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SELECTING AN EFFICIENT CONFIGURATION FOR EXCAVATOR-TRUCK COMPLEXES IN A MINING SITE WITHOUT CHANGING THE TOTAL NUMBER OF TRANSPORT UNITS

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Abstract.
This article examines the importance of optimizing the planning of excavation, loading, and transportation processes in open-pit mining operations with a goal of increasing productivity and reducing costs. It highlights the characteristics of the time distribution for loading of blasted rock by various excavators under real conditions at a mining operations site. The identified patterns of time distribution density were taken into account in the simulation modeling of an excavator-truck complex (ETC) at a mining site, consisting of several excavators and a corresponding fleet of dump trucks. The simulation model of the site's ETC was verified for adequacy and demonstrated its stability under changes in input parameters, specifically the number of dump trucks presented for loading. The identified "bottlenecks" in the ETC's operation (namely: uneven excavator utilization rates, increased downtime, and the average number of dump trucks waiting in line at an excavator) were mitigated using the developed model. This made it possible to make several management decisions: either to increase the site's rock-handling capacity or to balance the load on the excavators without reducing the site's existing capacity – all without changing the existing fleet of dump trucks. The proposed solutions also made it possible to balance the overall load on the dump truck fleet by reducing the average queue length at the excavators.

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Introduction

Although the mineral resource base is a natural competitive advantage for the national economy and the industrial sector of the Russian Federation – and serves as a driving force for the Russian economy due to the large volume and diversity of its mineral reserves, which support its development and transition to a new technological paradigm – there has recently been a decline in coal reserves: from 275.1 billion metric tons in 2020 to 272.4 billion metric tons in 2024 [1].

For Kuzbass, whose share of coal production accounts for 44.7% of the national total [2], a key challenge is reducing mining costs. This strategy was chosen to preserve jobs and alleviate social tensions amid the current difficult economic situation. Given that excavation and loading operations account for 15-40% of the total, depending on the properties of the rock mass, and that transportation accounts for 40-50% of the production cost (and more for deep surface mines) [3, 4], reducing costs in these open pit mining processes is a pressing priority.

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Materials and Methods

Changes in the parameters of the mining block, the height of the layer being mined, and the order in which coal is extracted from complex faces play a major role in excavator productivity [5–8], but overall, these changes cannot be considered in isolation from the organization of mining, loading, and transportation operations.

To analyze the operation of an excavator-truck complex (ETC) engaged in the loading and transportation of blasted rock, let us examine its structure using the example of one of the coal mining enterprises in the Kemerovo Region – Kuzbass. To extract the mineral resource at this enterprise, modern hydraulic and electric excavators of both domestic and foreign manufacture are currently used, ensuring high efficiency and safety in coal mining. Excavators with large bucket capacities are used for overburden removal: EKG-8U, EKG-18M, EKG-20, and P&H 2800, as well as BELAZ-7513 series dump trucks with a load capacity of 130 metric tons and BELAZ-7530 series dump trucks with a load capacity of 220 metric tons.

The main design parameters of the excavation and loading equipment used are presented in Tables 1 and 2.

Table 1. Technical characteristics of excavators
Таблица 1. Технические характеристики экскаваторов

Technical parameter	Unit	Value	Figure
EKG-8U			
Bucket capacity	m³	8.0	
Maximum dumping radius	m	32.0	
Operating weight with bucket	ton	800	
Maximum dumping radius	m	10.0	
Maximum dumping height	m	24.5	
Maximum digging height	m	30.0	
Tail section swing radius of the rotating platform	m	10.0	
Digging radius at ground level	m	20.2	
EKG-18M			
Bucket capacity	m³	18.0	
Maximum dumping radius	m	19.6	
Operating weight with bucket	ton	710	
Maximum digging radius	m	22.2	
Maximum digging height	m	16.6	
Maximum dumping height	m	10.7	
Tail section swing radius of the rotating platform	m	10.6	
Digging radius at ground level	m	15.6	
EKG-20			
Bucket capacity	m³	20.0	
Maximum dumping radius	m	20.9	
Operating weight with bucket	ton	1050	
Maximum digging radius	m	23.4	
Maximum digging height	m	17.0	
Maximum dumping height	m	11.5	
Tail section swing radius of the rotating platform	m	10.0	
Digging radius at ground level	m	15.2	

Technical parameter	Unit	Value	Figure
P&H-2800			
Bucket capacity	m³	30	
Maximum dumping radius	m	21.0	
Operating weight with bucket	ton	1020	
Maximum dumping radius	m	9.9	
Maximum dumping height	m	9.1	
Maximum digging height	m	16.6	
Tail section rotation radius of the swing platform	m	9.9	
Digging radius at ground level	m	16.4	

Table 2. Technical characteristics of dump trucks
Таблица 2. Технические характеристики автосамосвалов

Technical parameter	Unit	Value	Figure
BELAZ 75131 (7513D, 75137, 7513P)			
Load Capacity	ton	130	
Engine Power	kW	1194	
Body Volume (Geometric)	m³	50.1	
Maximum Speed	km/h	48	
Turning Radius (measured from the front outer wheel)	m	13	
Dimensions (Length)	m	11.5	
Dimensions (Width)	m	6.4	
Dimensions (Height)	m	5.9	
Wheel Diameter	m	3.1	
BELAZ 7530 (7530G, 75306, 75302)			
Load Capacity	ton	220	
Engine Power	kW	1715	
Body Volume (Geometric)	m³	92	
Maximum Speed	km/h	43	
Turning Radius (measured from the front outer wheel)	m	15	
Dimensions (Length)	m	13.4	
Dimensions (Width)	m	7.8	
Dimensions (Height)	m	6.7	
Wheel Diameter	m	3.6	

The operating parameters of the excavators used at the mining site are shown in Table 3.

The purpose of the study was to simulate the operation of the excavators at an active coal open-pit mine in order to identify and eliminate bottlenecks in equipment deployment.

The following actual time metrics for dump truck operations, provided by the company, were used as input data: waiting time for dump trucks during loading; time required for excavators to load dump trucks; travel time for loaded dump trucks to the spoil piles; unloading time; time spent by dump trucks traveling empty from the dump sites; lunch break time; downtime of excavation and transport equipment.

These timing indicators are presented in Table 4.

Table 3. The operating parameters of the excavators with corresponding dump trucks
Таблица 3. Параметры работы экскаваторов

Parameters	Unit	EKG-8U	EKG-18M	EKG-20	P&H-2800
		BELAZ-75131	BELAZ -7530		
Bucket capacity	m³	8.0	18.0	20.0	34.0
Rock category based on excavation difficulty	-	IV			
Bulk density	ton/m³	2.6	2.6	2.6	2.6
Rock loosening factor	-	1.5	1.5	1.5	1.5
Bucket fill factor	-	1.02	1.02	1.02	1.02
Excavation factor	-	0.68	0.68	0.68	0.68
Volume of excavated material in the dump truck bed (“heaped”)	m³	71.2	130	130	130
Volume of excavated material in the dump truck bed, taking into account its payload capacity and bulk density	m³	75.0	126.9	126.9	126.9
Operational time per loading cycle	s	33.0	37.0	37.0	38.0
Number of excavator cycles during loading	unit	9.0	7.0	7.0	4.0
Time to load a transport unit	min	5.0	4.3	4.3	2.5
Time to position the dump truck for loading	min	1.1	1.1	1.1	1.1
Dump truck waiting time	min	0.15	0.15	0.15	0.15
Shift working time:					
- shift duration	min	720	720	720	720
- time for preparatory and wrap-up work	min	35	35	35	35
- time for rest and meals	min	60	60	60	60
- time to clear the access road to the excavator	min	10	10	10	10
- excavator’s net working time	min	615	615	615	615
Number of shifts per day	shift/day	2	2	2	2
Number of transport units loaded	unit/day	100	113	113	170
Adjustment factor accounting for:	-	0.89	0.89	0.89	0.89
- excavation of sticky and frozen rock	-	1.0	1.0	1.0	1.0
- re-excavation	-	1.0	1.0	1.0	1.0
- blasting operations during the shift	-	0.97	0.97	0.97	0.97
- face watering during the shift	-	0.92	0.92	0.92	0.92
- work on unstable ground	-	1.0	1.0	1.0	1.0
Number of days per year:					
- mining operations	day	364	364	364	364
- downtime for repairs	day	30	30	30	30
- downtime due to weather conditions	day	7	7	7	7
- excavator travel time	day	10	10	10	10
- net excavator operating time	day	317	317	317	317
Number of excavator operating hours per year	hour	6499	6499	6499	6499
Hourly productivity	m³/h	406	814	545	1205
Shift productivity	m³/shift	4160	8340	5590	12350
Daily productivity	m³/day	8320	16680	11180	24700
Average annual productivity	thous. m³/year	2640	5290	3550	7830

Results and Discussion

The loading times of dump trucks are not uniformly distributed over the range from the minimum to the maximum value. Statistical analysis of the dispatching data revealed a log-normal distribution of dump truck loading times.

For each specific "excavator – dump truck" pair, the values of the parameters μ and σ of the probability density function for dump truck loading at time t differ and are calculated using methods of statistical analysis of real data. For example, for one of the time series of the EKG-8U excavator operating in conjunction with BELAZ 75130 and BELAZ 75131 dump trucks, the following values were obtained: $\mu \approx 1.685$; $\sigma \approx 0.272$. The selected distribution law quite accurately describes the actual distribution of the loading time for blasted rock by the EKG 8U excavator into the BELAZ 75130 and BELAZ 75131 dump trucks (Fig. 1). The hypothesis that the loading time follows a log-normal distribution – selected from among similar distributions (e.g., the gamma distribution) based on the principle of maximum entropy [9, 10] – is confirmed by testing using the χ^2 (Pearson) and Kolmogorov–Smirnov criteria.

The loading time of dump truck t can be calculated using the probability density function of the "occurrence" of such a time within a specific (for example, weekly, but no longer) time sample of dispatch data. In our case, the probability density function can be expressed as:

$$f(t)=\frac{e^{\left(\frac{-\ln(t-\mu)^2}{2\sigma^2}\right)}}{t\cdot\sigma\sqrt{2\pi}}=\frac{e^{\left(\frac{-\ln(t-1{,}685)^2}{0{,}15}\right)}}{0{,}68t}. \qquad (1)$$

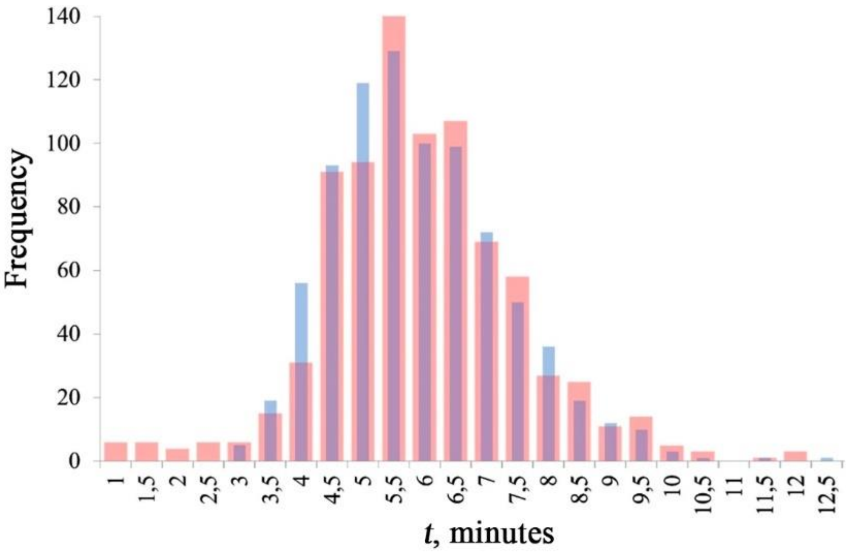

Fig. 1. Frequency (distribution density) of loading times for the BELAZ-75131 and BELAZ-7513D dump trucks loaded by an EKG-8U excavator: wide columns represent dispatch data; narrow columns represent the model

Рис. 1. Частота (плотность распределения) времени погрузки автосамосвала БЕЛАЗ-75131, БЕЛАЗ-7513D экскаватором ЭКГ-8У: широкие колонки – данные диспетчеризации, узкие – модельное представление

For other models of excavators and dump trucks, the values of μ and σ for the log-normal distribution will be different. For example, for the P&H-2800, the parameters of the log-normal distribution that best fits its operation are $\mu = 0.62$ and $\sigma = 0.2$ (Fig. 2).

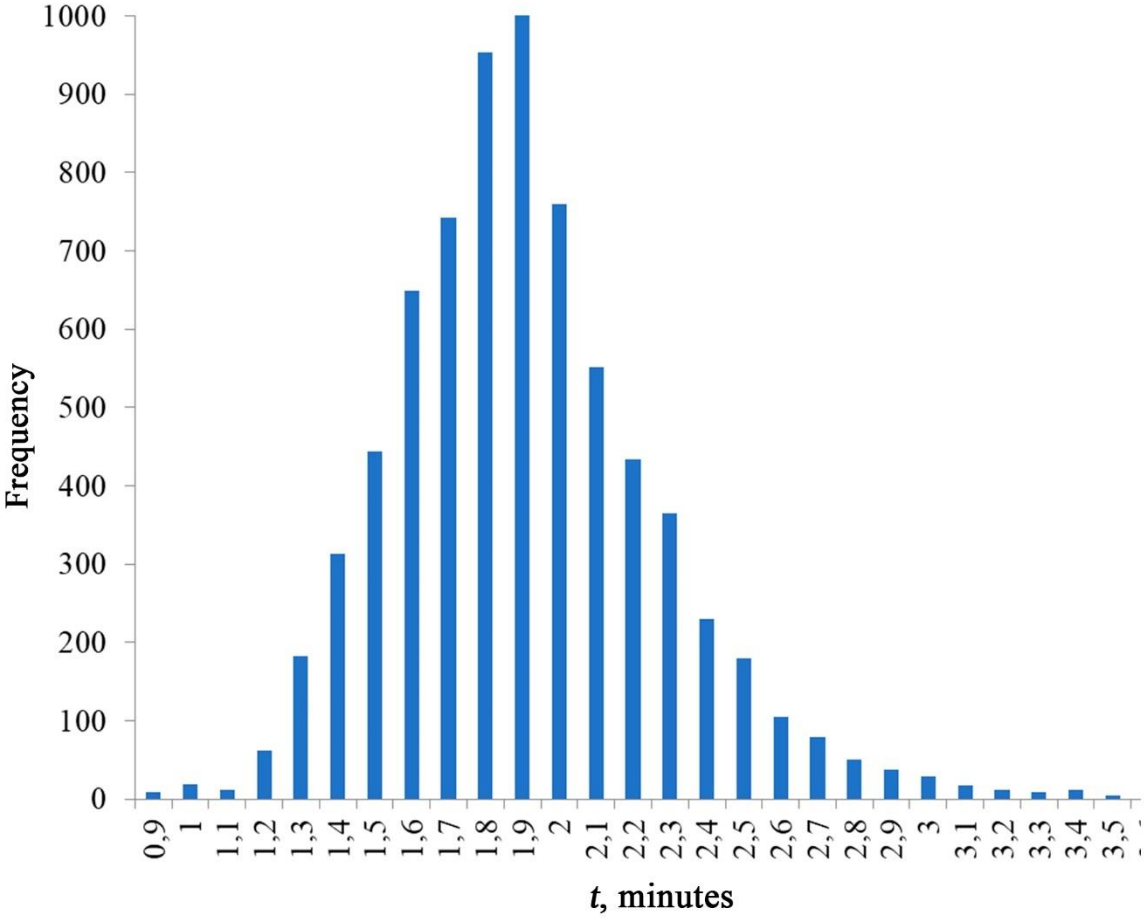

Fig. 2. Frequency (distribution density) of the actual loading time of a BELAZ-75230 dump truck by a P&H-2800 excavator
Рис. 2. Частота (плотность распределения) реального времени погрузки автосамосвала БЕЛАЗ-75230 экскаватором P&H-2800

For the EKG-18M and EKG-20 excavators (Fig. 3–5), the distribution law for loading time density changes to a gamma distribution:

$$f(x) = \frac{t^{\alpha-1}}{\beta^{\alpha}\Gamma(\alpha)} e^{-\frac{t}{\beta}}, \quad (2)$$

$$\Gamma(\alpha) = \int_0^t t^{(\alpha-1)} e^{-t} dt.$$

Presumably, this may be due to the design features of the excavators themselves or to the quality of the preparation of the blasted rock mass. The ratio of the excavator bucket's capacity to the dump truck's body capacity affects only the distribution parameter α, but has no effect on the law governing the distribution of loading time density – for example, the EKG-18M excavator maintains a gamma distribution when used with both 180-metric-ton and 220-metric-ton dump trucks (Fig. 3 and 4).

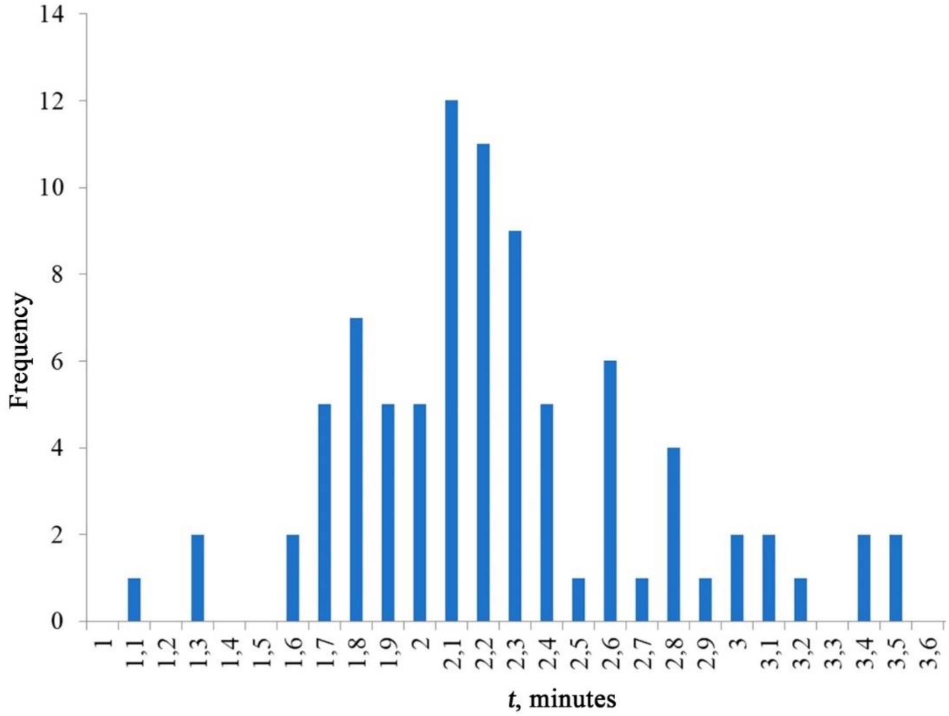

Fig. 3. Loading time frequency of the EKG-18M for BELAZ-75131 dump trucks (gamma distribution parameters: α = 16.25; β = 0.139)
Рис. 3. Частота времени погрузки ЭКГ-18М автосамосвалов БЕЛАЗ-75131 (параметры гамма-распределения: α = 16,25; β = 0,139)

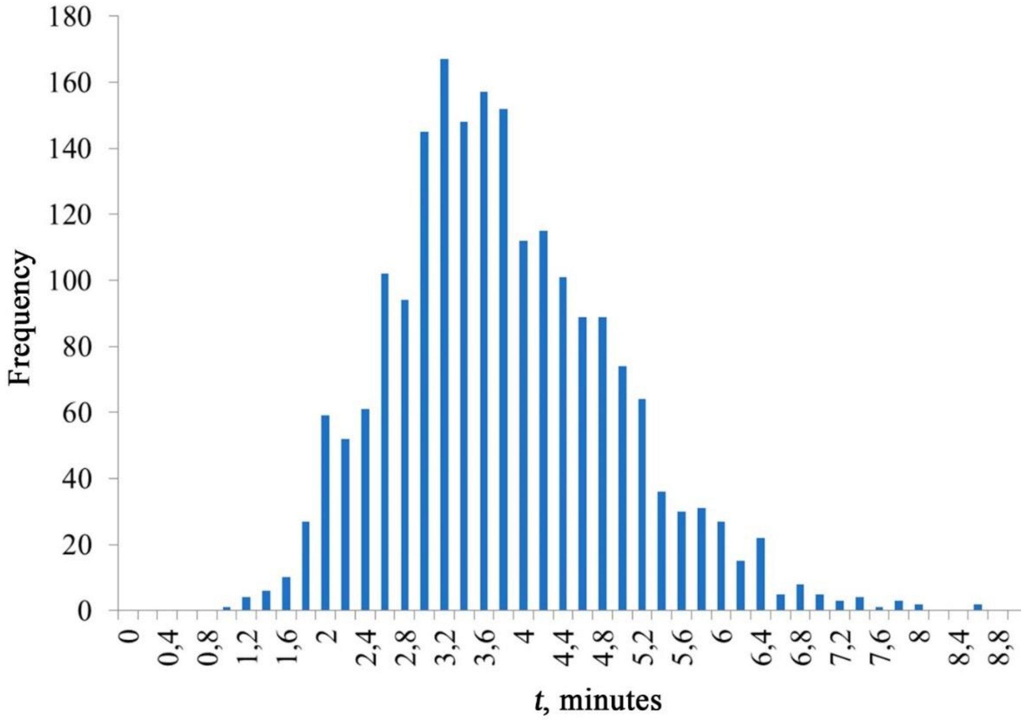

Fig. 4. Loading frequency of the EKG-18M on BELAZ-7530 dump trucks (gamma distribution parameters: α = 26.79; β = 0.137)
Рис. 4. Частота времени погрузки ЭКГ-18М автосамосвалов БЕЛАЗ-7530 (параметры гамма-распределения α = 26,79; β = 0,137)

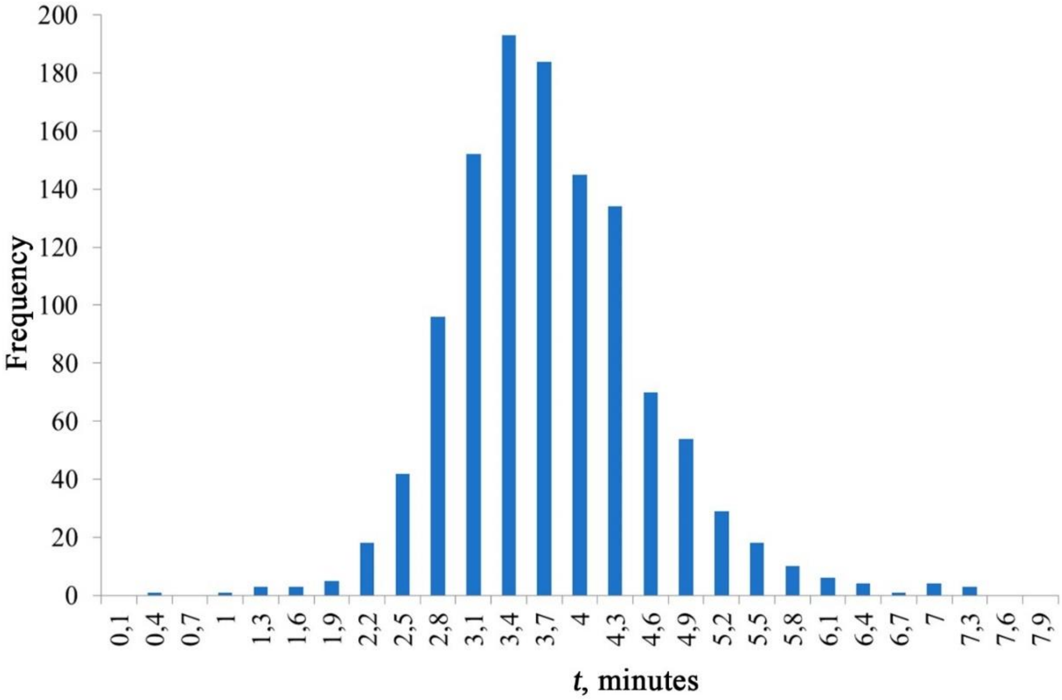

Fig. 5. Loading frequency of the ECG-20 for BELAZ-7530 dump trucks (gamma distribution parameters: α = 17.06; β = 0.218)
Рис. 5. Частота времени погрузки ЭКГ-20 автосамосвалов БЕЛАЗ-7530 (параметры гамма-распределения α = 17,06; β = 0,218)

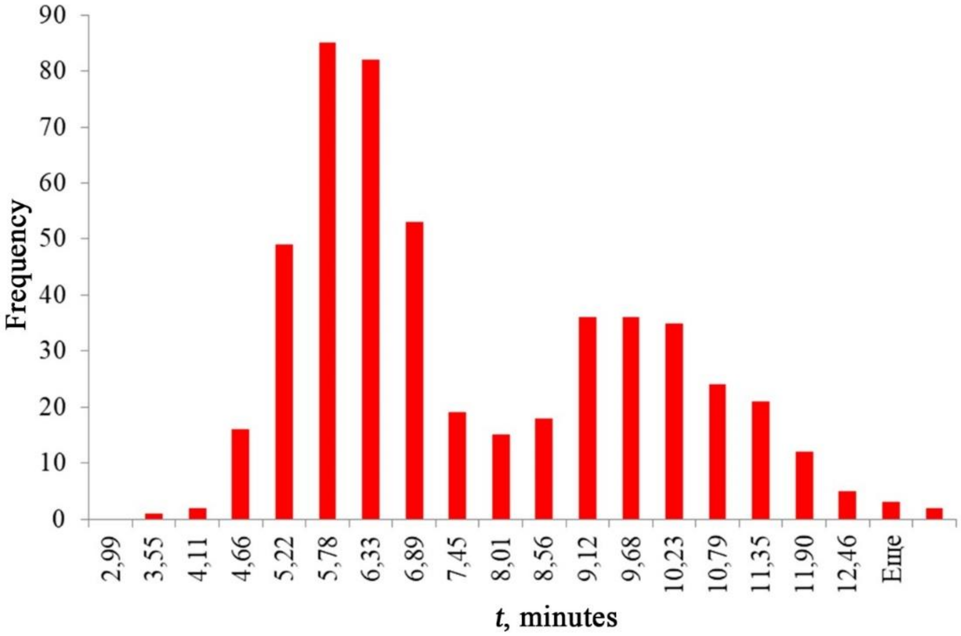

Fig. 6. Bimodal distribution of dump truck loading times
Рис. 6. Бимодальная форма распределения времени погрузки автосамосвала

It is possible to account for fluctuations in these distribution parameters over short time intervals (shifts or days) – that is, in the operational planning of mining operations – using the neural network solutions currently being developed by the authors.

An analysis of the enterprise's ETC operations and dispatch data revealed another distinctive feature. Given the presence of cyclical, sharply varying operating conditions for the ETC during each shift, for example, either when a trainee works for 3-4 hours, or when the quality of crushing (average rock particle size) is highly variable, or when there are issues with the surface of the work area across the excavator's pass through the blasted rock mass, a multimodal distribution of loading time emerges (Fig. 6). However, even in this case, the distribution density of loading time for each mode follows a log-normal (or gamma) distribution.

To evaluate the performance of individual ETC operating in a closed-loop dump truck feeding cycle, simulation models were developed in MATLAB Simulink [11–17], based on the principles of queueing theory and service-arrival theory [18–32] (Fig. 7).

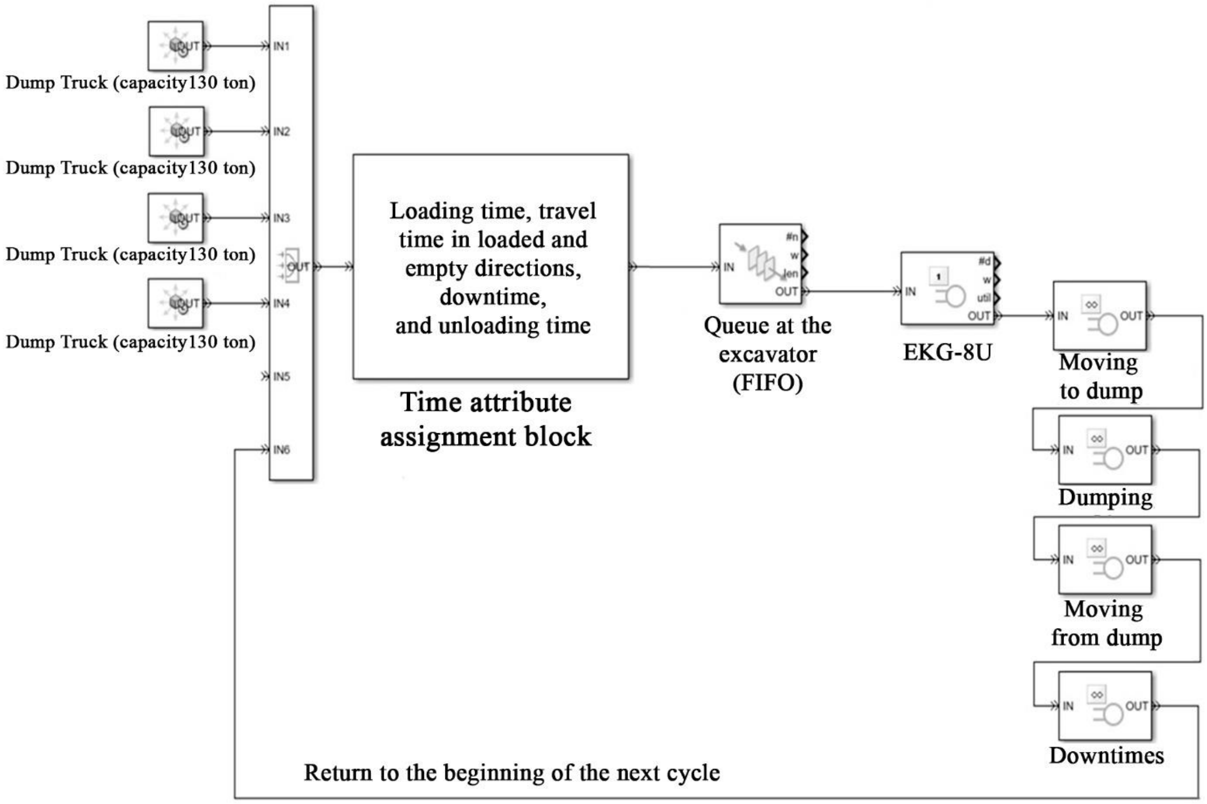

Fig. 7. A simplified example of a simulation model of a single ETC based on the EKG-8U
Рис. 7. Упрощенный пример имитационной модели отдельного ЭАК на базе ЭКГ-8У

This simulation model allows you to simulate the operation of a single ETC using the following input time data: loading time, travel time in the loaded and empty directions, unloading time, downtime, shift handover time, and lunch break (which are not considered downtime, even though no work is performed during these periods), all of which are specified based on real-world dispatching data.

In this model, the order of the blocks corresponds to the sequence of events that occur at the mining site in real time:

1) At the start of the shift, entities – dump trucks – are generated. Each dump truck is assigned a vehicle number, under which it enters the "Concentrator" block. From this block, the dump trucks proceed to the "Time Attribute Assignment Block," which models the start of a dump truck's trip;

2) While in the "Time Attribute Assignment Block," each dump truck receives updated weighted-average time attributes, namely: the time spent being loaded by the excavator, the time spent traveling with a load to the dump, the time spent unloading at the dump, the time spent traveling from the dump

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without a load, respectively, the downtime during the trip, and the start time and duration of the lunch break;

3) once the dump trucks have been assigned time metrics, they enter the "Waiting at the Excavator" block (on a "First In – First Out" basis) and each is loaded by the corresponding excavator in the order they were queued;

4) Next, the loaded dump truck travels to the dump site within the time assigned to it in the "Time Attribute Assignment Block," unloads (block with the "Unloading" time set), drives back from the dump site (the block with the "Return from Dump Site" time set); at the same time, the downtime for each trip is simulated and fed into the "Hub" block, which simulates a single dump truck trip;

5) afterward, the dump truck is reassigned new time parameters, and the next trip begins.

This model runs for 720 minutes of simulation time, which corresponds to a 12-hour work shift.

After constructing the model and running it a sufficient number of times, dependency graphs (by shift time) were obtained, based on which an analysis of the current operational status of the mining site was conducted:

- the utilization rate of each excavator;
- the current length of the dump truck queue at each excavator;
- the number of dump trucks loaded by each excavator during a shift,

and a comparison of these values with actual data to validate the model.

These dependency graphs are shown in Fig. 8–10.

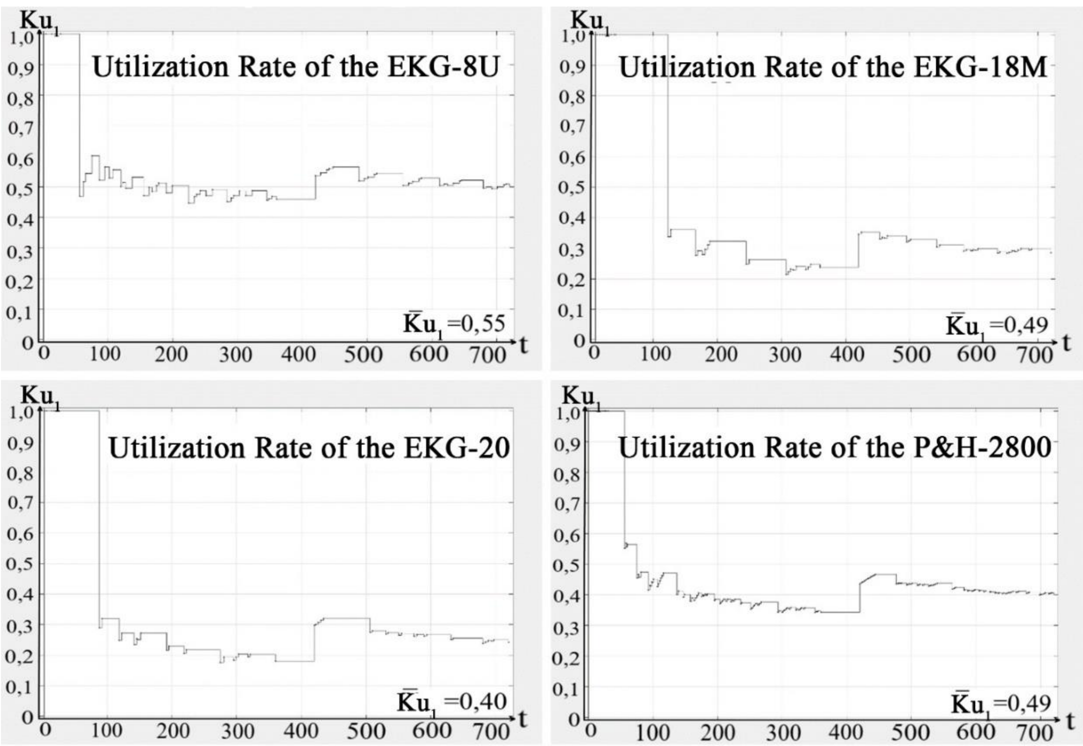

Fig. 8. Utilization rate Ku_1 of the EKG-8U, EKG-18M, EKG-20, and P&H-2800
Рис. 8. Коэффициент использования ЭКГ-8У, ЭКГ-18М, ЭКГ-20 и P&H-2800

A model utilization coefficient of K_u = 1 for the excavator at the start of the shift indicates that all dump trucks immediately line up to be loaded and the excavator is operating at 100% capacity. In reality, this rarely happens, since dump trucks do not arrive at the excavator simultaneously at the start of the shift. Therefore, the results from the first 80–110 minutes of the simulation should not be included in the calculations. A horizontal segment for each excavator in the middle of a shift (approx. at 400 min) indicates lunch time.

The graphs shown in Fig.9 indirectly confirm this.

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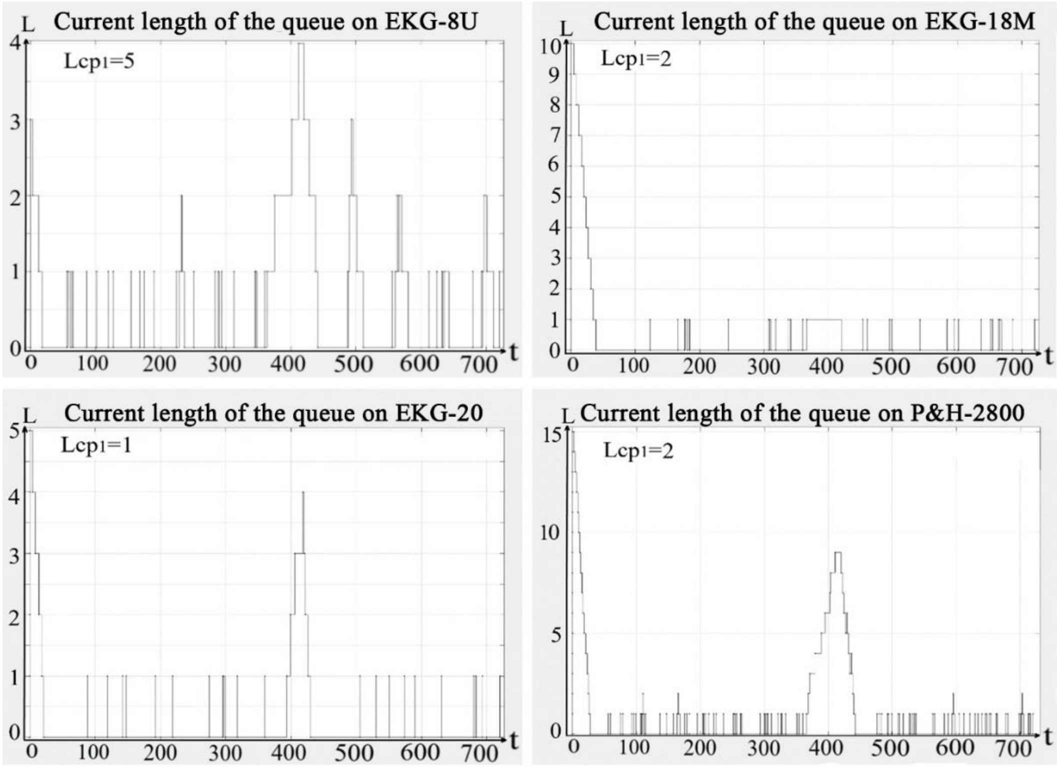

Fig. 9. Current length of the dump truck queue
Рис. 9. Текущая длина очереди автосамосвалов

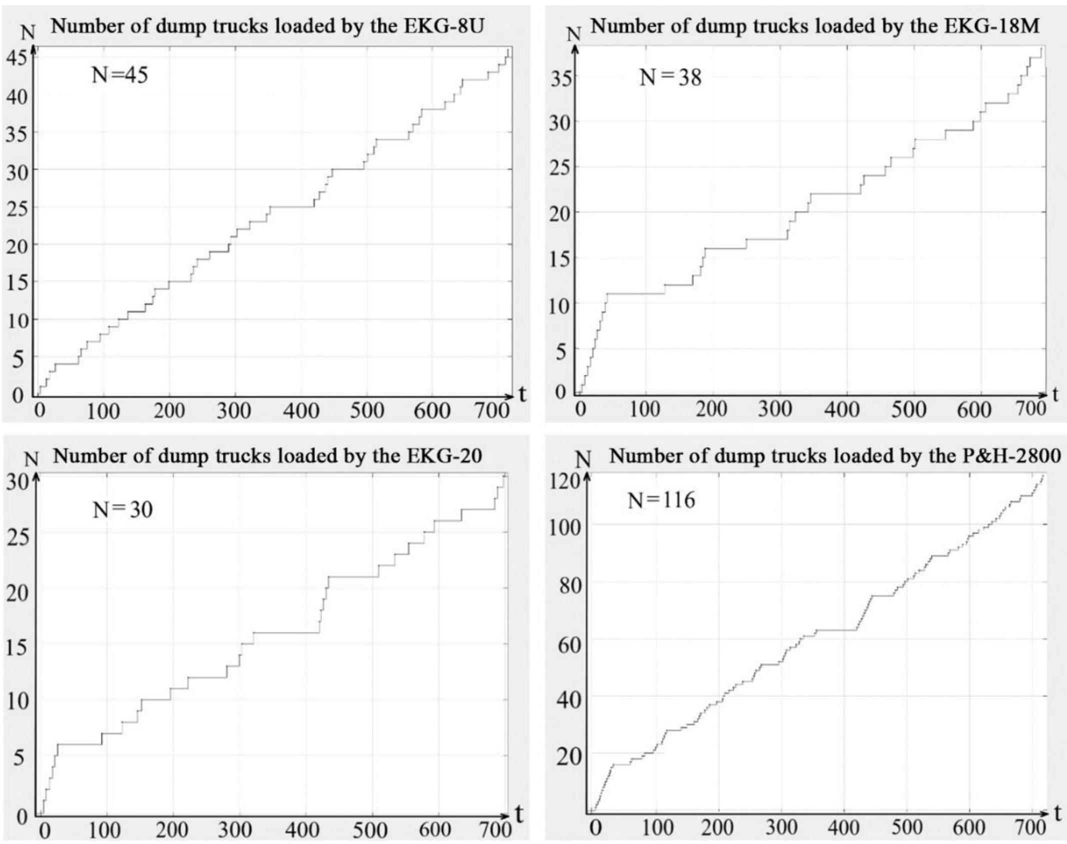

Fig. 10. Number of dump trucks loaded by the excavator during a work shift
Рис. 10. Число автосамосвалов, погруженных экскаватором в течение смены

Here, too, there is a localized accumulation of dump trucks in the loading queue at the start of the shift and at the start of lunch, although in reality it is not at all necessary for all dump trucks to arrive at the excavator at that time. Nevertheless, such localized "disturbances" do not have any significant impact on the ETC model's performance metrics during the rest of the shift.

The graphs shown in Fig.8–10 present the results of one of the model simulations. To average out the stochastically varying results, the necessary number of model simulations was performed, followed by averaging of the corresponding metrics. This is due to the law of large numbers and the central limit theorem: increasing the sample size reduces the variance of the estimates [33].

The required number of runs was calculated, and the maximum of the resulting values was selected, using the formula [34, 35]:

$$n = \frac{t_\alpha^2 \sigma_\alpha^2}{\varepsilon^2}, \tag{3}$$

where n is the required number of model' runs; α is the confidence level ($\alpha = 0.95$); t_α is the value of the Laplace function (for $\alpha = 0.95$, $t_\alpha = 1.96$); σ_a is the variance of a specific parameter (the number of dump trucks in the queue, the number of dump truck trips, etc.); ε is the required accuracy ($\varepsilon = 0.05$ was assumed).

Model calibration and validation were performed using the GEH statistic (the Heavers criterion), whose value did not exceed 2.65 in 85% of the model runs when compared to dispatch data.

For example, according to data from the dispatch department, the number of dump trucks loaded by excavators was as follows: EKG-8U – 45 units, EKG-18M – 37 units, EKG-20 – 29 units, P&H-2800 – 116 units. After comparing the actual and averaged model data, it was concluded that the simulation model was implemented correctly, its operational logic corresponds to the specified requirements, and it is ready for use in real-world conditions.

The input data also included the number of times a queue of a given length occurred during a shift for each excavator, as shown in Fig. 11–14 (based on dispatching data).

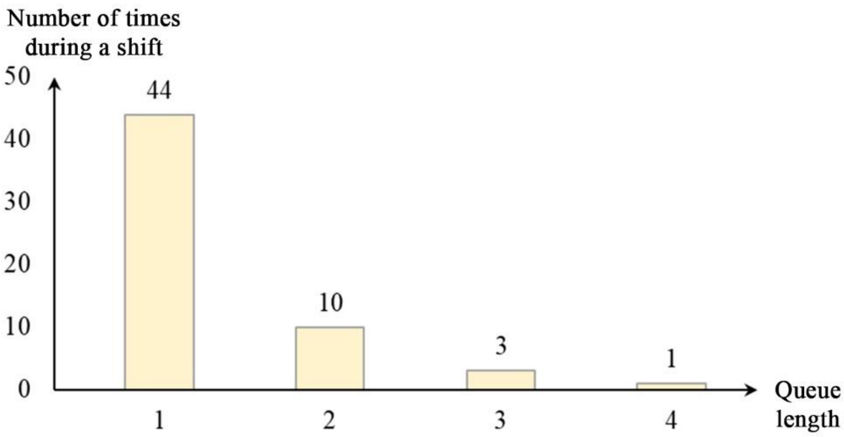

Fig. 11. The formation of a queue of a certain length for loading during a work shift for EKG-8U

Рис. 11. Возникновение очереди соответствующей длины в ожидании под погрузку в течение смены для ЭКГ-8У

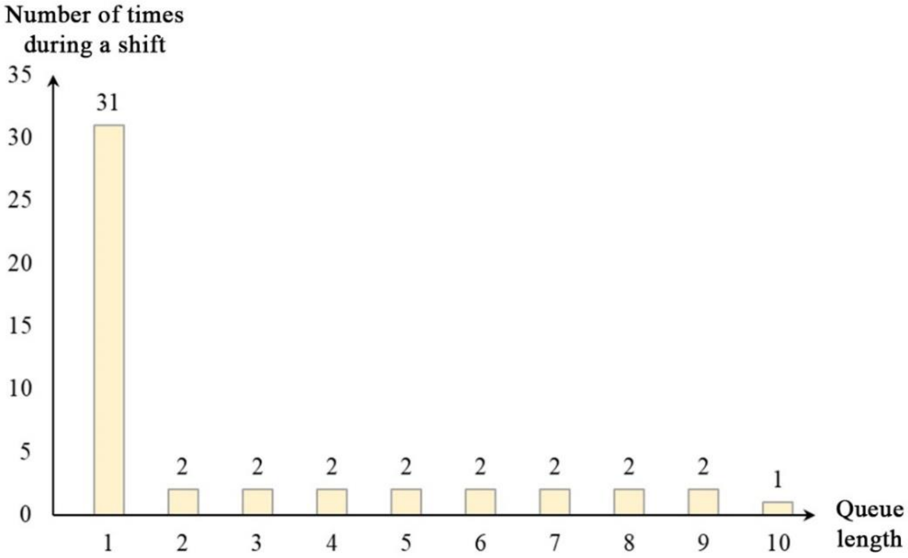

Fig. 12. The formation of a queue of a certain length for loading during a work shift for EKG-18M

Рис. 12. Возникновение очереди соответствующей длины в ожидании под погрузку в течение смены для ЭКГ-18М

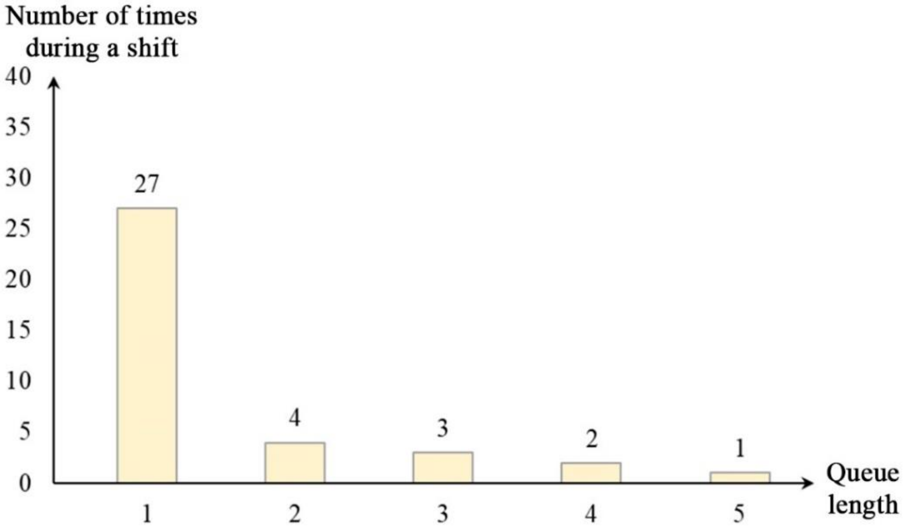

Fig. 13. The formation of a queue of a certain length for loading during a work shift for EKG-20

Рис. 13. Возникновение очереди соответствующей длины в ожидании под погрузку в течение смены для ЭКГ-20

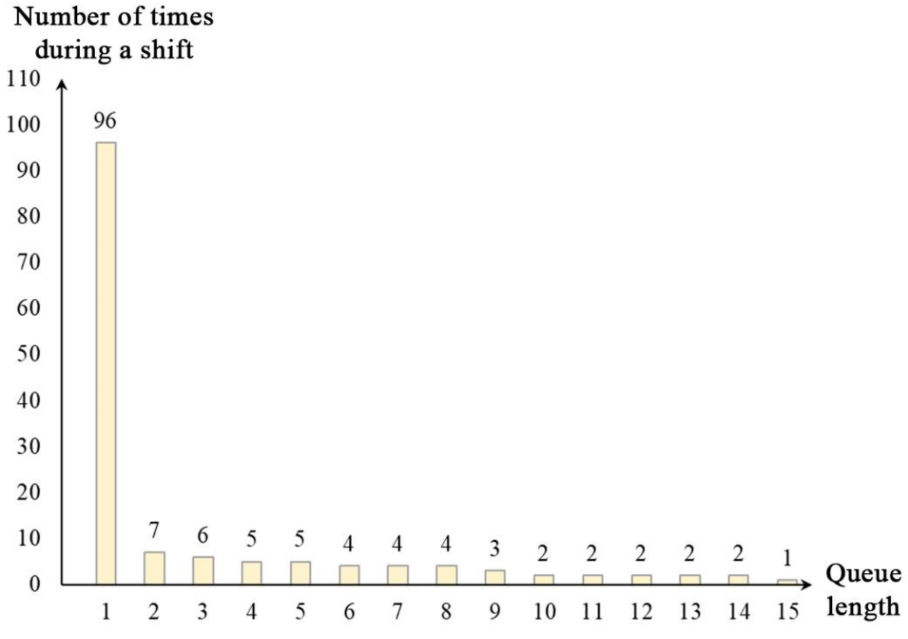

Fig. 14. The formation of a queue of a certain length for loading during a work shift for P&H-2800

Рис. 14. Возникновение очереди соответствующей длины в ожидании под погрузку в течение смены для P&H-2800

Based on the data from these graphs, "shortcomings" in equipment performance at the analyzed mining site were identified. By averaging the results of the equipment performance simulations at the site, the following values of the utilization coefficients K_u were obtained for the excavators used at the mining site: for the EKG-8U, K_u = 0.55; for the EKG-18M, K_u = 0.49; for the EKG-20, K_u = 0.40; for the P&H-2800, K_u = 0.49. Based on this, it can be seen that the mining site's excavation equipment is used unevenly, leading to underutilization of some excavators and their downtime (EKG-20) and the relative overloading of others (EKG-8U), which could operate with the same fleet of BELAZ-7513 dump trucks used with other excavators (EKG-18M).

The excavator utilization rate indicates how heavily the equipment is used and how efficiently its capacity is being utilized. Based on the graphs obtained (Fig. 8–10), measures were taken to organize operations at the mining site so that the load on the equipment would be evenly distributed. As a result, the utilization rates of the excavators were balanced, the number of dump trucks waiting in line for loading decreased, and the total number of dump trucks loaded per shift increased. These results were achieved by reassigning dump trucks from one excavator to another within the same mining site.

For example, one BELAZ-7513 dump truck was removed from the ETC based on the EKG-8U and reassigned to the EKG-20 (Fig. 15). Several similar reassignments were made involving other dump trucks and excavators.

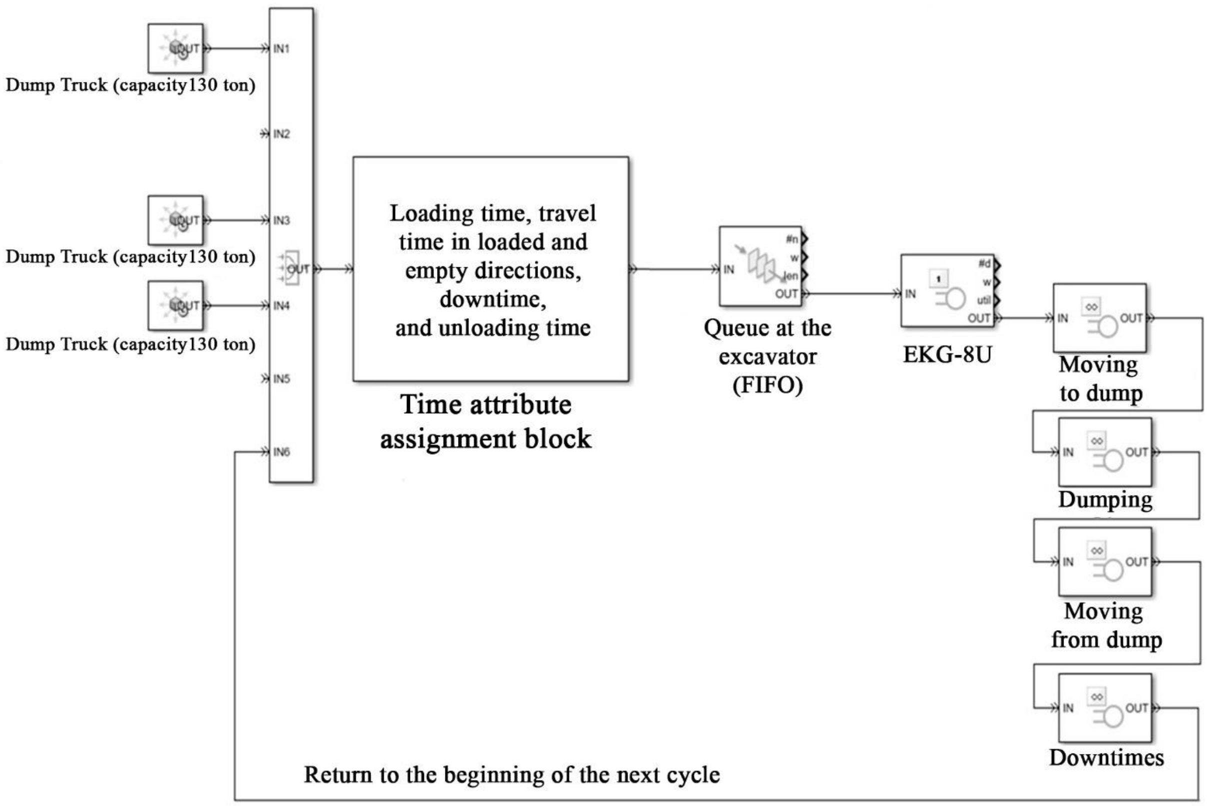

Fig. 15. A simplified simulation model of the operation of one of the excavators (EKG-8U) in the mining section after optimization
Рис. 15. Упрощенная имитационная модель работы одного из экскаваторов (ЭКГ-8У) горного участка после проведения оптимизации

After implementing optimization measures at the site, the following results were obtained: the utilization rate of the EKG-8U excavators used at the mining site was 0.46 (a 9% decrease); EKG-18M – 0.49 (no change); EKG-20 – 0.49 (an increase of 9%); P&H-2800 – 0.48 (a decrease of 1%), as shown in Fig. 16.

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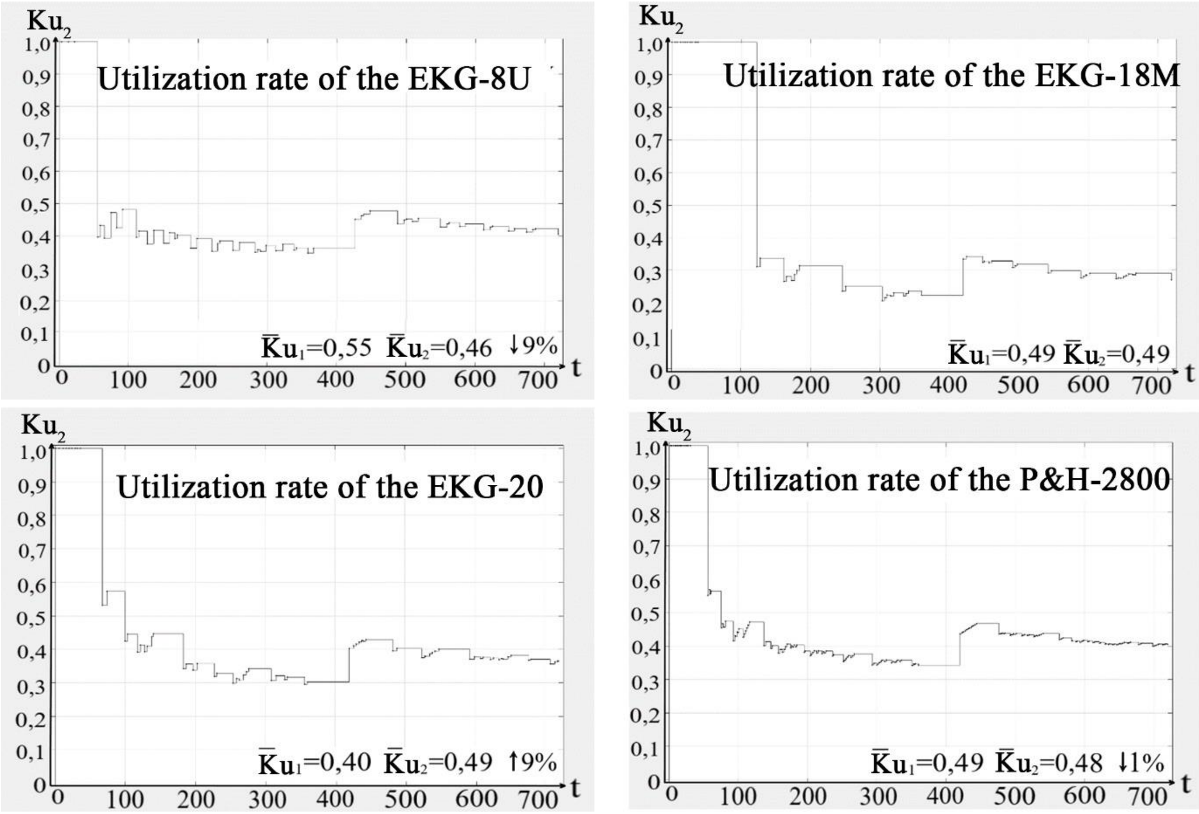

Fig. 16. Utilization rate Ku_2 of the EKG-8U, EKG-18M, EKG-20, and P&H-2800
($\overline{Ku}_1$ – currently median value, $\overline{Ku}_1$ – after optimization)
Рис. 16. Коэффициент использования ЭКГ-8У, ЭКГ-18М, ЭКГ-20 и P&H-2800 после проведения оптимизации

Despite a slight overall decrease in the excavator utilization rate at the site (by 1%), the current length of the queue waiting to be loaded also decreased (by 3 dump trucks across the entire site), and the total number of loaded dump trucks increased (by 5 across the site) during the shift (Fig. 17, 18).

The number of times a queue of a certain length occurred during a shift for each excavator also changed; the data (compared to the previous, non-optimized values) are shown in Fig. 19–22.

Conclusions

A comparative analysis of the initial data and the data obtained from simulation modeling shows that the efficiency of the equipment operating at the site improved following optimization. The following advantages of this simulation can be noted:

- The operation of all machinery at the mining site can be planned more evenly and rhythmically, resulting in less equipment wear and tear and more time available for additional operations (grading access roads, dismantling oversized loads, minor repairs, working with trainees, etc.);
- The number of dump trucks loaded by excavators during a shift can be increased by 6 units. Consequently, the site’s overall productivity will also increase;
- Reducing the “human factor” – specifically, by building a simulation model – will help avoid errors in equipment allocation on the site during dispatching operations and in the ongoing planning of the volumes of excavated rock to be shipped.

It will be possible to account for fluctuations in the distribution of dump truck loading times over short time intervals (shifts and days) by different excavators – that is, in operational short-term planning of mining operations – using the neural network solutions currently being developed by the authors.

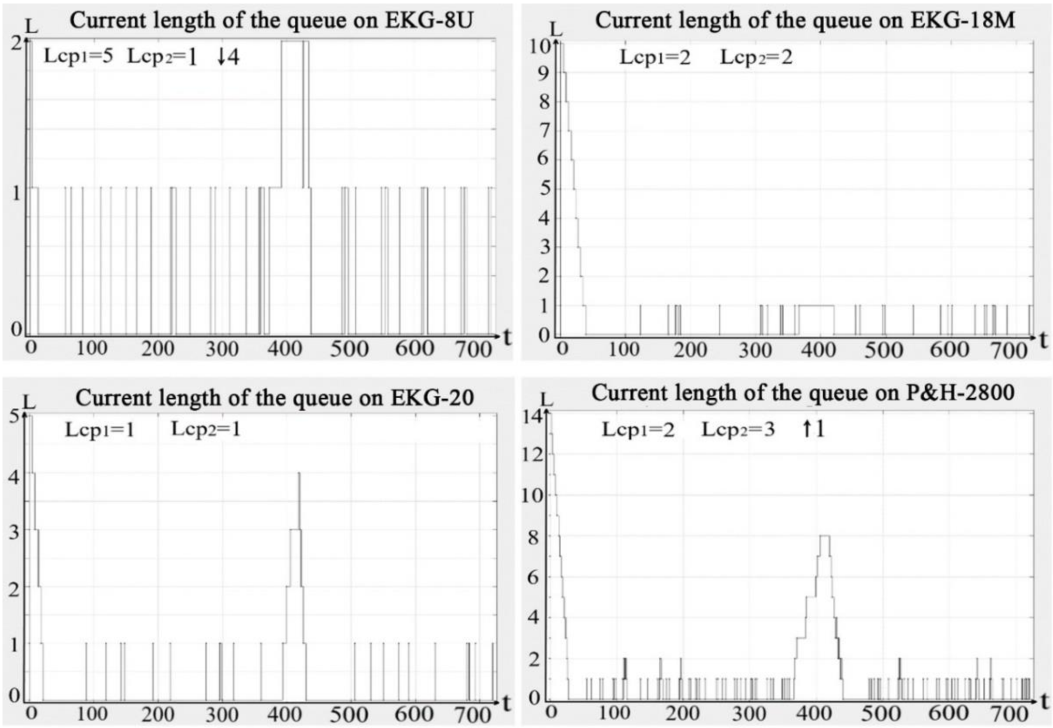

Fig. 17. Current length of the dump truck queue (L_1 – currently state, L_2 – after optimization)
Рис. 17. Текущая длина очереди автосамосвалов после проведения оптимизации

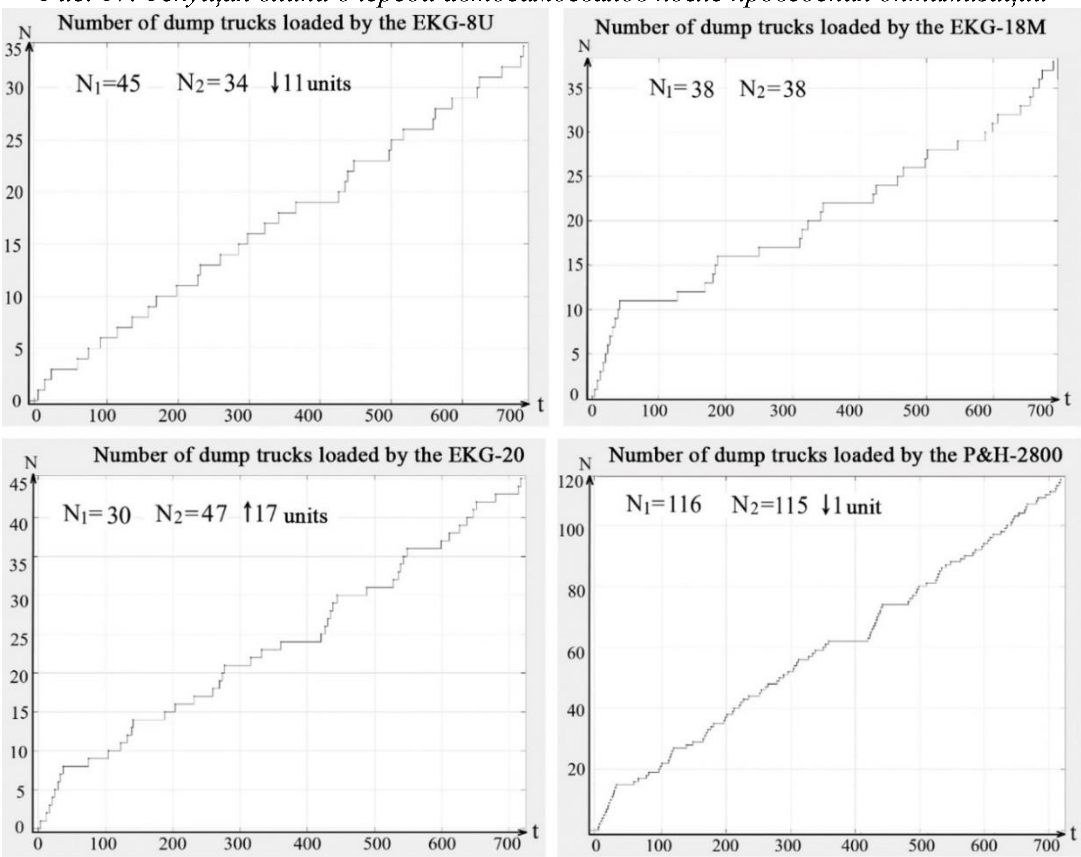

Fig. 18. Number of dump trucks loaded by the excavator during a work shift following optimization (N_1 – currently state, N_2 – after optimization)
Рис. 18. Число автосамосвалов, погруженных экскаватором в течение смены после проведения оптимизации

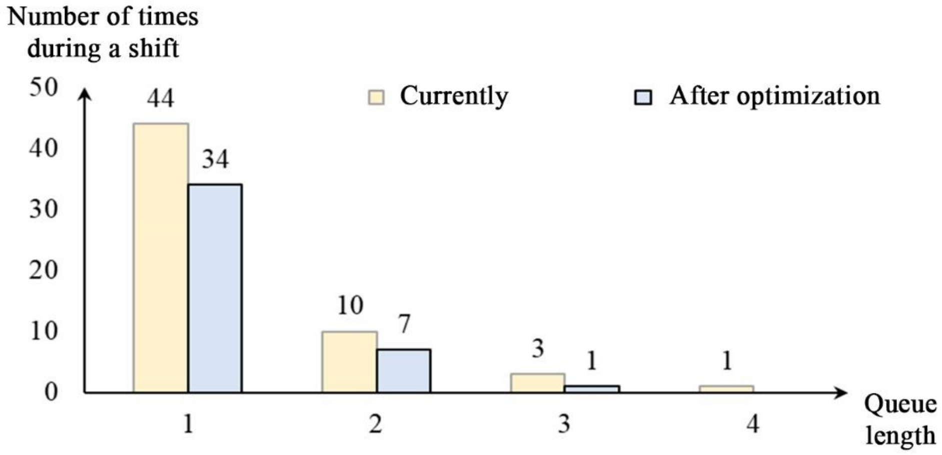

Fig. 19. Graph showing the relationship change between the number of queues and queue length during a work shift for the EKG-8U before and after optimization
Рис. 19. График зависимости числа возникновения очередей от длины очереди в течение смены для ЭКГ-8У

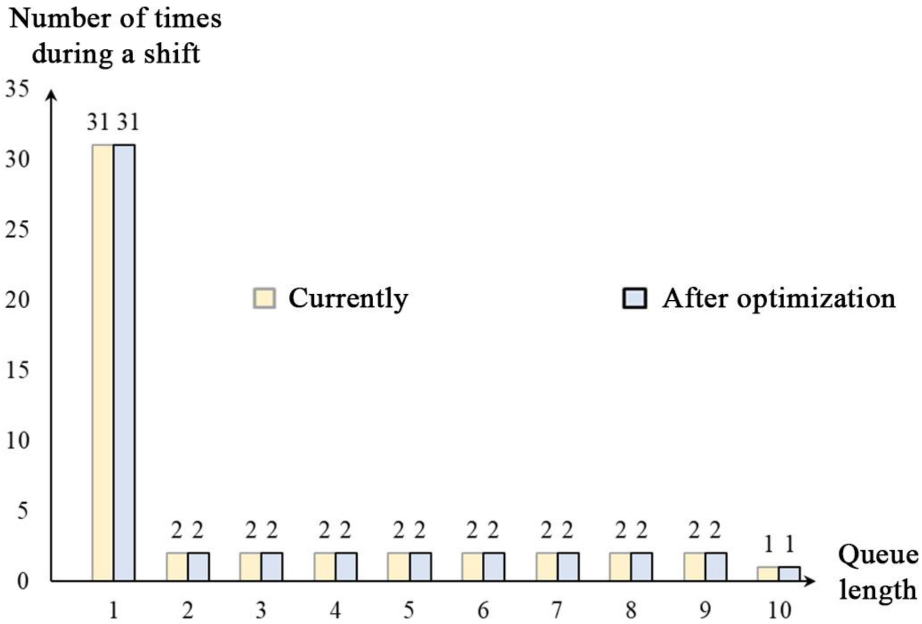

Fig. 20. Graph showing the relationship change between the number of queues and queue length during a work shift for the EKG-18M before and after optimization
Рис. 20. График зависимости числа возникновения очередей от длины очереди в течение смены для ЭКГ-18М

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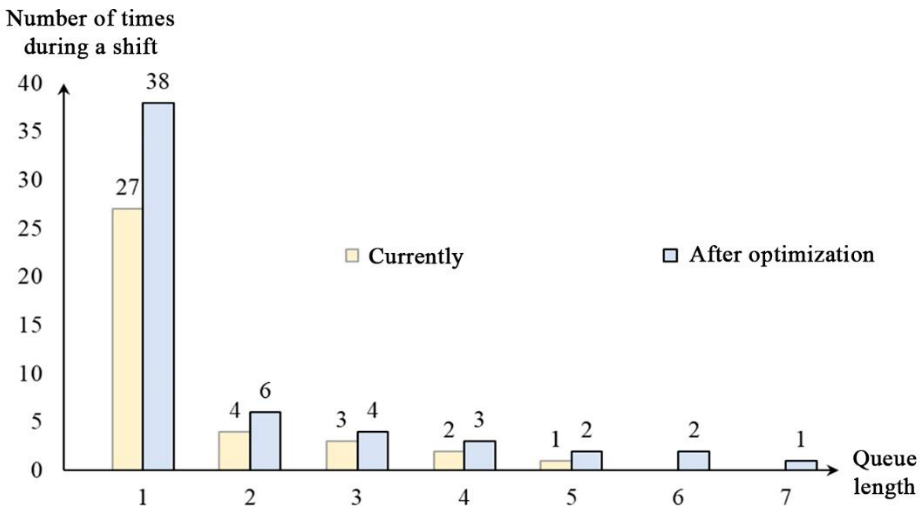

Fig. 21. Graph showing the relationship change between the number of queues and queue length during a work shift for the EKG-20 before and after optimization
Рис. 21. График зависимости длины очереди от числа раз ее возникновения в течение смены для ЭКГ-20

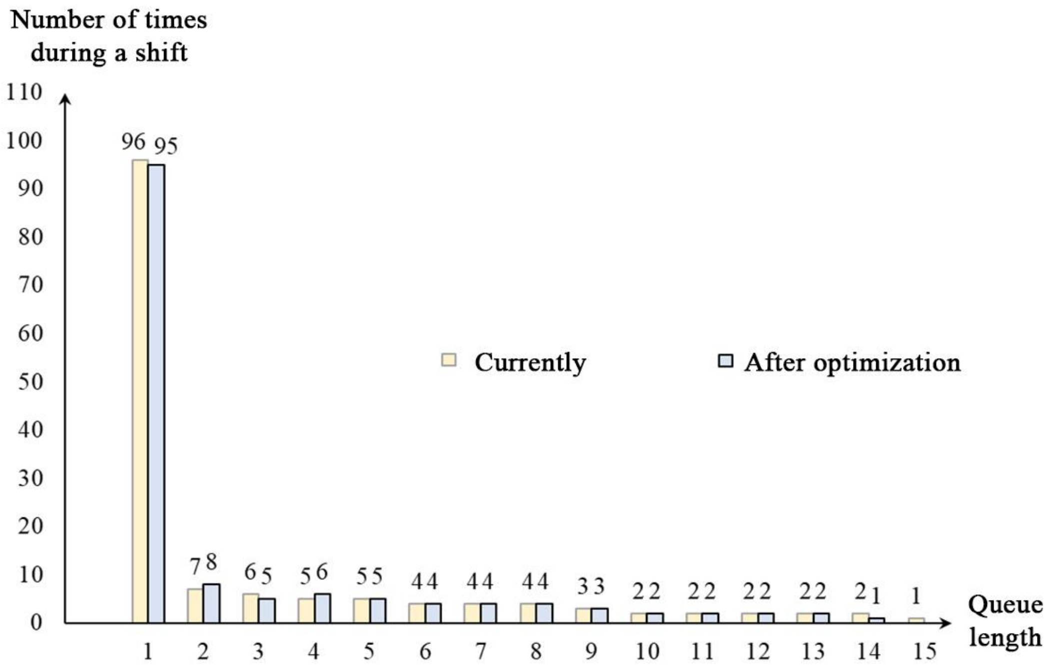

Fig. 22. Graph showing the relationship change between the number of queues and queue length during a work shift for the P&H-2800 before and after optimization
Рис. 22. График зависимости длины очереди от числа раз ее возникновения в течение смены для P&H-2800

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ВЫБОР РАЦИОНАЛЬНОГО СОСТАВА ЭКСКАВАТОРНО-АВТОМОБИЛЬНЫХ КОМПЛЕКСОВ ГОРНОГО УЧАСТКА БЕЗ ИЗМЕНЕНИЯ ОБЩЕГО КОЛИЧЕСТВА ТРАНСПОРТНЫХ ЕДИНИЦ

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Аннотация.
В статье рассмотрена актуальность оптимизации планирования выемочно-погрузочных и транспортных процессов на открытых горных работах с точки зрения повышения производительности и сокращения издержек. Показаны особенности распределения времени погрузки взорванной горной массы различными экскаваторами в условиях реального горнодобывающего предприятия. Выявленные законы плотности распределения времени учтены при имитационном моделировании экскаваторно-автомобильного комплекса (ЭАК) горного участка, состоящего из нескольких экскаваторов и соответствующего им парка автосамосвалов. Построенная имитационная модель работы участкового ЭАК проверена на адекватность и показала свою устойчивость при изменении входных параметров, а именно числа автосамосвалов, подаваемых под погрузку. Выявленные «узкие» места работы ЭАК (а именно неравномерность коэффициента использования экскаваторов, увеличенное время простоя, среднее число автосамосвалов в очереди под экскаватором) были снивелированы посредством использования построенной модели. Это позволило принять несколько управленческих решений: либо увеличить производительность участка по горной массе, либо выровнять нагрузку на экскаваторы без снижения имеющейся производительности участка, при этом без изменения исходного парка автосамосвалов. Предлагаемые решения также позволили выровнять общую нагрузку на парк автосамосвалов путем уменьшения средней длины очереди под экскаваторами.

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