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**ORIGINAL PAPER**

# MATHEMATICAL MODEL OF OPTIMIZING THE MANAGEMENT DECISIONS WHEN DETERMINING THE VOLUMES AND METHODS OF COAL MINING, PROCESSING AND TRANSPORTATION

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**Abstract.** In the context of digital transformation of coal industry enterprises, approaches to the organization of mining, processing and transportation of coal are changing, and the requirements for optimizing these processes are becoming relevant. The purpose of the study was to develop approaches to the formation of a mathematical model for determining the volumes of production, processing and transportation of coal, as well as the development of such a model for the coal mining company "Kolmar". The method for constructing a mathematical model is based on a resource model, which includes the main resource chains for the extraction, processing and production and logistics operations of coal products. A global criterion of optimality for the choice of the best solution to a management problem from the position of a top-level management system (supersystem) is proposed, while the criterion for assessing the optimality of a management decision of a company's top manager is the level of customer satisfaction with coal products. The optimality of the functioning of individual subsystems or coal mining enterprises belonging to a group of companies can be checked by a global criterion. The mathematical model of coal mining, processing and transportation for the coal mining company "Kolmar" is formed on the basis of constructing and solving a target function that minimizes the costs of these processes, in the context of limited economic, technological and technical factors, the volumes of coal mining, processing and transportation of coal to consumers. Cost minimization is ensured by the choice of the most rational controllable parameters, which are production technologies for each mining and processing plant and the volume of coal sent for processing. The use of the proposed mathematical model when planning the activities of the coal mining company "Kolmar" allows us to optimize resource flows, select effective technological schemes, form an optimal plan for loading equipment and transporting coal to the domestic and foreign markets.
**Keywords:** coal mining enterprises, cost optimization, logistics, mathematical model of optimization of decisions, mining and processing of coal

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**ОРИГИНАЛЬНАЯ СТАТЬЯ**

# МАТЕМАТИЧЕСКАЯ МОДЕЛЬ ОПТИМИЗАЦИИ УПРАВЛЕНЧЕСКИХ РЕШЕНИЙ ПРИ ОПРЕДЕЛЕНИИ ОБЪЕМОВ И СПОСОБОВ ДОБЫЧИ, ПЕРЕРАБОТКИ И ТРАНСПОРТИРОВКИ УГЛЯ

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**Аннотация.** В условиях цифровой трансформации предприятий угольной промышленности меняются подходы к организации добычи, переработки и транспортировки угля, актуальными становятся требования оптимизации этих процессов. Целью исследования явилась разработка подходов к формированию математической модели определения объемов добычи, переработки и транспортировки угля, а также разработка такой модели для угледобывающей компании «Колмар». Методика построения математической модели базируется на ресурсной модели, включающей в себя основные ресурсные цепочки по добыче, переработке и производственно-логистическим операциям угольной продукции. Предложен глобальный критерий оптимальности к выбору наилучшего решения управленческой задачи с позиции системы верхнего уровня управления (надсистемы), при этом критерием оценки оптимальности управленческого решения топ-менеджера компании является степень удовлетворения потребностей клиентов в угольной продукции. Оптимальность функционирования отдельных подсистем или входящих в группу компаний угледобывающих предприятий может проверяться по глобальному критерию. Математическая

модель добычи, переработки и транспортировки угля для угледобывающей компании «Колмар» сформирована на основе построения и решения целевой функции, минимизирующей затраты на эти процессы, в условиях ограниченных экономическими, технологическими и техническими факторами объемов добычи угля, его переработки и транспортировки потребителям. Минимизация расходов обеспечивается выбором наиболее рациональных управляемых параметров, которыми являются технологии добычи по каждому горно-обогатительному комбинату и объем угля, направляемый на переработку. Использование предложенной математической модели при планировании деятельности угледобывающей компании «Колмар» позволяет оптимизировать ресурсные потоки, выбрать эффективные технологические схемы, сформировать оптимальный план загрузки оборудования и транспортировки угля на внутренний и внешний рынки.
**Ключевые слова:** угледобывающие предприятия, оптимизация расходов, логистика, математическая модель оптимизации решений, добыча и переработка угля

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## Introduction

In the context of digital transformation of coal mining companies, methods of optimizing management decision-making based on mathematical models describing the processes of coal exploration, mining, processing and delivery to consumers have gained momentum. It ensures the sustainable operation of coal mining companies and improves the efficiency of their activities through new approaches to interaction between all participants of the industrial process of coal mining and processing and consumers of coal products. At the same time, "the processes of interaction of value-added chain participants are more integrative in nature due to the specific features of interconnection in the ecosystem built in a digital environment as the most effective form of the industry operation. The concept underlying the Industry 4.0 program directs collieries towards Digital Fields (DF) as adaptive digital systems selecting optimal coal mining, processing and transportation regimes" [1].

The generated mathematical models of coal exploration, mining, processing and transportation make it possible to evaluate cost-efficient mining patterns, coal processing methods and ways as well as logistics arrangements to transport or sell coal products [2].

The tasks of objective function-based optimization of transportation costs are well known and used in the arrangement of logistics operations [3].

Intelligent optimization methods, including genetic algorithm (GA), particle swarm optimization (PSO) and modified particle swarm optimization (MPSO), are known and used to optimize the coal mine project scheduling in China. The optimization result provides the information needed for management and decision-making by managers and developers. The optimization process involves activity chart-based optimization to the maximum NPV (Net Present Value). The commencement dates for all processes are variables for decision-making. The process order and time represent limits. The optimization result shows that MPSO is better than GA and PSO, and the optimized Net Present Value (NPV) is RMB 14974000 more than the initial plan [4].

Mathematical models of industrial processes make it possible to determine the optimal coal mining regimes by generating optimal drum design parameters and coal extraction kinematics using, for example, a genetic algorithm. The multi-objective model of coal mining optimization coupled with the real working conditions analysis and based on blade wear and careful consideration of coal loading speed, productivity, shearing area and specific energy consumption per shear has been developed [5].

At the same time, known mathematical models of coal mining company optimization use local optimization criteria, which give consideration to specific features of a particular coal producer and optimize by one parameter of an optimization criterion. A systemic and integrated approach to the problem solving requires that all major parameters of coal producer activities and not only company-specific, but also supersystem-wide interests, i.e., interests of the entire group of companies, region or state, be taken into account.

The effectiveness of multi-objective algorithms has been proven in the development of a multi-objective system dispatching model that includes economic cost, carbon emission costs to protect the environment and the degree of customer dissatisfaction with a reduced and progressive load. An improved evolutionary multi-objective algorithm that gives consideration to the limits of flexible load time series is further reviewed to efficiently obtain a set of multi-objective dispatching solutions. The said algorithm is applied to a coal mine with multiple scenarios, and the results show that such model is feasible and the algorithm-based evolutionary multi-objective dispatching is effective [6].

The study was performed to develop methodological approaches to creating a mathematical model for determining coal mining, processing and transportation volumes and methods based on global performance criteria and take into consideration specific features of Kolmar Group JSC operation. To do so, it is necessary to determine conceptual approaches to the formulation of global performance criteria for making optimal decisions, analyze possible options and identify company optimization criteria in view of specific features of activities and structure of Kolmar Group JSC. The study is focused on the measures Kolmar Group JSC takes to effectively arrange the work of its member enterprises engaged in coal products mining, processing and delivery to consumers.

The new approach to the use of production and technological resources of coal mining companies stems from the optimization of coal mining schemes, coal processing volumes and logistics operations arrangement, that allow to reduce the cost of mining and distribution of the mineral.

## Results and Discussion

A systematic and integrated approach to addressing the effective management challenges of the coal mining company "Kolmar" has been chosen as the basic principle of study in this paper. The task of choosing the optimal way to manage a company is solved by optimizing the objective function, which helps to choose a management decision that produces an extreme (maximum or minimum) value of one or more indicators.

In order to find an optimal decision, it is proposed to use not a local, but a global optimality criterion as a measure of quality of coal mining company management from the perspective of interests of the supersystem, the upper-level system of Kolmar Group JSC. In this context, the optimality of operation of all member enterprises of Kolmar Group JSC can be assessed against local criteria and verified by a global criterion [7].

A local criterion describes the optimality of system operation from the perspective of a single indicator. The cost of coal mining, processing and delivery to consumers can be used as criteria to assess the activities of member enterprises of Kolmar Group JSC. The mathematical model in this case is based on a resource model that includes major resource chains for coal products mining, processing and production, and logistics operations [8].

In general, three major economic indicators are used to select optimal management decisions: effect achieved (W), resource spend (C), and time (T); and one or any combination of these parameters can be chosen for each specific task. One of these indicators is then chosen as a criterion to assess management decision optimality and the other two act as limits.

Therefore, there are three types of problems in choosing optimal management decisions to manage coal products mining, processing and transportation to consumers (1-3):

1) $W \to \max$ with $C \leqslant Cout$, $T \leqslant Tset$ (1)
2) $C \to \min$ with $W \geqslant Wreq$, $T \leqslant Tset$ (2)
3) $T \to \min$ with $W \geqslant Wreq$, $C \leqslant Cout$ (3)

The criterion is usually as an objective function describing the optimality of achieving the goal and representing an economic and mathematical model. In this model, all three indicators (W, C, and T) are related to different factors effecting the criterion value and other indicators in the mathematical model. These factors are called control actions (control parameters). Selecting the right control actions makes it possible to achieve extreme value of the objective function and hence determine optimal management decisions.

Let us consider the mathematical model for optimizing coal mining, processing and transportation in the coal mining company "Kolmar" (*Fig. 1*).

The task determines the volume and methods of coal mining, processing and transportation for two mining and processing plants: Denisovsky MPP, JSC, and Inaglinsky MPP, JSC. The specific yield of processed products per run-of-mine coal unit of weight is assumed to be known for each of Denisovskaya, Inaglinskaya-1 and Inaglinskaya-2 coal-preparation plants.

Let us formulate the task in general terms. It is known that the coal mining company m (m = 2) of mining and processing plants (MPP), the output of which depends on each MPP's production and process capabilities (applicable mining technology, equipment capacity, the amount of coal reserves in the mine, etc.). The coal mined and not processed will be referred to as steam coal. A part of such coal is sent for processing to coal-preparation plants of the mining and processing plant. Specific yields of processed products from a steam coal unit volume are known. The cost of coal mining, processing and transportation from the mining and processing plant to consumers is known. All coal products of the coal mining company are distributed between consumers on the national and foreign (export) markets.

We will introduce the following designations to describe the mathematical model for coal mining, processing and transportation.

Input parameters:

- $i$ — number of the MPP, $i \subset I = \{1, 2, ..., m\}$;
- $t$ — number of extracted steam coal processing product, where $t = 1, 2, ..., T-1$;
- $T$ – steam coal;
- $f$ — number of the steam coal processing technology, where $f \subset F = \{1, 2, ..., F^*\}$;
- $r$ — number of coal marketing regions (national and export), $r \subset R = \{1, 2, ..., R^*\}$;
- $k$ — number of the selected coal production technology, $k \subset K = \{1, 2, ..., K^*\}$.

Quantitative indicators of MPP's performance can be presented as the following known values:

- $C_{iTk}$ — cost of coal production at the $i^{th}$ MPP that corresponds to production volume $B_{iTK}$;
- $P_{iTf}$ — cost of coal processing at a coal-preparation plant of the $i^{th}$ MPP with technology f;
- $Q_{itr}$ — cost of coal product transportation from the $i^{th}$ MPP to $r^{th}$ consumption area;
- $B_{tr}$ — demand for the $t^{th}$ steam coal processing product for r consumers, $r \subset R = \{1, 2, ..., R^*\}$;
- $B_{iTK}$ — volume of processing of coal with technology T mined by method K;

- $-\alpha_{itf}$ — yield of the t^th type of processed product at the coal-preparation plant of the i^th MPP with technology f.

Optimal parameters need to be chosen:

- $Z_{iTK}$ — share of using the k^th technology of coal production at the i^th MPP;
- $X_{jTf}$ — volume of processing product T at the coal-preparation plant with technology f at the i^th MPP;
- $X_{itr}$ — volume of coal product t sent to r^th region (national market or export) from the i^th MPP.

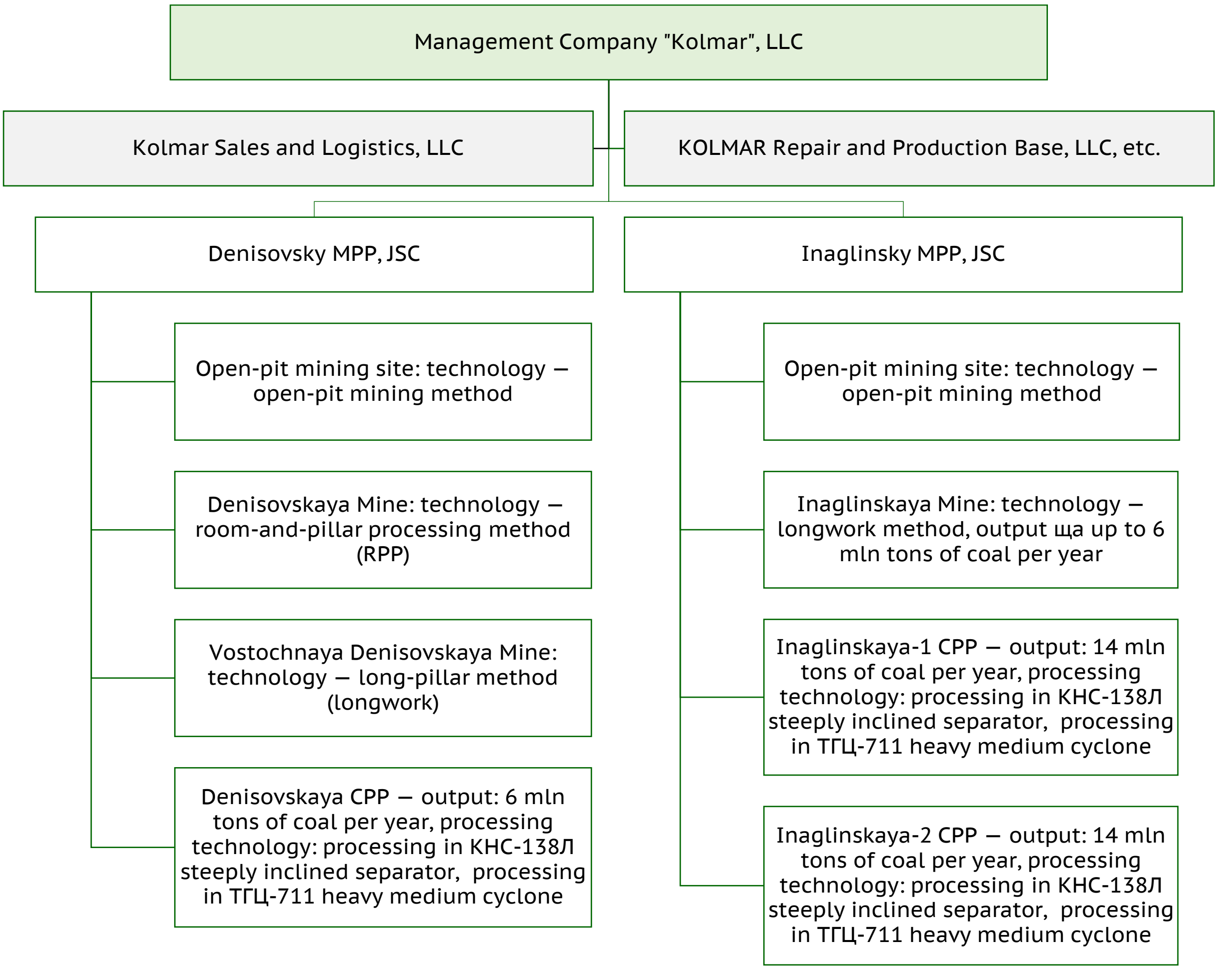


*Fig. 1.* **The Structure of the Management Company "Kolmar", LLC** / *Рис. 1.* **Структура ООО «Управляющая компания «Колмар»**

*Source:* constructed by the author based on data of the Management Company "Kolmar", LLC / *Источник:* построено автором по данным ООО «Управляющая компания «Колмар»

The mathematical model describing the processes of coal mining, processing and transportation in the form of an objective function (1), which is the minimum of the sum of expenses, will be as follows (4):

$$F(x,z) = \sum_i^I [\sum_k^K C_{iTK}\, Z_{iTK} + \sum_f^F P_{iTf}\, X_{iTf} + \sum_1^T \sum_r^R Q_{iTK}\, X_{iTr}] \rightarrow min, \quad (4)$$

under the following conditions (5-7):

$$\sum_k^K B_{iTK} Z_{iTK} = \sum_f^F X_{iTF} + \sum_r^R X_{iTr},\ i \subset I, \quad (5)$$

(condition (5) means that the volume of the coal produced with each mining technology is equal to the sum of the volume of the coal sent for processing and the volume of the coal sent to consumers without processing);

$$\sum_f^F \alpha_{tTf} = \sum_r^R X_{itr},\ i \subset I,\ t = 1, 2, ..., T\text{-}1, \quad (6)$$

(condition (6) means that the entire volume of the coal after its preparation at the plants with all technologies F will be sent to r consumers);

$$\sum_i^I X_{itr} = B_{tr} \quad (7)$$

(condition (7) means that the volume of run-of-mine coal and its products after preparation at the coal-preparation plants is equal to the total demand for the t^th processing product of all r consumers, no "work for storage" is expected);

$\sum_k^K z_{itk} = 1,\ i \subset I$ (the sum of proportions of coal produced with all technologies is equal to 1),

$X_{iTf} \geqslant 0,\ X_{iTr} \geqslant 0,\ i \subset I,\ f \subset F,\ r \subset R,$

$X_{itr} \geqslant 0,\ i \subset I,\ r \subset R,\ t = 1, 2, ..., T$

(the value of the volume of coal of all types sent to consumers is positive).

The results of solving this task will be as follows:

- the volumes of coal production by technology of production;
- the volumes of production of coal sent for processing to coal-preparation plants;
- the logistic scheme of coal products delivery to national and foreign markets according to the areas of influence of each MPP on regional markets.

Below is the calculation for the coal mining company "Kolmar".

The coal mining company "Kolmar" has two mining and processing plants: Denisovsky MPP, JSC (MPP 1) and Inaglinsky MPP, JSC (MPP 2).

Each enterprise can use three technological methods of coal production: open-pit mining, room-and-pillar processing and long-pillar method (k = 3).

When coal is prepared, the plants use a combined method of preparation: preparation in KHC-type counter-flow gravity separators and a heavy medium cyclone (f = 1), which results in three types of products (t = 3):

1) Concentrate;
2) Steam coal (middling);
3) Waste (mud concentrate).

We know: for each of the two MPPs (Denisovsky MPP — the first row, Inaglinsky MPP — the second row):

- we will write the volume of run-of-mine coal production (in thousand tons) by each of the three technologies as follows (8): the first column is for open-pit mining, the second column for room-and-pillar processing and the third column for long-pillar method (k = 1, 2, 3):

$$B_{iTK} = \begin{bmatrix} 2659 & 2600 & 0 \\ 880 & 0 & 1194 \end{bmatrix} \qquad (8)$$

$\alpha_{iTr}$ — the proportion of processed products yield (concentrate and steam coal (middling) and mud matrix row) at the coal-preparation plants of MPP 1 and MPP 2 from a unit weight of run-of-mine (mined, not processed) coal by a combined method of coal preparation as (9):

$$\alpha_{1tr} = \begin{bmatrix} 0.55 \\ 0.28 \\ 0.19 \end{bmatrix}, \quad \alpha_{21tr} = \begin{bmatrix} 0.54 \\ 0.29 \\ 0.18 \end{bmatrix} \qquad (9)$$

We know the following with respect to the national (the first column) and export (the second column) consumers:

- the volume of the national market and export demand for each product type: concentrate, steam coal (middling), waste (matrix rows) of coal processing (in thousand tons) as (10):

$$B_{tr} = \begin{bmatrix} 8 & 646 \\ 116 & 305 \\ 100 & 2 \end{bmatrix} \rightarrow \qquad (10)$$

- the volume of the national market and export demand for run-of-mine (unprocessed) coal in thousand tons as (11):

$$B_{Tr} = (1775 \quad 1721) \qquad (11)$$

Besides, for each MPP (matrix rows), we know the cost of run-of-mine coal production for each mining technology (columns) according to volume $B_{iTK}$ (RUB/t) as (12):

$$C_{iTK} = \begin{bmatrix} 2205 & 1155 & 347 \\ 1872 & 1155 & 607 \end{bmatrix} \qquad (12)$$

- the cost of run-of-mine coal processing at the coal-preparation plant of the i[th] MPP (matrix rows) with technology f (matrix column) (RUB/t) as (13):

$$P_{iTf} = \begin{bmatrix} 324 \\ 231 \end{bmatrix} \qquad (13)$$

- as well as the cost of transportation of a unit weight of run-of-mine coal and its derivative from each i[th] MPP (matrix rows) to the national market (the first column) and for export (the second column) (RUB/t) as (14):

$$Q_{itr} = \begin{bmatrix} 363 & 869 \\ 33 & 70 \end{bmatrix} \qquad (14)$$

We will assume that logistics costs are the same for all types of coal products.

With the data we know, the mathematical model of the task can be represented as the sum of expenses of MPP 1 and MPP 2 for coal mining, processing and transportation to customers as follows (15):

$$\begin{gathered} F(x,z) = 2205\, Z_{1T1} + 1155\, Z_{1T2} + 347 Z_{1T3} + \\ 1872\, Z_{2T1} + 0\, Z_{2T2} + 607\, Z_{2T3} + 324\, X_{1T1} + \\ 231\, X_{2T1} + 100\, X_{111} + 1000\, X_{112} + 100 X_{211} + \\ 1000 X_{212} + 100\, X_{121} + 1000\, X_{122} + 100 X_{221} + \\ 1000\, X_{222} + 100 X_{1T1} + 1000\, X_{1T2} + 100\, X_{2T1} + \\ 1000\, X_{2T2} \end{gathered} \qquad (15)$$

under the conditions stated below (16):

$$\begin{gathered} 2659\, Z_{1T1} + 2600\, Z_{1T2} \geq \sum_1^2 X_{1TF} + \sum_1^2 X_{1Tr} \\ 820\, Z_{2T1} + 1194\, Z_{2T3} \geq \sum_1^2 X_{2TF} + \sum_1^2 X_{2Tr} \\ 0.54\, X_{1T1} + 0.24\, X_{1T2} = \sum_1^2 X_{11r} \\ 0.28\, X_{1T1} + 0.15\, X_{1T2} = \sum_1^2 X_{12r} \\ 0.19\, X_{1T1} + 0.9\, X_{1T2} = \sum_1^2 X_{13r} \\ 0.54\, X_{2T1} + 0.24\, X_{2T2} = \sum_1^2 X_{21r} \\ 0.28\, X_{2T1} + 0.15\, X_{2T2} = \sum_1^2 X_{22r} \\ 0.19\, X_{2T1} + 0.9\, X_{2T2} = \sum_1^2 X_{23r} \\ \sum_{i=1}^2 X_{i11} = 8 \end{gathered} \qquad (16)$$

$$\sum_{i=1}^{2} X_{i12} = 646$$
$$\sum_{i=1}^{2} X_{i21} = 116$$
$$\sum_{i=1}^{2} X_{i22} = 305$$
$$\sum_{i=1}^{2} X_{i31} = 100$$
$$\sum_{i=1}^{2} X_{i32} = 2$$
$$\sum_{i=1}^{2} X_{iT1} = 1775$$
$$\sum_{i=1}^{2} X_{iT2} = 1721$$
$$\sum_{k=1}^{3} z_{1Tk} = 1$$
$$\sum_{k=1}^{3} z_{2Tk} = 1$$
$$\sum_{k=1}^{3} z_{3Tk} = 1$$

with the following conditions met (17):

$$X_{iTf} \geqslant 0, X_{iTr} \geqslant 0, \quad (17)$$

where i = 1, 2, r = 1, 2, t = 1, 2, T.

Today, mathematical modeling and tasks solving are increasingly based on digital platforms built in large holdings [9] and intelligent production management systems [10, 11].

Having solved the task by the known means [12], we can define the production technology for each MPP as follows (18):

$$Z_{iTK} = \{Z_{1T2} = 0.5;\ Z_{1T3} = 0.5;\ Z_{2T2} = 1\} \quad (18)$$

For the Denisovsky MPP, technology 2 (room-and-pillar processing) and technology 3 (long-pillar method) are most efficient. Technology 3 is preferable at Inaglinsky MPP.

The volume of steam coal sent for processing by each MPP is presented as follows (19):

$$X_{iTf} = \{X_{1T1} = 4390,\ X_{1T2} = 0,\ X_{2T1} = 0,\ X_{2T2} = 2223\} \quad (19)$$

The volume of processing (T = 1 – concentrate, T = 2 – steam coal, T = 3 – waste) supplied by the i$^{th}$ MPPs to the national market (r = 1) and for export (r = 20) is presented as follows (20):

$$X_{iTr} = \{X_{111} = 409,\ X_{112} = 2361,\ X_{121} = 700,\ X_{122} = 150,\ X_{131} = 0,\ X_{132} = 0,\ X_{211} = 283,\ X_{212} = 400,\ X_{221} = 700,\ X_{222} = 150,\ X_{231} = 0,\ X_{232} = 0\} \quad (20)$$

The calculations showed that in the end the total cost of coal products mining, processing and delivery to consumers F (x, z) is equal to 19844 mln unit cost.

The system-based mathematical model for the processes of coal mining, processing and delivery to consumers for the entire Kolmar Group JSC, and not for each MPP, makes it possible to calculate optimal cost-effective management decisions for the most efficient methods of steam coal production taking into account process capabilities of all enterprises of the coal mining company and the coal production technologies used. The calculations show that it makes sense to use two methods of coal production at Denisovsky MPP, JSC, and only the second (long-work) method for Inaglinsky MPP, JSC.

The second management task is related to the volumes of coal mining and processing. They depend on production and process capabilities of each MPP. According to the calculations, the minimum cost of coal production is equal to 3300 thousand conventional weight units for Denisovsky MPP, JSC, and 3511 thousand conventional weight units for Inaglinsky MPP, JSC. At the same time, Denisovsky MPP, JSC, sends 4390 thousand conventional weight units of steam coal for processing and Inaglinsky MPP, JSC, sends 223 thousand conventional weight units of extracted coal for processing.

The third management task is the determination of a cost-effective logistic scheme of coal products delivery to the national market and for export. In line with the multi-criteria approach, this task should be solved not only with an objective function for the minimum price (the so-called "transportation task"), but also for the maximum income received from the sale of products on the national and international markets. The calculations show that export of coal products is profitable for a coal mining company. The optimization of this task in view of the proposed approaches is planned to be reviewed in a separate study.

As can be seen from the above, the search for optimal management decisions of a coal mining company is based on digital models describing the processes of planning, current management of coal mining and processing in mathematical terms, which makes it possible to apply new approaches to the use of production and process resources available to coal mining companies. In this case, all such processes are interrelated and interdependent and form part of a certain so-called "ecosystem" of an enterprise, which represents the specific feature of coal mining companies in digital transformation settings [13].

The forming of a common information space and the rapid development of digital platforms constitute another major factor affecting the intensive development of mathematical modeling and mathematical optimization of management decision-making [14]. Such digital technologies make it possible to generate new economic benefits that improve resource efficiency of coal mining enterprises and form value-adding chains of coal products.

It is advisable to generate an effective coal mining company development model based on a resource model, which should comprise major resource chains, including coal mining, coal processing and the logistics system of transportation (sales). In such case the optimal scheme of coal mining enterprise operation can be defined in terms of resource flow optimization, building new resource allocation schemes and the optimization of production and logistics operations. This allows adjusting coal production volumes based on coal consumption forecasts and managing the resource value formation in a new way.

## Conclusion

The experience of digital modeling and search for optimal management decisions using mathematical models of coal products mining, processing and transportation to consumers has not been examined in sufficient detail and requires new methodical and practical approaches to its implementation. At the same time, now there are no doubts as to the efficiency of mathematical modeling in all sectors of the national economy. Modern digital systems make it possible to reduce company resource mismanagement, elaborate optimal plans for the use of available equipment in mines and reduce steam coal mining and preparation waste [15].

The purpose of the study has been achieved, because the article proposes a global optimality criterion for the best solution of the task from the perspective of a super-system, which is Kolmar Group JSC in its entirety, and produces a mathematical model for coal processing and transportation for this company, which helps to make optimal management decisions. The expenses of Kolmar Group JSC are minimized due to optimal technologies of coal mining for each mining and processing plant, coal mining and processing volume and efficient delivery to consumers.

Mathematical models of management decisions to optimize coal products mining, processing and transportation built as “digital twins” helps to develop a comprehensive “Digital Field” mathematical model, which ensures the efficient arrangement of production and use of production and process resources.

Future studies of coal products mining, processing and transportation optimization can be focused on the specification of global optimization criteria in view of specific features of particular coal mining companies and the use of digital platforms and the common information space of digital mines for making optimal management decisions.

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