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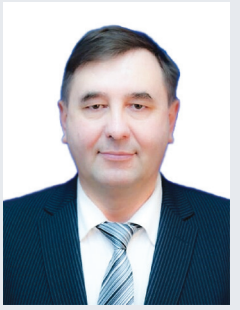

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DIGITIZATION OF MINING ASSETS

Abstract. The article considers the issues of using information technology to control mining companies' engineering and business processes. It reveals the urgency of implementing an automated management system for mining operations powered. This system provides the basis for creating a virtual source of a mining company. The paper presents the software functionality in creating 3D models of deposits and surfaces, as well as solutions for companies with both opencast and underground mining methods. The proposed software solution contains the widest range of applications and supports the highest data transfer rate. A comprehensive approach and integration with other systems installed at enterprises allow you to find the best option for managerial decisions in terms of optimizing resources and processes, time and data traffic.

Key words: *automation of mining operations, digital twins, industrial digitization, automated control system of mining operations, 3D modeling, scheduling, design of open pits and mines, industrial safety, management of mining companies, mining monitoring.*

Тау-кен өндіру активтерін цифрландыру

Аңдатпа. Мақалада тау-кен компанияларының инженерлік және бизнес-процестерін басқару үшін ақпараттық технологияларды пайдалану мәселелері қарастырылады. Бұл тау-кен компаниясының виртуалды көзін құруға негіз болатын тау-кен жұмыстарын басқарудың автоматтандырылған жүйесін енгізудің өзектілігін көрсетеді. Мақалада кен орындары мен беттерінің 3D-модельдерін құруға арналған бағдарламалық қамтамасыз етудің функционалдық мүмкіндіктері, сондай-ақ пайдалы қазбаларды өндірудің ашық және жерасты әдістерін пайдаланатын компанияларға арналған шешімдер ұсынылған. Ұсынылған бағдарламалық шешім қосымшалардың кең спектрін қамтиды және деректерді берудің ең жоғары жылдамдығын қолдайды. Кәсіпорындарда орнатылған басқа жүйелермен интеграцияланған тәсіл және интеграция ресурстар мен процестерді, уақыт пен деректер трафигін оңтайландыру тұрғысынан басқару шешімдерінің ең жақсы нұсқасын табуға мүмкіндік береді.

Түйінді сөздер: *тау-кен жұмыстарын автоматтандыру, цифрлық қосарластар, өнеркәсіптік цифрландыру, тау-кен жұмыстарын басқарудың автоматтандырылған жүйесі, 3D-модельдеу, карьерлер мен шахталарды жоспарлау, жобалау, өнеркәсіптік қауіпсіздік, тау-кен өндіруші компанияларды басқару, тау-кен жұмыстарының мониторингі.*

Цифровизация горнодобывающих активов

Аннотация. В статье рассматриваются вопросы использования информационных технологий для управления инженерными и бизнес-процессами горнодобывающих компаний. Это показывает актуальность внедрения автоматизированной системы управления горными работами, которая обеспечивает основу для создания виртуального источника горнодобывающей компании. В статье представлены функциональные возможности программного обеспечения для создания 3D-моделей месторождений и поверхностей, а также решения для компаний, использующих как открытые, так и подземные методы добычи полезных ископаемых. Предлагаемое программное решение содержит самый широкий спектр приложений и поддерживает самую высокую скорость передачи данных. Комплексный подход и интеграция с другими системами, установленными на предприятиях, позволяют найти оптимальный вариант управленческих решений с точки зрения оптимизации ресурсов и процессов, времени и трафика данных.

Ключевые слова: *автоматизация горных работ, цифровые двойники, промышленная цифровизация, автоматизированная система управления горными работами, 3D-моделирование, планирование, проектирование карьеров и шахт, промышленная безопасность, управление горнодобывающими компаниями, мониторинг горных работ.*

Introduction

Digital technology is improving daily and is actively integrating into all economic sectors. Today's economic environment makes digitization a crucial link in the technological progress and development of mining companies and society. The digital transformation vector has become a hallmark of anchor companies. More flexible production processes, higher productivity and growth of new business models have been made possible mainly through digital solutions. Automated mining management systems are being implemented to reduce costs, improve the safety of mining operations and sustainable development.

The effective functioning of companies in a market environment is only possible with the comprehensive digitization of basic and auxiliary operations. Meeting these requirements helps improve the efficiency of subsoil use and avoids uncontrollable lost production [1, 2].

Materials and Methods

Implementing of intelligent systems significantly cuts the time required to perform production activities, reduces costs and, consequently, lowers the prime cost of mining operations.

Special intelligent software helps automate most processes of engineering assistance for mining operations at the enterprises. A single information space and the multiuser mode simplify and accelerate the information processing, increase the calculation accuracy, help consider several scenarios of mining operations within a specified time interval and optimize the workflow using the criteria and limitations of the company [2].

The K-mine professional software is used for all mining stages in both opencast and underground mining of mineral deposits. It is based on an integrated approach to automation, combining core and auxiliary processes into a single information manufacturing chain. Software has a complex structure and focuses on using its graphical core, a single database and a set of unique software

solutions for solving production tasks[1] (Figure 1) [2, 3].

Let's define a range of software solutions to fully meet the company's requirements, considering mining-geological and mining-technical conditions. Note that the geological and surveying software solutions are versatile and used for both opencast and underground mining.

The construction of deposit digital twins is essential for the digital transformation of solid mineral extraction. It helps visually reflect the deposit characteristics at any mining stage.

Software solution for geological modeling includes the complete cycle of tasks from developing a database structure for storing sampling and geophysical survey data to creating geological and economic block models of deposits for reserve estimation, scheduling tasks, etc. Using calculations performed in this module, you can set local trends and patterns, and calculate the project economics. Generating reports showing the exploration results on mineral resource and reserve estimates are conducted in accordance with the requirements of the CRIRSCO International Reporting Template (JORC, NI 43-101, PERC, SME codes) based on various classification systems, including the United Nations Framework Classification (UNFC) and the National Classification System[1, 2].

In addition, the geological complex covers implicit modeling, a fast, automated method of constructing wireframe models directly from the database. It involves creating triangulation surfaces using the radial basis function (RBF). The main advantage of implicit modeling is speed. It allows you to perform hundreds of constructions, changing some modeling parameters of the same data set. It also provides an opportunity to use other data sources in the geologic modeling process in addition to exploration drillholes. These data sets may include geophysical data, spectral analysis results, mine scan data, etc.

The system automates office studies of surveys, geometric construction of mine workings from the survey and mining-geometric calculations, estimation of excavation volumes, current tasks of the Surveying Service, etc. This software solution supports all formats of measurement tools and drones. The documentation generated using this module meets all the requirements of the surveyor's instructions and technical inspection authorities [3, 4].

Software helps automatically construct combined geological-and-surveying sections containing simultaneously geological information integrated with the current and design mining positions (Figure 2).

The company has developed the Drill and Blast module for companies using blast energy in their operations. Based on the up-to-date model of actual mining position, it is possible to solve the following tasks: drillhole location design within the block boundary, identifying drillhole diameters, choosing explosive types considering rock strength parameters and categories, selecting charge designs, calculation of switching systems, data exchange with adjacent systems, etc. Projects for drilling and blasting of individual blocks are a data source for preparing and reporting on a mass blast.

It is possible to solve the task of determining and controlling the grain size of blasted rocks using the corresponding software solution. It allows you to control the quality of rock mass preparation using blasts. Based on the calculated data, it is possible to timely adjust the parameters of blasting patterns (drilling grids and charge designs) to prepare mining blocks in the specified area of the open-pit field. It helps obtain essential economic benefits[1] [5].

The latest mining and geological models represent the information background for the design and multivariant scheduling for the development of mining operations.

Using software for scheduling and design provides mining engineers with the basic tools to create cost- and time-optimized geologic models of solid minerals and determine the optimal sequence of deposit mining (Figure 3).

The design software solution includes a set of tools for designing all mining structures: open pits, dumps, haul roads and railways.

The mining scheduling is attached to time intervals. It helps combine mine planning with its economic component and find optimal mining programs in terms of implementation and cost. The software solution for determining the optimal boundary

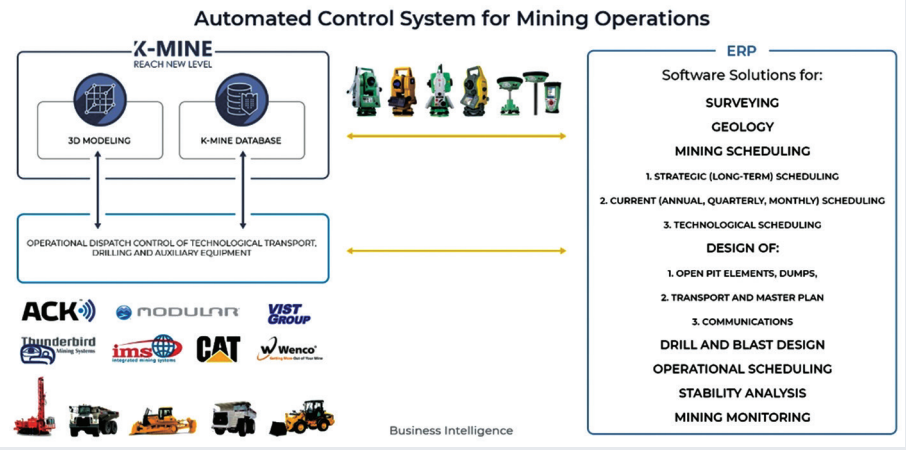

Figure 1. Automated mining control system.
Сурет 1. Пайдалы қазбаларды өндіруді басқарудың автоматтандырылған жүйесі.
Рис. 1. Автоматизированная система управления добычей полезных ископаемых.

[1]*The use of the K-MINE geoinformation system in various fields of activity: A collection of reports of the III International Scientific and Practical Seminar «SVIT GIS-2016». – Krivoy Rog: FL-P Chernyavsky D.A., 2016. – 280 p. (in Russian)*

[2]*Rudko G.I., Nazarenko M.V., Khomenko S.A., Netskiy O.V., Fedorova I.A. Geoinformation technologies in subsurface management (by the example of K-mine geoinformation system)]. – Kyiv: Akadempres, 2011. – 336 p. (in Russian)*

of the open pit allows you to determine the optimal pit boundary of mining and substantiate the most viable option of deposit mining.

Modules for determining the pit wall stability and monitoring mining operations help estimate pit wall slope angles and dump lifts.

In addition, these modules help regulate compliance with technological norms and standards in opencast mining and automatically

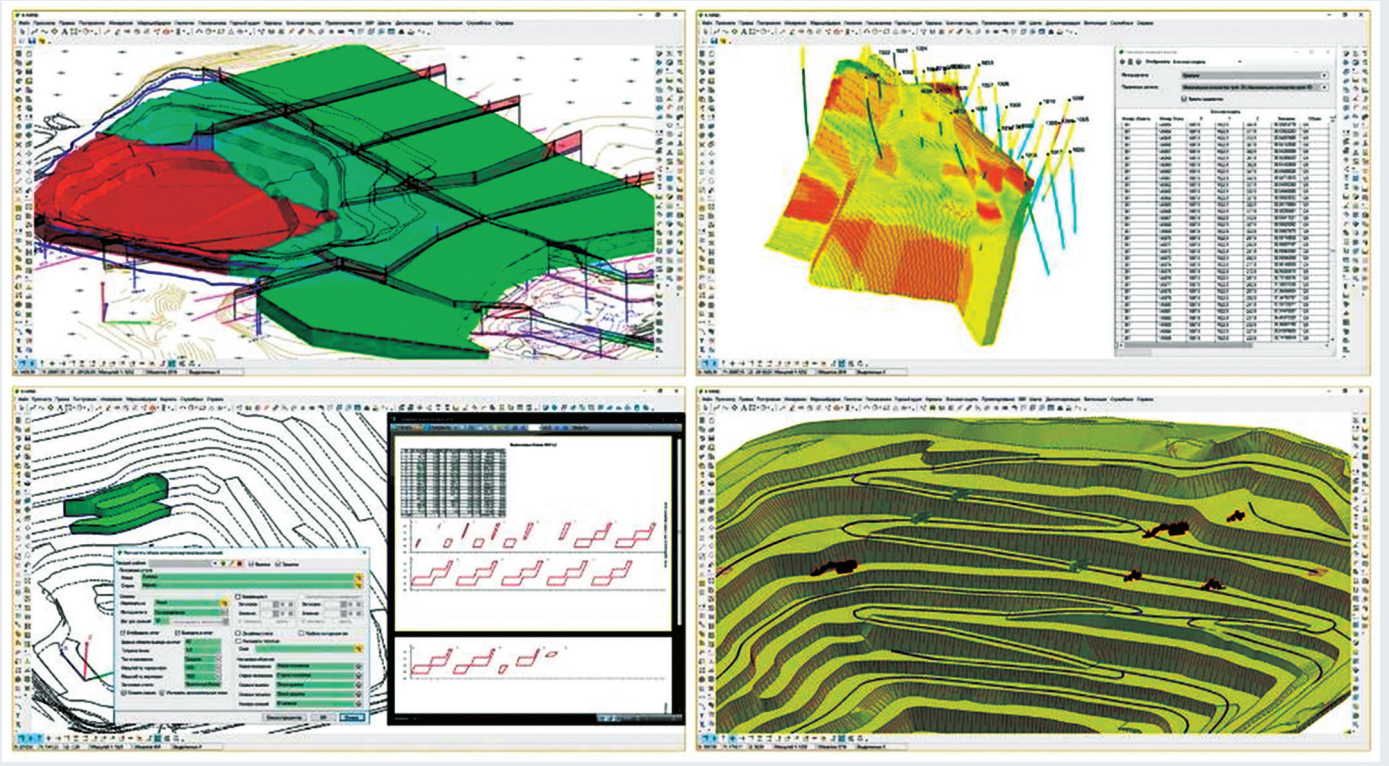

Figure 2. Examples of construction geological and surveying models.
Сурет 2. Геологиялық және геодезиялық модельдерді құру мысалдары.
Рис. 2. Примеры построения геологических и геодезических моделей.

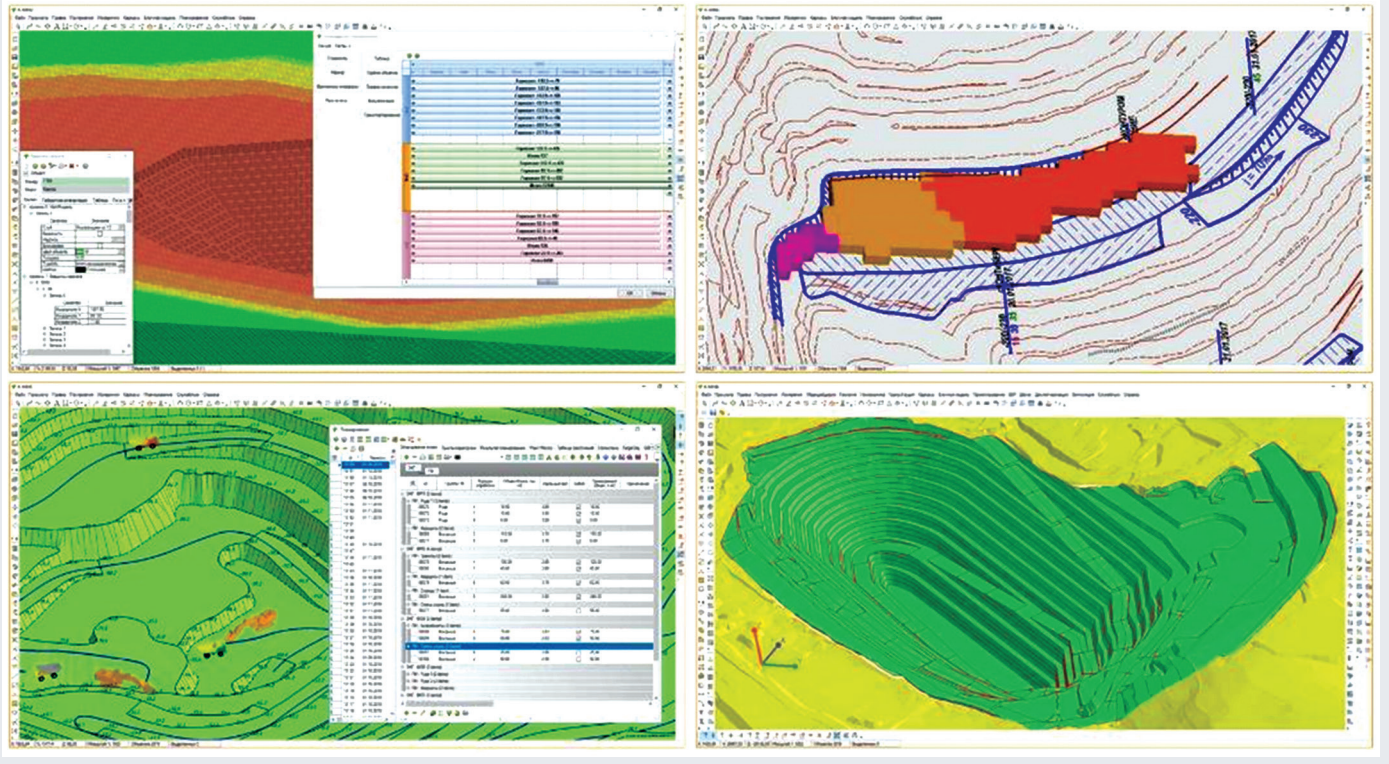

Figure 3. Examples of scheduling and designing opencast mining activities.
Сурет 3. Ашық пайдалы қазбаларды өндіру жөніндегі жұмыстарды жоспарлау және жобалау мысалдары.
Рис. 3. Примеры планирования и проектирования работ по открытой добыче полезных ископаемых.

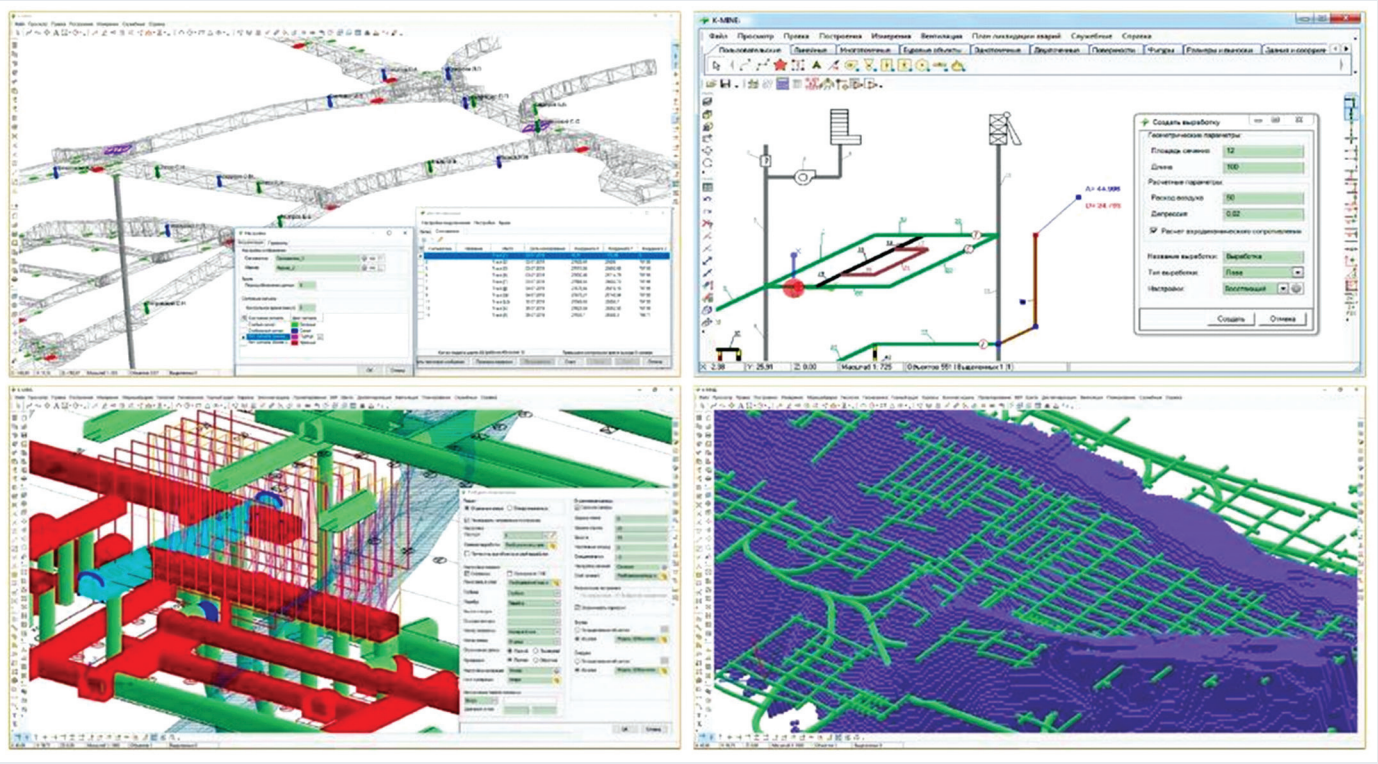

Figure 4. Examples of mine design, ventilation and dispatching.
Сурет 4. Шахталарды жобалау, желдету және диспетчерлеу мысалдары.
Рис. 4. Примеры проектирования шахт, вентиляции и диспетчеризации.

analyse the parameters of mining elements [5, 6].

The dispatching software solution makes it possible to control all cargo traffic processes, including minerals and overburden removal in real-time in an open pit 3D model. This software solution provides monitoring of mining and transportation targets, allows quickly correct deviations and evaluates the qualitative indicators of burden material per working shift within the planned period.

Companies involved in underground mining use the functionality below. K-mine has a great tool for underground design, allowing you to solve mine design tasks in the development of a new deposit and at any stage of operation in the mine. This software solution helps automate basic production design processes: tunnelling of capital mine workings, development and face-entry drivages, second working, as well as drilling and blasting operations (Figure 4) [2, 5, 7].

The mine dispatching complex helps monitor the location of personnel and equipment in underground mines online, and provides voice and signal communication of mine workers with the surface. Perfect work coordination of personnel and machinery guarantees maximum efficiency and no equipment downtime.

The mine ventilation software system is used to solve the following tasks: design of ventilation schemes and networks, calculation of ventilation modes and fan unit operating modes, preparation and implementation of emergency response plans, etc.

Software has a user-friendly solution for planning infrastructure development, capable of creating interactive electronic maps and databases. Companies can efficiently manage production infrastructure through up-to-date information about the current state of production facilities at the industrial site. It is possible to monitor the operating history of infrastructure facilities, conduct technical audits, inventories, certification and accounting of production infrastructure facilities, plan the development of company infrastructure, repairs and upgrades, create schedules for preventive maintenance of communications and facilities, etc.

A complex for chief executives helps top managers take reasonable and optimal managerial decisions on mining operations. A wide range of tools characterizes this software solution for quick measurements and calculations, obtaining real-time information about the state of the actual and design situation in mining process[1] [5, 7].

Using the software solutions, it is possible to create digital copies of mining companies and calculate scenarios for developing open pits/mines [7]. In addition, it is possible to generate the results as reports for further best managerial decisions based on the data obtained[3].

Conclusions

The data bank and digital deposit models created can be used to solve the problems of differently oriented companies with both

[3]*Kaputin Y. E. "Veroyatnostnoe strategicheskoe planirovanie razvitiya kar`erov" [Probabilistic strategic planning for career development].—SP: Nedra, 2019, p. 31. (in Russian)*

opencast and underground mining methods. The software can be used at different stages of the company's lifecycle, as well as for monitoring and scientific support of subsoil use. Ready-to-use and time-tested software solutions are proven by long-term experience of companies in CIS, Europe and Central Asia.

As a result, the digitization of mining assets with K-mine serves as a development multiplicator. It eventually provides the maximum benefits for mining company management through a substantial increase in mining output, cost reduction, increased efficiency and safety benefits of mining.

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