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Development of decision- making mechanism in engineering design of phased coal mines technical upgrade

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Abstract. The approach to a choice of a new mine design and technical upgrade of operating coal mines is substantiated. The choice of the option is made in the following way: the elements of the mine technological system are defined, for each element of the system two levels of costs are allocated – capital and operational; a graph of alternative options of the system is formed by matrix enumeration taking into account the possibility of simultaneous application of different elements, up to 10 000 scenarios are formed; capital and operating costs of options are estimated in the form of coefficients as the cost-to-cost ratio in the base variant, which has already been implemented and the costs of which are already known; ranking of the options at the level of costs and the definition of the 10 preferred are performed. It is established that the application of partial enumeration allows the costs relative to the base variant to be reduced by 10 %; the main constraint of costs reduction is the need to comply with all conditions that ensure industrial safety.

1. Introduction

Technical and economic indicators of coal mines of Kuzbass are less stable in comparison with the corresponding performance of coal mines. The implementation of the underground coal mining technology requires, in comparison with the open development, with other equal external influences, a higher qualification of the personnel, significant investments in maintaining the design level of production and compensation of the probability of occurrence of hazardous industrial situations.

The main factors hampering the development of underground coal mining technology, including the reduction of costs of underground coal mining, can be divided into two groups: external, which are manifested by the impact of coal market, and internal natural and technogenic conditions [1 - 6].

The first group of factors should include the volatility of prices and volumes of coal sales in the coal market and the low competitiveness of coal products in comparison with oil and natural gas.

Internal complicating factors are:

- reduction in the volume of geological exploration and depletion of in-situ coal reserves favorable for the application of modern high-intensive technologies of underground coal mining;
- restriction of investments for the construction and technical re-equipment of coal mines with a full range of buildings, structures, machinery and equipment on the surface and underground;
- spatial variability of mining, geological and technological characteristics and parameters of the massif within the field and mining allotment, including those not identified during geological exploration and at the design stage;

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- "human factor", the influence of which is especially pronounced in underground conditions as a result of improper actions of employees performing technological processes and operations, use of technical means, implementation of incompetent control actions and other cases of abnormal behavior of personnel. The influence of "human factor" has been repeatedly pointed out in the investigation protocols of many accidents in coal mines, for example, [7, 8].

2. Methods of research and results

The operative step-by-step implementation of the project solutions is proposed to be carried out according to the following scheme: analysis of a specific market, mining-theological and mining-technical situation, the formation of an alternative and selection of a rational scenario for the technical re-equipment of a mine under construction or operation.

The general idea behind the choice of design solutions is as follows. After the development of the project documentation and its partial implementation, the author's audit and analysis of the specific situation and indicators of the enterprise under construction or the launch complex is carried out. As a tool for choosing the options for design solutions, the partial matrix enumeration method [9 - 12] is applied. If the design and actual indicators do not coincide, or if there is a need to improve the design parameters in the event of changes in internal or external conditions, scenarios for improving indicators and introducing new technological and organizational solutions in the real situation are developed.

The graph of technological system of an operating mine is shown in figure 1.

In the matrix (table 1), for each element of the mining technical system of the mine (STSM), two levels of costs are identified: capital for the construction or reconstruction of facilities and operational. Alternative options for each element of STSM are formed by experts. One of the options, as a rule, already implemented and the costs for which are known, is taken as the base one with indication of real costs. The costs of other alternatives are estimated as coefficients, as the cost ratio in the base case. In a matrix enumeration in accordance with the data from table 1, an additive convolution of coefficients for all elements is carried out. By comparing the coefficients for each element with respect to the costs of the basic options for the STSM element, the costs are accumulated [13 - 15].

Table 1. Elements of mine technical system of a mine for matrix enumeration of alternative variants.

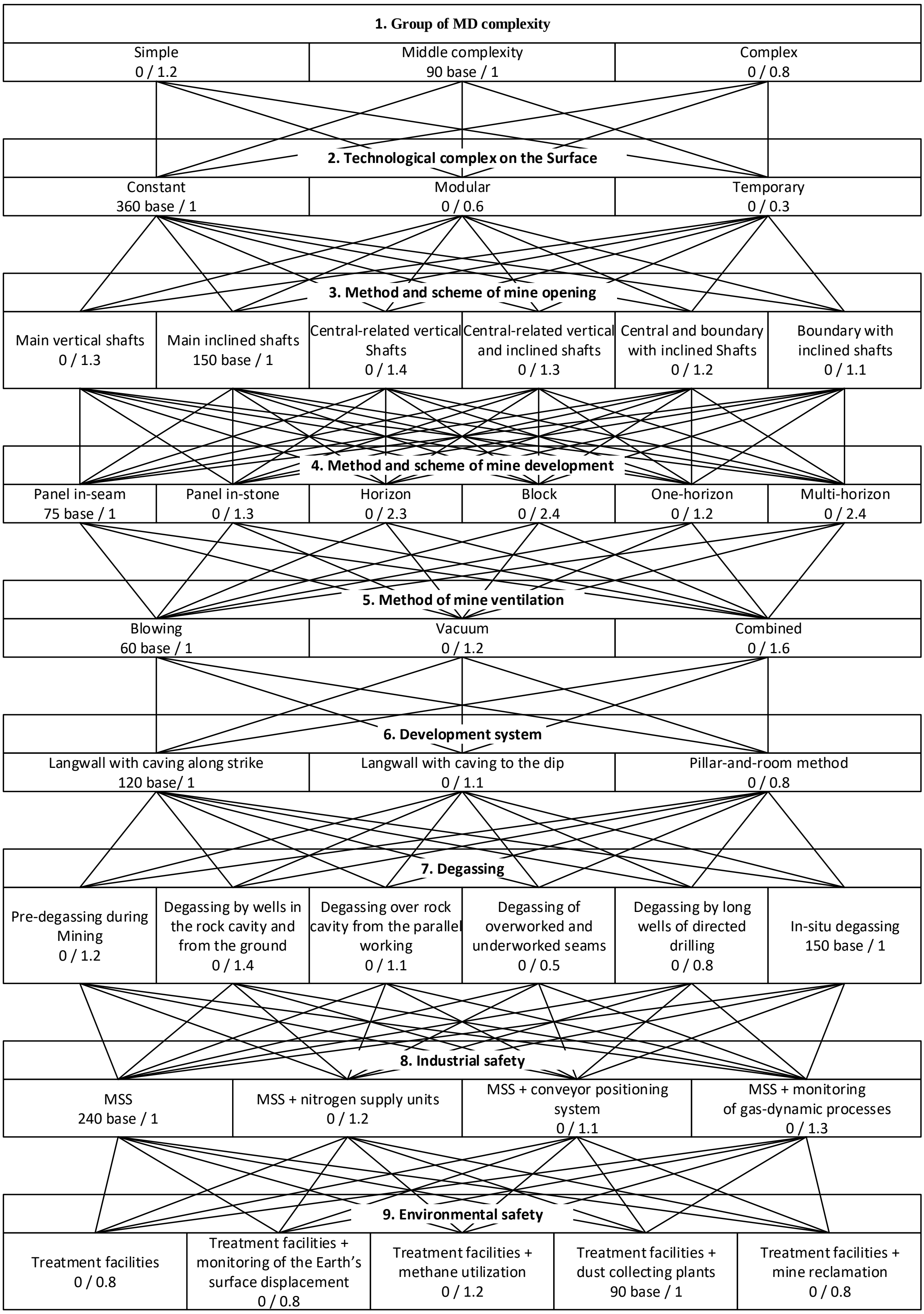
Level number on the graph	Name of STSM elements and cost elements	Numbers on the graph and the names of variants of STSM elements, costs					
		1	2	3	4	5	6
	Group of MD complexity	1st group, simple MD	2nd group, middle complexity MD	3rd group, complex MD			
1	Costs for license purchase, rub/t cost-to-base ratio	0/1.2	90 (base)/1	0/0.8			
	Costs for operational supplementary exploration, rub/t / cost-to-base ratio	0/0.8	75 (base)/1	0/1.25			
	Technological complex on the surface	constant	modular	temporary			
2	Construction costs, rub/t / cost-to-base ratio	360 (base) /1	0/0.6	0/0.3			
	Operating costs, rub/t / cost-to-base ratio	60 (base)/1	0/0.9	0/1.2			
3	Method and scheme of mine opening	main vertical shafts	main inclined shafts	central-related vertical shafts	central-related vertical and inclined shafts	central and boundary with inclined shafts	boundary with inclined

							shafts
	Construction costs, rub/t / cost-to-base ratio	0/1.3	150 (base)/1	/1.4	0/1.3	0/1.2	0/1.1
	Operating costs, rub/t / cost-to-base ratio	0/1.2	135 (base)/1	0/1.5	0/1.2	0/1.1	0/1.1
4	Method and scheme of mine development	panel in-seam	panel in-stone	horizon	block	one- horizon	multi-horizon
	Construction costs, rub/t / cost-to-base ratio	75 (base)/1	0/1.3	0/2.3	0/2.4	0/1.2	0/2.4
	Operating costs, rub/t / cost-to-base ratio	60 (base)/1	0/0.9	0/1.4	0/1.3	0/1.4	0/2.0
5	Method of mine ventilation	blowing	vacuum	combined			
	Construction costs, rub/t / cost-to-base ratio	60 (base)/1	0/1.2	0/1.6			
	Operating costs, rub/t / cost-to-base ratio	75 (base)/1	0/1	0/1.5			
6	Development system	langwall with caving along strike	langwall with caving to the dip	pillar-and-room method			
	Costs for preparation of working area, rub/t / cost-to-base ratio	120 (base)/1	0/1.1	0/0.8			
	Operating costs, rub/t / cost-to-base ratio	600 (base)/1	0/1.2	0/1.4			
7	Degassing	pre-degassing during mining	degassing by wells in the rock cavity and from the ground	degassing over rock cavity from the parallel working	degassing of overworked and underworked seams	degassing by long wells of directed drilling	in-situ degassing
	Construction costs, rub/t / cost-to-base ratio	0/1.2	0/1.4	0/1.1	0/0.5	0/0.8	150 (base)/1
	Operating costs, rub/t / cost-to-base ratio	0/1.1	0/0.8	0/1.1	0/0.3	0/0.9	90 (base)/1
8	Industrial safety	MSS	MSS + nitrogen supply units	MSS + conveyor positioning system	MSS + monitoring of gas-dynamic processes		
	Construction costs, rub/t / cost-to-base ratio	240 (base)/1	0/1.2	0/1.1	0/1.3		
	Operating costs, rub/t / cost-to-base ratio	150 (base)/1	0/1.1	0/1.2	0/1.2		
9	Environmental safety	treatment facilities	treatment facilities + monitoring of the Earth's surface displacement	treatment facilities + methane utilization	treatment facilities + dust collecting plants	treatment facilities + mine reclamation	
	Construction costs, rub/t / cost-to-base ratio	0/0.8	0/0.8	0/1.2	90 (base)/1	0/0.8	
	Operating costs, rub/t / cost-to-base ratio	0/0.7	0/1.1	0/0.7	150 (base)/1	0/1.4	

To select a rational design scenario using the data from table 1 by means of partial matrix enumeration up to 10 000 scenarios the ranking according to the level of production costs of 10 preferred variants is carried out, from which the decision maker selects the rational variant.

As it follows from table 2 and the graphs in figure 2 optimization of variants of technical re-equipment for the conditions shown in figure 2, allows the costs in relation to the base variant to be reduced by 8.5 %, and in relation to the most costly variant – by 47.6 %.

Table 2 shows fragments of total costs for one of the scenarios of technical re-equipment of "Erunakovskaya VIII" mine: the top line in each cell is a rational design variant; the middle line is the base variant, the bottom line is the most expensive variant. The histogram of costs distribution for these options is shown in figure 2.



*MD – mineral deposit; **MSS – multifunctioned safety system

Figure 1. Graph of alternative variants of the mine technological system.

Table 2. Costs of one of the scenarios of coal mine technical re-equipment.

Level number and name of STSM elements	Number of STSM element vertex on the graph	Sum of costs by STSM elements, rub/t		
		capital	operating	total
1. Group of MPI complexity	2	90.00	75.00	165.00
	2	90.00	75.00	165.00
	2	90.00	75.00	165.00
2. Technological complex on the surface	3	198.00	147.00	345.00
	1	450.00	135.00	585.00
	1	450.00	135.00	585.00
3. Method and scheme of deposit opening	6	363.00	295.50	658.50
	2	600.00	270.00	870.00
	3	660.00	337.50	997.50
4. Method and scheme of mine development	1	438.00	355.50	793.50
	1	675.00	330.00	1005.00
	4	840.00	415.50	1255.50
5. Method of mine ventilation	1	498.00	430.50	928.50
	1	735.00	405.00	1140.00
	3	936.00	528.00	1464.00
Development system	1	618.00	1030.50	1648.50
	1	855.00	1005.00	1860.00
	3	1032.00	1368.00	2400.00
7. Degassing	3	783.00	1129.50	1912.50
	6	1005.00	1095.00	2100.00
	6	1182.00	1458.00	2640.00
8. Industrial Safety	1	1123.00	1279.50	2330.50
	1	1245.00	1245.00	2490.00
	4	1494.00	1638.00	3132.00
9. Environmental Safety	3	1131.00	1384.50	2515.50
	4	1335.00	1395.00	2730.00
	5	1566.00	1848.00	3414.00

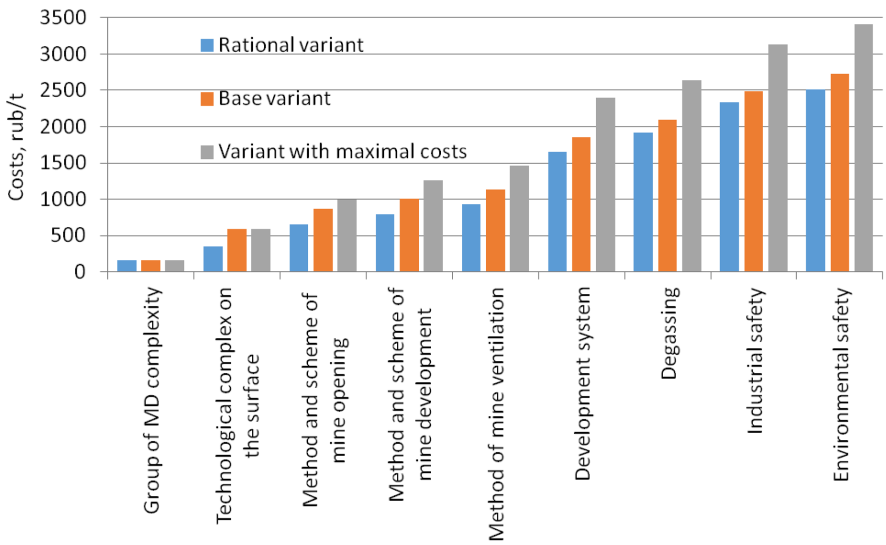


Figure 2. Costs distribution by elements of mining-engineering system of a mine.

3. Conclusions

A mechanism was developed for selecting project solutions of technical re-equipment of the existing mine, including a partial enumeration of alternative variants and selection of a rational scenario for the technical re-equipment of the mine in operation.

Based on the results of a search for new progressive design technological and technical solutions, it was established that there are reserves for exceeding the actual production as compared with the designed one. However, the excess of actual production compared to the design project is a violation of the requirements of Article 8, paragraph 2 of the Federal Law "On industrial safety of hazardous production facilities".

Taking into account the methodological possibilities of the phased design system, the correction of project documentation was performed. The implementation of new design solutions in this documentation ensured almost complete compliance of the project and actual volumes of coal mining, while meeting the requirements of the current regulatory documents.

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