves. Issues that require an integrated approach are touched upon: taxation, state financing of the industry, development of science, staff development, interaction of companies with the stock exchange, second-tier banks and development institutions. Therefore, the state has designated a transition period (2018-2023) to the KAZRC standards and a complete rejection of the hopelessly outdated thirty-year-old Soviet system of the GKZ RK and the taxation regime.

Until January 1, 2024, two standards are in force in Kazakhstan: the Soviet GKZ standard, and the KAZRC standard. The fundamentally different approach in the standards is expressed in the following. In both cases, a large number of participants are expected to work with information and a report, however, according to the KAZRC standard, all responsibility is assumed by a competent person who meets the requirements of CRIRSCO, signs the report and is responsible not only for the code of ethics (which, by the way, is not in the GKZ standard), but even up to criminal, if the reporting reflects incorrect data. In the GKZ standard, no one bears personal responsibility.

In 2024, a full transition to the KAZRC Code is planned. A full transition to reports on reserves and resources according to international standards such as KAZRC, JORC, in compliance with all the requirements for quality control QA / QC and the use of acQuire software, will accelerate the solution of tasks to ensure transparency and reliability of the state balance, control the compliance of reports on mineral resources and reserves, trained by competent persons, training of domestic highly qualified specialists, introducing the principles of ESG (Environmental, social, and governance) into national standards, accelerating the transition to an international system of geological reporting. In the face of fierce competition for investment in the global mineral market, any extension of the transition period until the full implementation of the KAZRC code may be perceived by potential investors as a change in state policy regarding the integration of Kazakhstan into the international system and the state's desire to maintain the old system to control the results of the assessment of mineral resources and reserves.

The main purpose of the full transition to KAZRC:

- transparency and reliability of information about the state of the mineral

resource base of Kazakhstan, facilitating access to historical geological information, the introduction of an Interactive subsoil user map available online, the absence of double standards in information provided to the Government and potential investors;

- increasing the competitiveness of the geological and mining industries of Kazakhstan;

- attraction of foreign and development of domestic junior companies.

Innovations of KAZRC: significant liberalization of subsoil use procedures and transition to the international standard; radical simplification of the licensing procedure, introduction of the principle of the first application: «The first who has come gets the first.»

Thanks to the introduction of a general procedure for issuing licenses on the basis of the "first application" principle, the adoption of a program for managing the state subsoil fund, reducing the time for issuing licenses and consolidating the transition to international reporting standards, more than 700 domestic junior companies were formed, with the involvement of major players in the global market, such as Rio Tinto, Fortescue and Yildirim.

An approximation to world practice should be the transition of Kazakhstan from outdated mining tax (OMT), the rate of which, for example, in Western Australia, varies depending on the depth of processing of mineral raw materials: the sale of ore - 7.5 %, concentrate - 5.0 %, metal - 2.5 %. This stimulates the creation of high redistribution in mining, in contrast to the OMT, which repels foreign investors.

For fields that have not reached a fifteen percent profitability from 2024, a reduction in the OMT is planned. This practice is borrowed from Australia, where concessions are given only at the initial stage of field development. However, if in developed countries they do not interfere in the activities of companies, only at the initial stage they fix reduced rates for new investors for a certain period and subsequently do not check the calculations and actual data, then in Kazakhstan the rates can change during the operation stage. In addition, due to the complexity of administration, it is planned to regularly check the received data on direct and indirect costs and income.

To increase the investment flow in the geological and mining and metallurgical industries, a financial mechanism for sustainable financing of the industry has been introduced in the form of 1% deductions from the income of subsoil users under each contract for replenishing the resource base.

Digital transformation of the mining sector. Since 2017, Kazakhstan has been undergoing a legal reform that has created conditions for attracting private investment in mineral exploration. The steps taken have led to the formation of over 700 local junior companies, to attract major players in the global market in the exploration of solid minerals, access to 1.6 million square meters has been opened. km. territory, through the portal of the National Data Bank of Mineral Resources of the Republic of Kazakhstan, 21 main processes of subsoil use are automated.

The variety of enterprise processes cannot be covered by a single information

system. Used both domestic and foreign software resources cover the most demanded tasks of collecting, storage and managing geological data. Available source data set can be used to interpret the ore body, create a resource model, and ensure strategic and operational planning of mining and geological works.

An important component of digital transformation, which determines the technical trend in the mining industry of Kazakhstan, is mining and geological information systems (GGIS), as an essential component of the IT infrastructure of a mining enterprise. At the moment, within the framework of the designated systems, progressive digital solutions are used, including artificial intelligence. Along with the introduction of universal software products, enterprises are developing their own software for solving narrower tasks (for example, modeling a geological and economic assessment taking into account specific mining and geological conditions).

For subsequent integration into existing information-analytical and mining-geological systems, enterprises use common open data formats (CAD, text formats), data transfer between packages for three-dimensional modeling and planning - Open Mining Format (OMF), which allows transferring 3D models from all their attributes, which is more efficient than the text format.

Modern software for a mining enterprise involves a large number of information flows covering all heterogeneous strategic and operational, technological and managerial business processes, which can be scientifically assessed of the economic efficiency of the enterprise. As a result, the task of forming a digital ecosystem of the enterprise is solved.

To solve production and economic problems, enterprises use systems of different developers, with which their own IT system must be integrated to make a systemic decision - from resource base modeling to tactical planned work. The accuracy of the assessment of reserves and the content of a useful component depends on many factors, the most important of which is the qualitative characteristics of the digital products used.

With the help of GGIS tools Micromine, GEOVIA MineSched, Studio OP, MapInfo, ArcGIS technologies that form the digital basis of geodata, tasks related to the exploration and evaluation of resources and reserves, the creation of block models of dumps are solved, which expands the understanding of the distribution of quality indicators and the total reserves of useful fossil in them in accordance with KAZRC standards and the JORC code. Volumetric modeling of reserves allows you to radically evaluate deposit using industry methods of geostatistics.

The presence of such a wide functionality allows you to make high-quality and optimal decisions throughout the entire life cycle of the enterprise. The effectiveness of the use of these tools consists in a proactive assessment of the risk of non-confirmation of geological information associated with the completeness of the use of the actual material on the objects and the adjustment of the reserves calculation obtained according to the Soviet system. Also, the built-in mathematical algorithms for data interpolation reduce the influence of the human factor when performing calculations, interpreting exploration data and subsequent evaluation of reserves.

To solve environmental problems, it is not enough to simply collect information about harmful substances contained in dumps, since this is only part of the information required. Information about environmentally hazardous objects, the degree of use of various natural resources are in demand. Modern MGIS include the basis for solving these problems - data structures for storing spatially distributed information, they are used to search for options for processing old dumps or tailings and cost-effective extraction of useful components from them.

The first step in stock measurement that defines the shape or volume of a deposit and accelerates the modeling of geological data into 3D is 3D visualization and a set of CAD tools. With the help of a three-dimensional geological model of the deposit, a simulation model of its work is created and the subsequent development of the dumping model is optimized, the reclamation process is modeled, and strategic and tactical mining plans are developed. For the subsoil user, at the moment, the mining process itself is a priority. However, as the legislation in the field of environmental standards is updated and fines for their violation are tightened, subsoil users will be interested in solving the identified problems.

Enterprises must use hardware and software from leading manufacturers. At the same time, Kazakhstani developers of mining and geological information systems, taking into account the accumulated world experience, are striving to create systems that allow full management of the deposit.

The most important goals of introducing digital technologies for the exploration and production of minerals are: reducing the time for obtaining and processing large amounts of data, increasing the accuracy of production forecasting, diminishing inefficient equipment operation time, preventing accidents, timely optimization of operating modes and diminishing the time for well workover, optimizing cargo logistics and online monitoring of production processes.

Benchmarks for digital inclusion:

- artificial intelligence technologies (including machine learning), Big Data and remote monitoring are used as part of creating digital twins of deposits, integrated production management and equipment reliability management;

- smart field technologies will provide key competitive advantages for companies and their survival in crisis situations and stochastic external environment.

Software can be modelled to accompany optimization of the field regardless of the current life cycle and current state of mining. The used explosion modeling and rock mass displacement prediction technologies minimize the loss and dilution of the useful component during extraction, and estimate the amount of the mineral transported to the dumps. The development of new enrichment technologies will increase the effectiveness of the use of rock mass for the extraction of minerals.

Consider such a tool for studying mining and geological systems as neural modeling. Comprehensive digital transformation at all cycles of subsoil development, which provides for the introduction of digital technologies in various business processes of enterprises in the industry, is the basis for ensuring the sustainable development of mining systems. Its successful implementation is ensured by a

combination of intellectualization of geotechnologies and digital transformation of mining production with on-line display of quantitative information about the state of the technogenic and environment, transparency of production and social business processes.

Neural modeling assumes the scientific validity of the calculation of mineral reserves: an objective and reliable assessment of the indicated geological and physical prerequisites, the quality and correctness of the construction of a geological and economic model; qualitative analysis of predictive indicators and adopted design decisions.

For high-quality verification of the initial data array, on the basis of which the enterprise forms scientifically based management decisions, it is necessary to clearly understand the scientific and production validity of expenses, to have reliable primary information and up-to-date software.

The basis for the formation of innovative competencies in the management of mining and geological operations using neural modeling is structured technological initiatives. In recent years, new prerequisites for building adaptable neural models have appeared: the demand for big data processing methods, an increase in the amount of knowledge, and increased commercial competition. These prerequisites were updated as new regularly updated practical and experimental data became available or the scope of possible application of multifunctional models of mining and geological systems expanded.

The main difference in the application of artificial neural network technologies compared to traditionally used methods is the ability to train the system on the basis of dynamically changing geological and economic data that are formed at various stages of mining and geological work. It is these data that determine the management decisions that are made on the basis of their analysis using artificial intelligence methods.

New approaches to assessing the quality of application and functioning of artificial intelligence systems in conditions of uncertain mining and geological conditions involve a comparative economic analysis of technological operations and adaptation of the neural network model to the mining and geological conditions of a particular field in real time. For any technological processes, neural networks, along with the introduction of big geodata technologies, the integration of industrial platforms and blockchain, are necessary to take into account uncertainties, technological limitations in obtaining and processing information based on modern communication channels and the Internet of things. Tools that use modern machine learning technologies and cloud processing to build geological models allow you to quickly build models for mining planning

A feature of the proposed algorithm is its universal predominantly qualitative nature. The neural network models underlying the algorithm for implementing the adaptive model can be applied both to an arbitrary element of the internal environment of an enterprise (for example, to a specific field) and to the entire enterprise (Fig. 1).
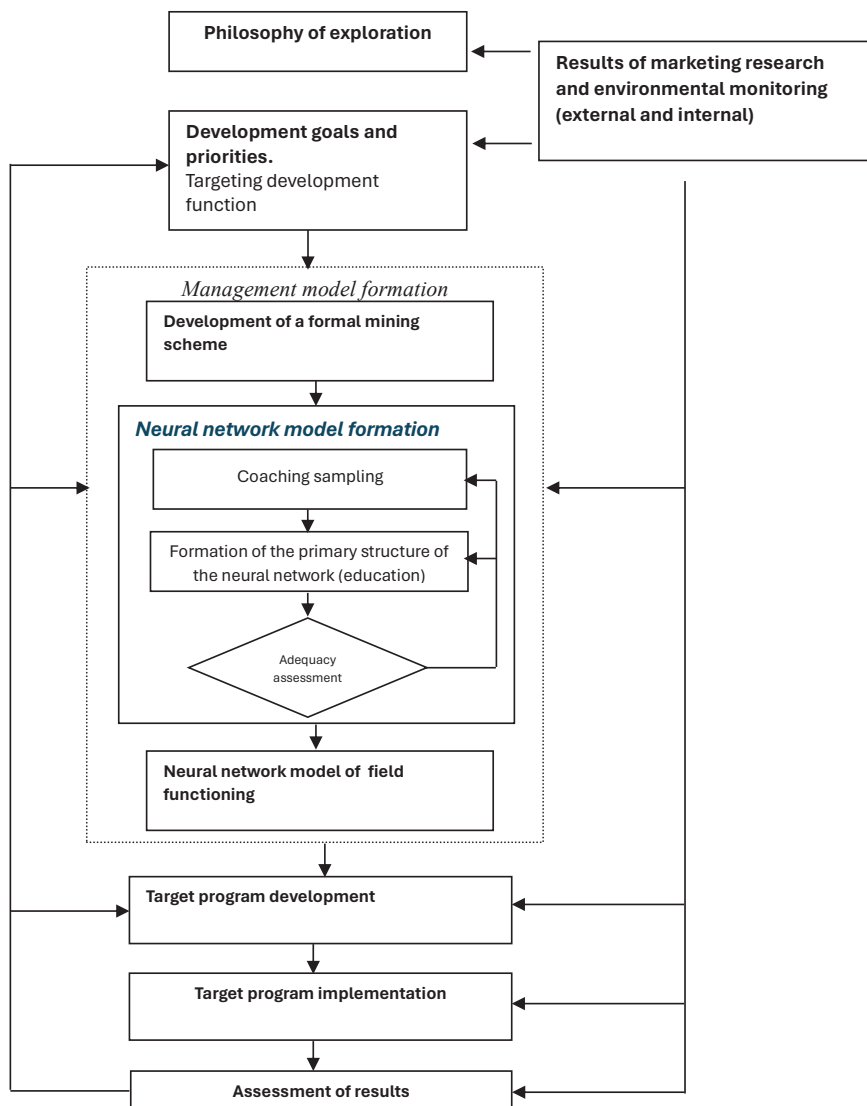
Figure 1 - Adaptive model implementation algorithm flowchart

It is largely because of this, but also because of the need to preserve the possibilities of an individual approach to each field, taking into account the given technical and economic parameters, the most generalized version of the algorithm is presented. On the basis of neural network modeling, huge data arrays are processed qualitatively and quickly, a wide range of applied financial, economic and technical problems are solved.

Subsequently, on the basis of neural network algorithms, an adaptive model of the enterprise is formed:

- the use of an array of time series for "training" a multilayer self-organizing

neural network allows you to explicitly establish the relationship between the parameters of the external and internal environment of the field (enterprise);

- the trained neural network is used to predict the dynamics of the main parameters of business processes;

- according to the forecast data, a consistent calculation of all indicators is carried out, a conclusion is made about the predicted change in the financial and economic condition of the enterprise;

- on the basis of a neural network, a simulation model of possible ways to change endogenous parameters is built to maintain the dynamics of indicators of the financial and economic state at a given level;

- the results of simulation modeling allow making scientifically based management decisions;

- as new information about changes in the parameters of the external and / or internal environment of the enterprise arrives, the neural network "retrains" (adjusting the monitored parameters allows the model to remain adequate to real conditions and make the control adaptive) (Werbos, 1990; Hu et al., 2019).

Kazakhstan needs to carry out even small works that evaluate the prospects of deposits, if there are prerequisites for the discovery of minerals and an increase in the prospecting reserve. But this requires highly effective technical products that accelerate the involvement of hard-to-recover reserves in the production process.

By 2035, most of the significant deposits of copper, gold and zinc in Kazakhstan will be depleted and there will be no reserves of these metals. Therefore, in the next ten years, it is necessary to renew the reserve base for the sustainable development of priority areas of the mining and metallurgical complex. Replenishment of reserves will be in two directions - based on the results of exploration work, and through the development of technology, as a result of which objects that were not considered as reserves become profitable for development. For example, in the mid-80s, the average metal content in the mined ore from the Konyrat deposit was 0.4 %, at the moment it is already 0.2 %. Now, even from the previously accumulated dumps of the deposit with a content of about 0.15 %, copper is extracted. Such a content in Soviet times was not considered at all, such ores were considered unsuitable.

In the context of the above, it is advisable to use neural networks to control production in pilot areas of mature fields, where the economic feasibility of scaling this technology has been confirmed. Algorithms for managing waterflooding in mature fields make it possible to form a constraint model and evaluate the effectiveness of geological and technical measures for specific areas. The created model allows you to plan production using optimization tools and calculate the financial and economic indicators of the block model. As a result, an idea of the form and placement of stocks is formed.

The effectiveness of digital solutions in exploration and production is largely determined by the impact of factors such as the deterioration of the quality of the resource base and the depletion of traditional deposits and the transition to a low-carbon economy. Replication of unique technologies, an individual approach to

each site, additional loading of secondary processes, including through deepening intra-production integration, makes it possible to achieve progress in production.

In the short and medium term, cardinal measures will have to be taken at operating fields, aimed at increasing productivity, reducing costs, and scaling up technologies. At new fields, the problem of increasing the effective implementation of new projects is becoming more urgent.

In solving the assigned tasks, an invaluable role is played by the introduction of IT technologies aimed at increasing the efficiency of production processes, specializing models of artificial neural networks and machine learning methods that expand the range of target tasks to be solved, including the geological and economic assessment of the enterprise.

In the future, based on the methods of neural networks, a generalized functional diagram of production processes can be implemented for the geological and economic assessment of the enterprise. In the mining sector, neural network methods are a self-sufficient tool for analyzing and predicting various technical and economic management decisions. Forecasting with the help of neural networks allows you to develop a test example of decision making for the rapid response of an enterprise to changes in the external and internal environment.

In the near future, the city-forming enterprises of Kazakhstan will have to solve the problem of "seamless" integration of third-party software into a single digital enterprise, an important place in which will be given to generally accepted open file formats: dxf / dwg, shp, csv, xml. In practice, the data exchange standard for mining and geological graphics is in demand - the dwg / dxf format (for example, AutoCAD), for block models - the csv format.

At the moment, there are no standards for specialized mining and geological information systems in Kazakhstan. But since the need for them is growing and work is being done in this direction, such standards should appear in the foreseeable future.

In general, the conducted studies allow us to draw the following conclusions:

1. Despite the geopolitical tensions that create uncertainty in the foreseeable future for Kazakhstan, at the moment the country is diversifying the economy, creating special economic zones, strengthening trade corridors between Europe and Asia. In the long term, due to the growing dependence of the economy on minerals and hydrocarbons, high levels of greenhouse gas emissions, Kazakhstan will face "climatic" challenges in the energy sector. Therefore, adherence to certain investment standards, the willingness to implement the principles of sustainable development in the activities of mining enterprises, the development of the international set of standards of the Global Reporting Initiative (GRI) and the principles of ESG are of decisive importance.

2. Despite the steps taken by the state, the economic model of Kazakhstan does not yet meet international environmental standards, the national system of state planning does not include a strategic environmental analysis of the concepts of future development. Science-based decarbonization of the mining industry in Kazakhstan

will increase the efficiency of mining, accelerate progress towards a zero carbon footprint. Achieving carbon neutrality in industrial production, the implementation of projects aimed at changing the climate impact and green projects require significant costs both on the part of companies mastering responsible financing tools, as well as financial institutions and the state. In light of the foregoing, the planned reduction of the low-carbon footprint and the gradual phase-out of thermal coal makes it necessary to accelerate the transition of mining enterprises to international CRIRSCO standards, the introduction of a management, health and safety system in accordance with international standards ISO 45001, ISO 9001, ISO 14001, ISO 50001, support for UN Sustainable Development Goals 8.

3. The depletion of traditional reserves and the rapid growth of "hard" resources bring to the fore the question of the economic efficiency of their development. Due to systemic problems (low funding, insufficient level of interaction in the management system, lack of a National Database, lack of competent personnel, unaffordable commodity prices for domestic industry, weak sectoral infrastructure, in particular the lack of laboratories and core storage), the resource potential of Kazakhstan is completely not disclosed, geological exploration remains at a low level, intensive production has brought the country closer to the depletion of the reserves of existing deposits, which, without appropriate replenishment, will be depleted in the near future; over the past thirty years, not a single large deposit has been discovered in the country. It is necessary to develop a clear understanding of the economic efficiency of mining deposits due to the flexibility and transparency of tax charges, increasing the tax base through the introduction of a differentiated approach to deposits in general and to their individual sections. This approach will increase the number of new fields and increase the liquidity of the taxable base of existing fields.

4. Advantages of the KAZRC Code in comparison with the GKZ standard: a significant increase in the requirements for the quality of geological exploration, personal disciplinary responsibility of Competent Persons for the reliability of reports and conclusions, susceptibility of reports by investors and international financial institutions due to compliance with CRIRSCO standards, prompt preparation of reports, stimulation of the introduction of modern technologies for preparing, storing and processing geological information, a significant reduction in the cost of preparing reports (by 25–50 %), reducing the time for reviewing reports by the authorized body by 5–6 times, eliminating the need for total involvement of foreign consultants to bring reports to the international standard .

5. Climate management and green transformation are on the minds of mining companies. Following global trends and approaching the best global practices in the mining and geological industry, enterprises are moving towards the principles of sustainable development, supporting the global GRI reporting initiative, introducing ESG indicators in their business models that assess the investment attractiveness of enterprises in the financial market, which becomes an important condition to access capital markets. However, they integrate current industry

practices in accordance with international standards and trends, mainly enterprises with state participation and public enterprises listed on international platforms. Private business is developing very slowly in this direction.

6. Barriers to the adoption of digital decisions by enterprises: restrictions on the availability of obtaining initial data for a comprehensive analysis and performance of mining and geological works; lack of model standards in the mining sector for organizing the collection and configuration, structuring, storage, distribution and use of reliable and transparent information from common databases; underdevelopment of requirements for the creation and use of existing digital platforms; structure barriers and protectionism..

7. The development by enterprises of their own technologies that increase energy efficiency, environmental friendliness and safety of the production process and reduce professional risks, involves the development of international data exchange standards, including data exchange between various mining and geological information systems using the OMF format. In addition, the exchange between MES systems, dispatching systems is in demand. Enterprises are required not only to assist in the development of new standards, but also to master open exchange standards (CSV, DXF), support for reading and writing their formats. This approach opens up new opportunities for integration with systems not only of foreign developers, but also of national IT services. Enterprises need not only to purchase software, but also to organize competent support for the process of its implementation, joint work of users with developers.

8. For mining enterprises, neural network optimization is not only a machine learning technology integrated into the tasks of the geological and economic assessment of the deposit. These are new business processes and competencies; the ability to work with a limited set of geological surveys; apply a set of limited, partially distorted initial data; approximate various surfaces with high accuracy, combining various approaches to automating business process analysis.

Conclusion

In conclusion, there are emphasized that the digitalization of mining production transforms resource and raw materials mining into an innovative development industry using the Industry 4.0 management model. The key factor in digital transformation is the integration of input data flows and the adoption of science-based management decisions in real time.

The introduction of digital technologies will make it possible not only to clarify the volume of reserves and the distribution of useful components, but also to reduce the cost of preparing reserves, which will ensure that the potential of unconventional inaccessible deposits is unlocked. The effectiveness of digital solutions will affect the accuracy of reserves estimation, which depends both on the quality and reliability of the initial exploration data, and on the subsequent competent interpretation of not only the shape of the ore body, but also the geological structure of the deposit.

The direction of future research is related to the study of the effectiveness of digital solutions for the junior market in the context of bringing the mining sector of Kazakhstan closer to international standards.

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