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DIGITALIZATION AND THE POTENTIAL FOR IMPROVING THE DESIGN AND PLANNING OF MINING OPERATIONS IN OPEN CAST MINING

Abstract. Modern traditional and most widely used technologies for the development of mineral deposits by the open method using cyclical technologies have significant potential for improving efficiency and reducing the cost of mining and transport operations. This article focuses on how and by what means this potential can be realized.

The potential and directions of improving the efficiency of mining and transport operations on open cast mining are revealed by the example of scientific and practical research using the methodology of automated corporate management of geotechnological complexes.

Today, in the field of open-pit mining, most widely automated accounting and control systems, and also, automated dispatching systems for mining and transport operations managing are used. However, they make it possible to realize only a third of the existing potential for improving the efficiency of the mining process.

In conclusion the article concludes that in the context of the transition to Industry-4.0, improving the efficiency of mining and transport operations on open cast mining is possible only on the basis of a unified methodology of design, planning and management of geotechnological complexes, developed on the basis of in-depth analysis in the framework of an automated corporate approach using the economy of process management.

Keywords: mining-transport work, management, organization, efficiency, digitalization, automation.

Introduction.

To increase the efficiency of mining and transport works in open pits with auto, rail and combined auto-rail transport, accounting and control systems, automated dispatching systems of mining and transport works are traditionally used. At this level of organization of production management, only a small part of the potential for improving efficiency is realized. Analogical directions are developed in geology [1]. It's possible mainly due to the increasing the discipline of production and faster and more efficient distribution of trucks on loading and unloading points. For a more complete realization of existing potential at the enterprise, a more complete and in-depth digitalization of the main production processes is required.

The modern stage of development of automation of mining technological processes, characterized by flexible and non-standard production, corresponds to the concept of "Industry 4.0", which is based on two fundamental principles [2]:

1. Automated intellectual interaction between the operator and the equipment involved in the production process.

2. Relationship of logistics operations throughout the value chain of cost forming of the product to increase the efficiency of technological processes.

The necessary approach can be implemented in the framework of the automated corporate management system of the geotechnological complex (the AKSU GC) "CEBADAN-Mining", the structure and content of which are presented in figure 1.

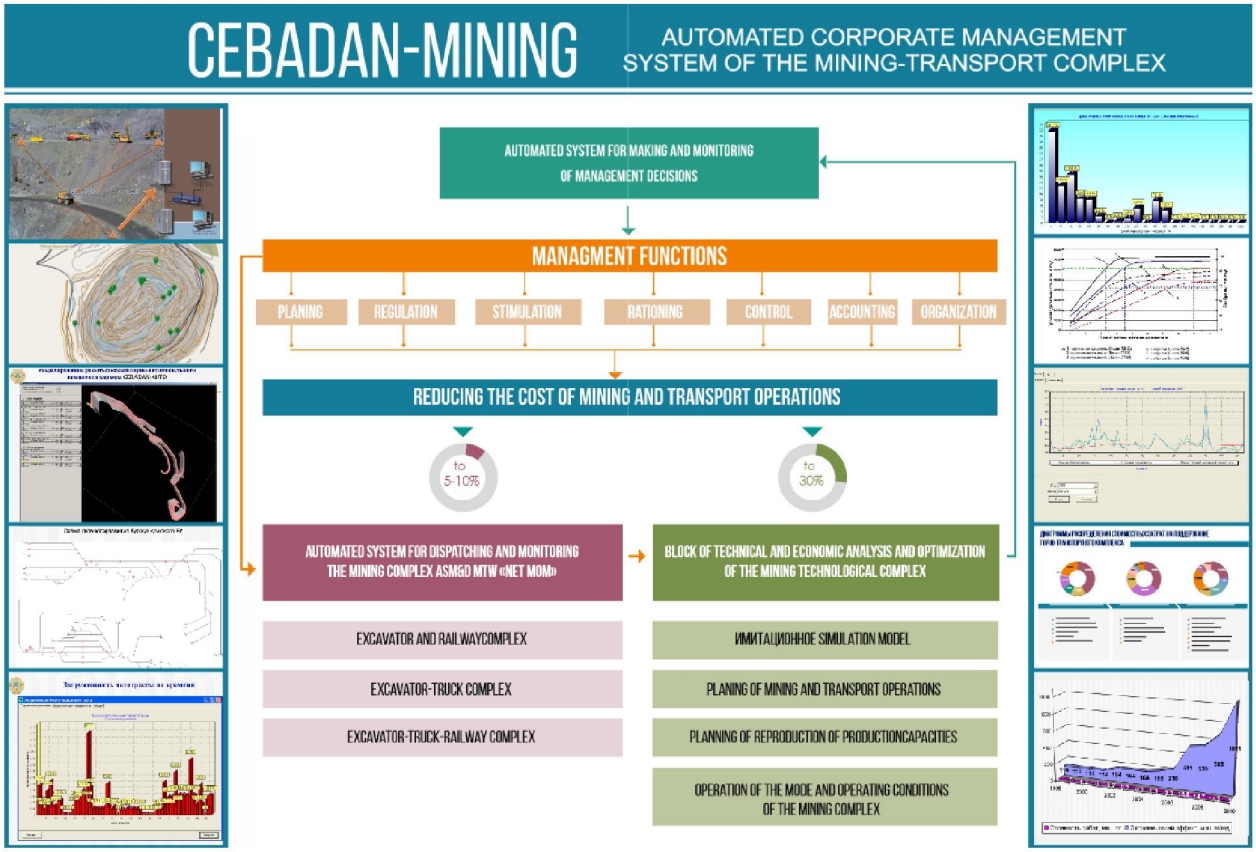

Figure 1 – Structure and content of the automated corporate management system of the geotechnological complex "CEBADAN-Mining"

The system includes the automated monitoring and dispatching system for mining and transport operations – ASM&D MTW "Net-MOM|", based on the information and technical platform of the positioning and communication system – ASP&C. The second important module of the System is the analytical block, which is based on the methodological support of technical and economic analysis of the functioning of geotechnological complex utilizing specialized method of simulation modeling of analyzed mining and transport processes. The third module is an automated system for the adoption and monitoring of management decisions.

The main task resolved within the System is the intellectual interpretation of information about the dynamics of factors of external and internal environment of the enterprise. Accordingly, intellectual analytic data processing plays a key role: a methodological base, implemented in the form of software, that not only records and transmits the data received from sensors, but also forms operational solutions based on a holistic view of the content of the process in a particular context. Thus, within the framework of the AKSU GK system, a completed cycle of analytics 3.0 has been implemented, which ensures continuous production of the necessary information, search for optimal management decisions and a feasibility study of their implementation.

One of the main functions of the AKSU GK is a quality, reliable and operational information support of the management system of the geotechnological complex, based on its adequate and deep digitalization. In order to implement this, the task of organizing the collection, processing and production of derivative information about the work and the state of the geotechnological complex of the enterprise is being solved. At open-cast mining, notion of a "geotechnological complex" is a single complex of the mine workings and the mining and transport system of a quarry, as it is assumed by the notion of "Geotechnology" [3]. Accepted, within the framework of the adopted approach, as a single object of automated management, the geotechnological complex is characterized by its specific mining and technical, mining and geometric, mining and geological, organizational and economic parameters, which should be

adequately taken into account. The first task related to the digitization of production processes is solved at four principal levels.

The first level is related to the formation of initial database, which includes existing standards, technical characteristics, principles of production organization, indicated in the relevant instructions, accepted methods, restrictions, equipment certificates, design solutions, work plans, etc.

At the second level, the collection of the necessary objective, reliable and operational data is provided by the generated automated positioning and communication system. The first to be resolved are, issues of operational accounting of the state of all elements, subsystems and the geo-technological system as a whole. Information is recorded with a certain step. At the same time, the data on the operating time and downtime of the equipment is generated. Working time, as well as in idle times, can be recorded by separate operations (excavation, preparation of the face, stages of the excavation cycle, technological and unplanned downtime, reservation time of transport sections, etc.) and in general per shift. At the same stage, according to the approved methods, the primary data from metering and control devices on the state of the fuel tank, tire pressure, useful mass, energy consumption, current and average speeds, and the amount of emissions are accumulate.

An important condition for collecting and processing information at the second stage is operational economic assessment of the forming cost of mining and transport works by the end of each shift. An economic-mathematical model, built into the monitoring and communication system, allows to evaluate and summarize all integrable costs by operation and, depending on the actual performance of the mining and transport complex, calculate their unit cost per ton/m3.

At the third level, in the automated mode, all derivative information on work of the mining-transport complex is formed. This information further is analyzed by specialist.

At the fourth level the formation of information data on the work of the mining and transport complex, at analytic stage, as part of technical and economic analysis of the actual it's work on the data formed at the second stage, using a reliable model of the mining and transport complex operations, develops more effective and predictable options for its functioning.

The architecture of the «EcoStruxure» software and information complex of «Schneider Electric», one of the largest players in the field of industrial automation, was built in a very similar way [4]. The system is based on a three-tier architecture, which combining all the equipment at the object, and is capable of collecting, analyzing and using the information obtained. At the bottom level – connected "iron", for example, shields, flow meters, sensors, and so on. Products and solutions for the collection and processing of primary data – this is already the second level. The third one occurs when various applications and services that evaluate all the processes at the object and give recommendations for optimizing its work.

The distinctive feature and effectiveness of the application of automated control systems for Geotechnological complexes, in comparison with the traditionally used automated accounting and control systems in the world, as well as automated dispatching systems for mining and transport works, are shown in table 1.

Firstly, automated accounting and control systems, as well as automated dispatching systems for mining and transport works, due to the limited realizable accounting and control functions, operational regulation and partly organization of the production process, are clearly limited in realizing the existing potential for improving the efficiency of mining-transport quarry systems. In this case, the potential to reduce the cost of mining and transport works is 5-10% by eliminating unauthorized fuel discharges, increasing production discipline and eliminating some downtime of the main mining and transport equipment, which depends on the quality of operational distribution of transport on loading and unloading points. Unlike them, unified management of the geotechnological complex, implemented with the help of AKSU GK, provides an opportunity to reduce the cost of mining and transport works by 20-30% or more.

Secondly, automated dispatching systems for mining and transport works, as calculations show and confirms the practice of their use, have a limitation on their profitability. On quarries with the number of transport units less than 10-12 pieces they do not pay back themselves. Therefore, as a rule, in small and medium open-pit mines, especially those not related to the extraction of precious minerals, they are used much less frequently and do not provide a possible economic effect.

At the same time, in-depth automated analytics, based on in-depth automated digitalization of the process of functioning of a geotechnological complex, allows to realize a significantly greater potential for

Table 1 – The effectiveness of implementation of the main functions of mining and transport operations management in the framework of the AKSU GK

FUNCTIONS	EFFECT AND CONDITIONS OF ITS GAINING	LEVELS OF EFFECTS GAINING	POSSIBILITIES
Recording	Once only for 5-10%	Dispatch system	Improvement of production discipline, monitoring of major TEI
Control			
Regulation	Operationally within the frames of a shift		
Organization			
Norm setting	In case of permanent performance up to 30%	Analytical unit of the ACMS GC	Optimization of modes and conditions of operation of the major technological equipment
Stimulation			
Planning	Within the frames of short-, medium- and long-term periods		
Regulation			
Organization			

competitiveness in comparison with an approach focused on the use of high-level production capacities, main mining and transport equipment, as follows from table 2 [5].

As follows from the data presented in the table, factors of automation, integration and perfect organization of mining and transport operations play a significant role in mining. Practically similar conclusion can be drawn from the diagrams shown in figure 2. It follows from the diagrams that a complete renovation of the main technological equipment with the former system of management of mining and transport operations allows for a temporary cost reduction of 10-15%, but with each subsequent year of its operation, this effect decreases and disappears. At the same time, only replacement of the organization of the mining and transport complex management to ones with a corporate and process ensures a reduction in the cost of mining and transport operations by 30-35% and more, and over the years this effect remains unchanged. Ideal case incurs the automated corporate management of the mining and transport complex combined with the optimal level of its profitability.

Table 2 – Factors of competitiveness of a mining enterprise

П/П	ЭЛЕМЕНТЫ И ИХ ГРУППЫ	ОЦЕНКА ВЛИЯНИЯ,%*	
		В СТРАНАХ ЛИДЕРАХ	В СТРАНЕ
1	ЭЛЕМЕНТЫ ТЕХНИЧЕСКОЙ ГРУППЫ		
1.1	Уровень производственных технологий	12	16
1.2	Уровень основного и вспомогательного оборудования	10	14
1.3	Уровень информационных систем и их технических средств	1	0,5
1.4	Уровень локальных систем автоматизированного управления и робототехники	2	1
1.5	Уровень комплексной автоматизированной системы управления технологическими процессами	18	6
1.6	Уровень интегрированной организационно-технической АСУ предприятием	10 (6+4)	3
1.7	Уровень управления производственно-технологическими и ремонтно-профилактическими процессами в плане соблюдения технологических нормативов и требования техники безопасности труда	1	0,5
1.8	Степень оптимизации технологических процессов и эксплуатационных режимов работы оборудован-ия (материало- и энергоэффективность, качество продукции и минимизация её себестоимости)	12	4
1.9	Степень комплексного использования сырьевых ресурсов	2	1,5
1.10	Степень оптимальности ремонтно-профилактических работ по основному и вспом-му оборудованию	3	1,5
1.11	Соответствие организационно-технологической структуры производства требованиям теории надежности и резервирования	1	0,8
1.12	Рациональность компоновочного размещения в пространстве и на площадках элементов производственно-технологического комплекса предприятия	1	0,7
2	ЭЛЕМЕНТЫ ЭКОНОМИЧЕСКОЙ ГРУППЫ		
2.1	Эффективность менеджмента предприятия (все аспекты)	6	4
2.2	Эффективность маркетинговой деятельности с учетом достижений логистики по оптимизации потоковых процессов различных видов (грузовых, информационных, энергетических и финансовых)	11	1,5
2.3	Финансовые элементы	4	1,5
2.4	Инвестиционные элементы	6	0,2
ВСЕГО		100	63,2

At times of lack of investment resources, the most significant direction of intensifying the reduction of mining production costs without significant capital investments is the introduction of process management of the mining and transport complex [6,7]. The process approach in production management allows more fully and efficiently to realize its basic functions of planning, organizing, rationing, regulating, controlling and accounting for the operation of the mining and transport complex, which greatly increases its efficiency and, therefore, the competitiveness of the enterprise itself.

The process management of the mining and transportation complex in a quarry is carried out by taking into account a combination of factors of the external and internal environment of an enterprise based on economic and mathematical modeling of production processes [8]. The basis for managing production processes is automated monitoring and dispatching of mining and transport operations within the corporate management system, which ensures the rapid collection and analytical processing of reliable information on the operation of the mining and transport complex in specific mining and technical, mining and geological, economic and organizational conditions for its functioning [9,10].

The basis of intellectual automation of production processes is an economic-mathematical model that provides formalized economic representation of economic objects, processes, phenomena and their interconnections [11,12].

As practice shows, overwhelming majority of modern mining enterprises use an economic analysis system that corresponds to the functional management of the mining transport divisions and is based on local criteria: an excavator park - the cost of the rock mass mining, a park of trucks and locomotives - the cost per ton-kilometer, etc. [13-16].

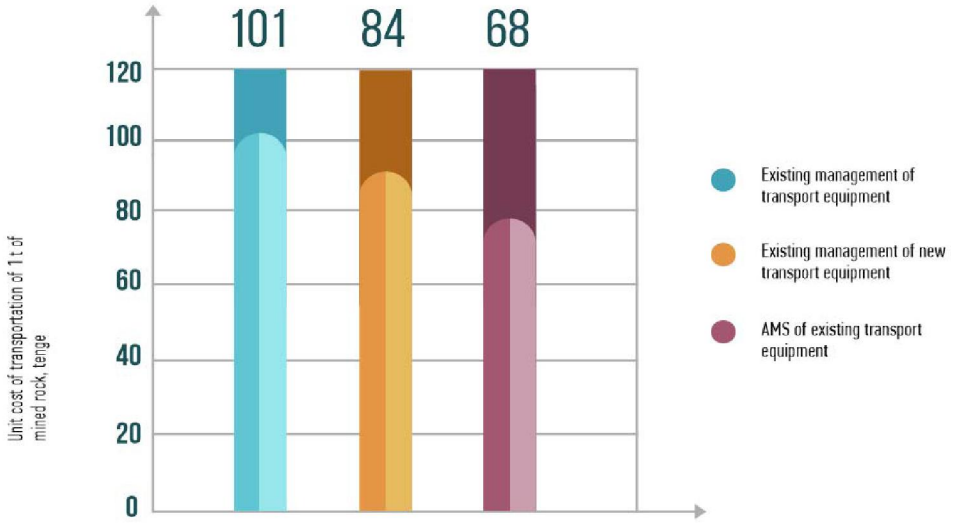

Figure 4 – Efficiency of organizational and technical factors of mining production

In general, according to the technological scheme of enterprise, the main economic indicator of its work is the cost of 1 ton (or 1 m^3) of extracted mineral raw materials. For example, the indicator of the cost of extracting rock mass, which is considered as a complex and widely used in the T. Kemm model [17-18] of the formation of costs for open work, is calculated by

$$c = c_d + k_v c_v, \quad (1)$$

where C_d is the cost of mining without stripping operations, USD/t; C_v is the cost of stripping, in US dollars/m^3; K_v - stripping coefficient, m^3/t.

As can be seen, this approach suggests calculating the cost of production by simply summing up the values of two albeit key, but separate indicators: the cost of extracting the useful mineral and the cost of overburden excavation.

In the proposed approach, the main criterion of economic efficiency of the results of mining-transport complex work is the specific current costs of extracting one cubic meter of rock mass, calculated by the formula:

$$C_{\text{RM}} = \frac{C_E + \text{A}}{V_{\text{RM}}}, \quad (2)$$

where C_E - operating costs; A - depreciation deductions; V_{rm} - the volume of extracted rock mass per shift, m^3.

The optimization of the parameters of the mining and transport complex in a quarry with a combined transport (for example truck - rail way) is made according to the criterion of minimum unit operating costs with an objective function of the following form:

$$C_{\text{RM}} = f(C_e, C_a, C_{\text{rw}}, C_{\text{ol}}) \rightarrow \min, \quad (3)$$

where C_e, C_a, C_{rw} and C_{ol} – respectively specific operating costs for excavation, auto transport, rail way transport and overloading warehouses. At the same time, indicators on the volumes of mined ore, overburden, as well as the average content of the useful component in the ore serve as limitations.

The scientific and methodological base of the analytical unit of the AKSU GK allows not only to analyze and purposefully correct the current state of the geotechnological complex, but also to conduct a technical and technological audit of new design, investment, innovative and organizational solutions. At the stage of implementation of the AKSU GK with the help of an analytical unit, a preliminary technical and economic assessment is carried out, which makes it possible to determine with a high degree of accuracy existing potential of a real increase in efficiency and a decrease in the cost of mining and transport works. For large and medium-sized quarries, it is usually about 15-30%, which provides savings of about $1-3 million/year. In contrast to automated dispatching systems, due to a more complete realization of the existing potential, the use of this system is economically feasible in small pits too.

Conclusion. In condition of the transition to the Industry-4.0, the main drivers of which are digitalization and automation, for the successful implementation of the existing potential to improve the efficiency of open cast mining operations, it is obvious the expediency of developing a unified methodology for the design, planning and management of geotechnological complexes on the basis of in-depth analytics (operational level) within the automated corporate (integrated) approach using the economy of process management.

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АШЫҚ ТАУ-КЕН ЖҰМЫСТАРЫ КЕЗІНДЕГІ ТАУ-КЕН ТРАНСПОРТЫНЫҢ ЖҰМЫСТАРЫН ӘЛЕУЕТТІК ЖОҒАРЛАУ ТИІМДІЛІГІ ЖӘНЕ САНДЫҚ ЖҮЙЕСІН ЖОБАЛАУ ЖӘНЕ ЖОСПАРЛАУ

Аннотация. Циклдік технологияларды пайдалана отырып, ашық әдіспен пайдалы қазбалар кен орындарын игерудің қазіргі заманғы дәстүрлі және кеңінен қолданылатын технологиялары пайдалы қазбаларды өндіру және тасымалдау жұмыстарының тиімділігін жоғарылату және құнын төмендету үшін елеулі әлеуетке ие. Мақалада осы әлеуетті қалай іске асыруға болатынын қарастырады. Карьердегі тау-кен және көлік жұмыстарының тиімділігін арттырудың әлеуеті мен бағыттары геотехнологиялық кешендерді автоматтандырылған корпоративтік басқару әдіснамасын қолдана отырып, ғылыми-практикалық зерттеулер мысалында анықталды.

Бүгінгі таңда ашық карьерді өндіру саласында ең көп бухгалтерлік және бақылаудың автоматтандырылған жүйелері, тау-кен және тасымалдау операцияларын автоматтандырылған диспетчерлеу жүйесі қолда-

нылатын. Алайда, олар тау-кен жұмыстарының тиімділігін арттыру үшін бар әлеуеттің үшінші бөлігін ғана іске асыруға мүмкіндік береді. Мақалада әлеуетті барынша толық іске асыру механизм мен мүмкіндіктері ашылады. Автоматтандыру және санды жүйесі тиісті ғылыми-инновациялық әлеуетті дамыту жағдайында ғана қажетті нәтиже беретінін атап өткен жөн.

Инвестициялық ресурстардың жетіспеушілігі жағдайында күрделі капиталды салымдарсыз тау-кен шығындарының төмендеуін жеделдетудің маңызды бағыты тау-кен-көлік кешенін технологиялық басқаруды енгізу болып табылады. Процесс тәсіл - бұл кәсіпорынның қызметін өзара байланысты өндірістік процестер жиынтығы ретінде қарастыратын басқарудың қазіргі заманғы тұжырымдамасы. Өндірісті басқарудағы технологиялық тәсіл бізге тау-кен-көлік кешенін жоспарлау, ұйымдастыру, реттеу, бақылау және есепке алудың негізгі функцияларын неғұрлым толық және тиімді жүзеге асыруға мүмкіндік береді, бұл оның тиімділігін, демек кәсіпорынның бәсекеге қабілеттілігін айтарлықтай арттырады.

Карьердегі тау-кен-көлік кешенін технологиялық басқару өндірістік процестерді экономикалық және математикалық модельдеу негізінде кәсіпорынның сыртқы және ішкі ортасы факторларының үйлесімін ескере отырып жүзеге асырылады. Өндірістік процестерді басқарудың негізі корпоративті басқару жүйесі аясында тау-кен жұмыстарының автоматтандырылған мониторингі және кестесі болып табылады, ол нақты тау-кен, геологиялық, экономикалық және ұйымдастырушылық жағдайларында тау-кен тасымалдау кешенінің жұмысы туралы шынайы ақпаратты жедел жинау және аналитикалық өңдеуді қамтамасыз етеді.

Мақалада ашылған тағы бір маңызды сала - карьерлердің геотехнологиялық кешендерін тұрақты және бағдарланған технологиялық жаңғырту үшін цифрландырудың іргелі маңыздылығы. Цифрландыру, оның мазмұны бойынша, үнемі дамып келе жатқан ғылыми-әдістемелік әлеуетке сәйкес келуі керек, бұл геотехнологиялық кешендердің жұмысын сапалы жедел талдауға мүмкіндік береді. Бұл әртүрлі инновациялардың техникалық және ұйымдастырушылық тиімділігін бағалауға мүмкіндік береді. Цифрландыру – бұл кәсіпорынды жаңарту процесінің негізгі кезеңдерінің бірі және оны технологиялық саясат аясында жүйелі түрде жүргізу керек. Ол кәсіпорынның менеджерлері мен талдаушылары үшін оның даму стратегиясын анықтайтын тиімді құралға айналуы керек.

Геотехнологиялық кешендерді корпоративті басқарудың автоматтандырылған жүйелерінің бағдарламалық-аналитикалық потенциалы пайдалы қазбалар кен орнын игеруді жобалау аясында іске асырылған геотехнологиялық кешенді жобалау сатысында, сондай-ақ оларды пайдалану кезеңінде, жиі кездесетін қайта құру кезінде басқару шешімдерін әзірлеу кезінде де бірдей қолданылуы керек. Тау-кен өндірісіндегі орны. Бірыңғай әдістеме кен орындарын пайдалану кезеңінде жүзеге асырылатын әртүрлі шараларды жобалаудың тиімділігін салыстырмалы бағалауды жүргізуге практикалық мүмкіндік береді.

Қорытындылай келе, мақалада Индустриалды-4.0-ге көшу кезінде, автоматтандырылған корпоративтік тәсілдің шеңберінде терең талдау негізінде әзірленген геотехнологиялық кешендерді жобалау, процестерді басқарудың экономикасын пайдалана отырып жоспарлау және басқарудың жалпы әдіснамасы негізінде ашық тау-кен өндірісінде тау-кен жұмыстарының тиімділігін арттыруға болады деп қорытынды жасалады.

Түйін сөздер: тау-кен жұмыстарын жүргізу, басқару, ұйымдастыру, тиімділік, сандық жүйе, автоматтандыру.

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ЦИФРОВИЗАЦИЯ И ПОТЕНЦИАЛ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ ПРОЕКТИРОВАНИЯ И ПЛАНИРОВАНИЯ ГОРНОТРАНСПОРТНЫХ РАБОТ НА ОТКРЫТЫХ РАЗРАБОТКАХ

Аннотация. Современные традиционные и наиболее широко применяемые технологии освоения месторождений полезных ископаемых открытым способом с применением цикличных технологий имеют существенный потенциал повышения эффективности и снижения себестоимости горнотранспортных работ. Статья посвящена тому, каким образом и за счет чего можно реализовывать этот имеющийся потенциал. Потенциал и направления повышения эффективности горнотранспортных работ в карьере раскрываются на примере научно-практических исследований с использованием методологии автоматизи-рованного корпоративного управления геотехнологическими комплексами.

На сегодня в области открытых горных работ наибольшее распространение получили системы автоматизированного учета и контроля, автоматизированные системы диспетчеризации горнотранспортных

работ. Однако они позволяют реализовать только третью часть имеющегося потенциала повышения эффективности добычного процесса. В статье раскрывается механизм и возможности в существенной степени более полной реализации имеющегося потенциала. Отмечается, что автоматизация и цифровизации могут дать нужный эффект лишь в условиях развития соответствующего научно-инновационного потенциала.

В условиях дефицита инвестиционных ресурсов наиболее существенным направлением интенсификации снижения затрат горного производства без значительных капитальных вложений является внедрение процессного управления горнотранспортным комплексом. Процессный подход − современная концепция управления, которая рассматривает деятельность предприятия как совокупность взаимосвязанных производственных процессов. Процессный подход в управлении производством позволяет более полно и качественно реализовывать его основные функции планирования, организации, нормирования, регулирования, контроля и учета работы горнотранспортного комплекса, что в значительной мере повышает его эффективность, а значит и конкурентоспособность самого предприятия.

Процессное управление горнотранспортным комплексом в карьере осуществляется с учетом совокупности факторов внешней и внутренней среды предприятия на основе экономико-математического моделирования производственных процессов. Основой управления производственными процессами являются автоматизированный мониторинг и диспетчеризация горнотранспортных работ в рамках системы корпоративного управления, которые обеспечивают оперативный сбор и аналитическую обработку достоверной информации о работе горнотранспортного комплекса в конкретных горнотехнических, геологических, экономических и организационных условиях его функционирования.

Другим, важным направлением, раскрываемым в статье, является принципиальная значимость цифровизации для устойчивого и целенаправленного процесса технологической модернизации геотехнологических комплексов карьеров. Отмечается, что цифровизация, по своему содержанию, должна соответствовать постоянно развивающемуся научно-методическому потенциалу, позволяющему осуществлять качественный пооперационный анализ функционирования геотехнологических комплексов. Это создаёт возможность оценки эффективности различного рода инноваций, как в техническом плане, так и в организационном. Цифровизация является одним из базовых этапов процесса модернизации предприятия и должна осуществляться системно в рамках реализуемой им технологической политики. Она должна стать эффективным инструментом менеджеров-аналитиков на предприятии, определяющих стратегию его развития.

Программно-аналитический потенциал автоматизированных систем корпоративного управления геотехнологическим комплексам должен быть в одинаковой степени применим как при выработке управленческих решений на стадии проектирования геотехнологического комплекса, реализуемого в рамках проектирования освоения месторождения полезных ископаемых, так и на стадиях их эксплуатации, а также реконструкции, которые часто имеют место в горном производстве. Единая методология обеспечивает практическую возможность проведения сравнительной оценки эффективности проектирования различного рода мер, реализуемых на стадии эксплуатации месторождения.

В заключении статьи приводится вывод о том, что в условиях перехода к Индустрии-4.0, обеспечение повышения эффективности горнотранспортных работ на открытых разработках возможно лишь на базе единой методологии проектирования, планирования и управления геотехнологическими комплексами, развиваемой на основе углубленной аналитики в рамках автоматизированного корпоративного подхода с применением экономики процессного управления.

Ключевые слова: горнотранспортные работы, управление, организация, эффективность, цифровизация, автоматизация.

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REFERENCES

[1] Koishina A.I., Kirisenko O.G., Koilybayev B.N., Agayeva K.K. Decision-making for choosing of geological and engineering operation: Current status and prospects / News of the National Academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. N 4. 2018. P. 155-167. ISSN 2224-5278

[2] Bauernhansl T., (2014) Die vierte industrielle Revolution. Der Weg in ein wertschaffendes Produktions paradigm. P. 3-35. In: Bauernhansl T., M. ten Hompel and Vogel-Heuser B., 2014: Industrie 4.0 in Production, Automatisierung und Logistik: Anwendung, Technologie, Migration (in Eng.).

[3] Trubetskoy K.N. and others (1997) Mining sciences. The development and preservation of subsoil of the earth. Ed. Mining Academy. 478 p.(in Russ.).

[4] https://kz.schneider-electric.com/ru/work/campaign/innovation/platform.jsp (in Eng.).

[5] Tkach V.M., Solomakha V.N. (2015) Assessment of the competitive potential of iron ore enterprises is the basis for the formation of a strategy for their development in the context of globalization. Mining Journal. N 3. P.62-65 (in Russ.).

[6] Dokholyan S.V., Petrosyanc V.Z. (2014) Realization of process approach for management by Industrial enterprises. Approbation. N 6. P. 52-57 (in Russ.).

[7] Kaplan A.V., Galiyev S.Zh. (2017) Process by mining and transport complex at pit quarries on the base of economic criterials. Mining journal, 2239. M. P. 28-33 (in Russ.).

[8] Galiyev S.Zh., Akhmedov D.Sh., Tatishev E.N., Zhusupov K.K., Boyandinova A.A., Dzhaksybaev A.Kh. (2004) Automated control technologies for geotechnical complexes in the field of open pit mining. Almaty. P. 250 (in Russ.).

[9] Galiev S.Zh., Zhusupov K.K., Tatishev E.N., Boyandinova A.A. and etc. (2007) Automated corporate management of geotechnological complexes on open-cast mining/ Under total ed. S. Zh. Galiyeva. Almaty. P.237 (in Russ.).

[10] Dovjenok A.S. (2001) Perfection of management by the motor transport systems of quarries – Ekaterinburg: URD RAS. P. 93 (in Russ.).

[11] Kaplan A.V. (2015) Management of Social-economic development of Mining enterprice. M: Economica. P. 270. (in Russ.).

[12] Sokolovskiy A.V., Cherskikh O.I., Kainov A.I. (2015) Strategy and parameters of development of coal quarries OAO «SUEK» Mining journal. N 11. P. 62–65. DOI: 10.17580/gzh.2015.11.12 (in Russ.).

[13] Kaverina O.D. (2014) administrative account: theory and practice: textbook for bachelors. 2-e edition, processed. and add. M.: UYwrite. 488 p. (in Russ.).

[14] Bulgakova S.V., Podobedova N.V. (2014) Cost calculation on the processes of activity at the administrative account of economic subject, International record-keeping. N 45. P. 14–24 (in Russ.).

[15] Camm T.W. Simplified (1991) Cost Models for Prefeasibility Evaluations: Information Circular 9298. U.S. Department of the Interior. 42 p. (in Eng.).

[16] Hohryakov V.S., Sacancev G.G., Yashkin A.Z. (1977) Economic-Mathematic modeling and projecting of quarries. M. Nedra. 200 p. (in Russ.).

[17] Khokhryakov B.C., Sakantsev G.G., Yashkin A.Z., and others(1977) Economic-mathematical modeling and design of quarries / M. Nauka. 199 p. (in Russ.).

[18] Kalimoldayev M., Akhmetzhanov M., Kunelbayev M., Sundetov T. Information systems of integrated machine learning modules on the example of a verbal robot / News of the National Academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. N 6. 2019. P. 215-222. ISSN 2224-5278