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Methodological Approach to Substantiation of Capital Investments of Gold Fields Based on Unit Costs

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Issues of assessing capital expenditures for setting mineral deposits into operation are considered. Existing methods have a number of advantages and disadvantages, but they are determined separately for each type of fixed assets of the field. A simple method, that allows to quickly and easily determine the amount of capital costs for setting gold deposit into operation, based on data on ore reserves, as well as unit costs, taking into account the degree of infrastructure development at the deposit, is proposed.

Presented methodology allows one to determine the real amount of initial capital expenditures of a gold deposit, calculate their marginal (recommended) value, and also assess the balance of capital investments in the development of a particular deposit, taking into account the existing one in the company's investment portfolio.

The methodology is based on analysis of empirical material, which used real capital costs for development of gold deposits (and foreign-metal impurities) by Polymetal International plc. As a result of a statistical study, method for determining the marginal cost of a field is obtained.

Key words: assessment; capital expenditures; investments; field value; PLC Polymetal

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Introduction. Reliable estimate of capital investment amount directed to field development is of great importance. Firstly, value of the field will depend on the size of capital investments when it is estimated by income method. When implementation of projects is aimed at increasing value of the company, importance of this factor is undeniable, as evidenced by a significant number of publications aimed at improving methods for valuation of deposits [5-7].

Secondly, knowledge of capital investment amount allows investor to make an informed decision on feasibility of developing the field or on attracting outside investors (or even on sale of the field). The fact is that, despite expected high income from operation of the field, capital investments may be excessively high for an individual investor and will pose a threat to sustainability of his business [2, 11];

Thirdly, knowledge of the necessary amount of capital expenditures will help to avoid excessive investments in the field development and limit only those investments that are really necessary for its effective operation. This problem is very relevant for our country, where excessive investments in field development are not uncommon [3, 14, 15].

Formulation of the problem. Calculation of the amount of production investment in evaluation of deposits is carried out using specific indicators. The indicator of unit capital costs per unit is calculated by the formula

$$I_{un} = CC/TDO,$$

where CC – capital costs in monetary terms; TDO – technical data of the object in physical terms (volume of output, working area, production capacity, in relation to specifics of mining industry – mineral reserves in the field for operation of which object is being created).

If industry average value of the indicator of specific capital costs and estimated technical data of the created object are known, it is possible with an acceptable degree of accuracy to calculate capital costs of creating this object [4].

Capital costs can be calculated in two ways:

- using estimated prices on the basis of catalogs of estimated norms, costs and prices;

- based on empirical formulas; At the moment a significant number of empirical formulas have been developed for different types of minerals that describe the dependence of capital investments on various characteristics of the field [8, 13].

In practice, accurate and objective calculation of capital costs is achieved by combinations of these methods. The use of consolidated (aggregated) parameters 3-5 times reduces complexity of calculating capital investments. In addition, it allows to carry out calculations in the absence or incomplete readiness of project documentation, which is especially valuable at an early stage of project preparation.

The main methods for calculating capital investments using specific indicators are [12]:

- method for calculating basic elements of construction costs;
- Lang method – calculation of the object construction cost depending on the cost of technological equipment using transitional empirical coefficients;
- Hand method – calculation of object construction cost depending on the cost of technological equipment using transitional empirical coefficients differentiated by type of equipment;
- method of empirical dependence of enterprises construction cost on their production capacity;
- method for determining capital investments cost based on specific indicators of annual production capacity, measured in physical terms;
- method of calculating value through integrated structural groups of capital costs.

In the course of calculations, cost of constructing objects is divided into enlarged components by method of calculating them by type of construction work and structural elements. Costs of technical re-equipment of production, which do not require installation and commissioning, are determined on the basis of commercial offers of manufacturers or their sales representatives.

As a rule, value of specific indicator is set by analogy with existing deposits of a similar profile, however, in calculation process it can be adjusted up or down depending on the field.

As noted earlier [1], capital costs depend on a number of factors:

- difficulties in mining and geological conditions of the field;
- uncertainties of technological and technical development parameters;
- economic and geographical characteristics (remoteness of an object, availability of infrastructure).

Mining enterprises may also have other capital construction projects (trunks, canals, water conduits, bridges, dams). Composition and number of such facilities depends primarily on characteristics of development of a particular field [9]. Calculation of capital expenditures amount by types of fixed assets is based on the averaged data on unit capital expenditures.

As shown in [9], the main capital investments of a mining enterprise can be expressed by the formula

$$C = C_1 + C_2 + C_3 + C_4 + C_5, \quad (1)$$

where C_1 , C_2 and C_3 are capital investments for the construction of a mine (quarry), a processing factory and auxiliary facilities, respectively; C_4 – the cost of deposit liquidation; C_5 – capital investments in transport and energy communications (outside the mining allotment of the field).

Consider in detail each of the types of costs. The cost of constructing mining facilities – mine (quarry) C_1 is determined as multiplication of specific capital investments I_{unl} and annual production capacity of the mine Q_{mine} :

$$C_1 = I_{unl} Q_{mine}. \quad (2)$$

Specific cost indicator is established on the basis of deposits with similar mining and geological conditions. With an open-pit mining method (quarry), specific index I_{unl} is multiplied by mine productivity in rock mass, and in underground mining – by productivity in ore [9].

The cost of processing capacities of C_2 , for example, for concentrating or gold recovery factories, depends on the amount of ore entering the processing, as well as complexity of the technological scheme due to characteristics of ores [9]. In practice, specific capital investments for the creation of processing capacities are established by analogy with existing factories with a similar technological scheme [9]. The amount of capital costs is determined by the formula

$$C_2 = I_{un2} Q_{fac}, \quad (3)$$

where Q_{fac} is annual production capacity of the factory.

Alternative and more accurate way to calculate capital costs for creation of processing facilities, i.e. ore dressing or gold mining plants, is the Lang method. Its essence is to determine the cost of construction work as a percentage of the cost of equipment and materials (Table 1).

Table 1

Direct construction costs

Number in order	Equipment and materials	Cost of work related to the total cost of equipment and materials, %
1	Pipelines	50
2	Electricity of the net	20
3	Instrumentation	10
4	Metal structures	10
5	Materials for reinforced concrete work, taking into account materials and labor	5
6	Materials for architectural (other) works	5
Total amount		100

Note. Unforeseen expenses depend on the degree of project development and range from -5 to +25 % of direct construction costs

Capital investments in auxiliary facilities of the enterprise C_3 (energy, housing and communal services, storage facilities, transport, mechanical repair shops) make up from 10 to 20 % of cost from the sum of $C_1 + C_2$. In practice, costs for each object of auxiliary facilities are determined on the basis of analogous object with similar technical characteristics.

Capital investments for liquidation of the field and environmental measures C_4 include the costs of building demolition, dismantling and disposal of equipment, restoration of land and water resources, and environmental monitoring. As a rule, the size of capital investments is within 3-5 % of total cost $C_1 + C_2 + C_3$.

The amount $C_1 + C_2 + C_3 + C_4$ characterizes investments directly related to the field.

Capital investments in transport and energy communications K_5 are included in formula (1) to give it logical completeness, however, in practice, they are most often not taken into account in the total capital expenditures of a private investor for opening a deposit, since development of transport and energy infrastructure relates to state prerogatives. Adoption of appropriate costs by a private investor is possible in exceptional situations, but it can create undesirable risks for its economic sustainability (as shown by the example of Mechel, which created transport infrastructure for the development of the Elga deposit on its own).

Research Methodology. The above methods have a significant drawback, because they take into account capital costs for each type of fund separately and rely, as shown by formulas (2) and (3), on different types of unit costs and on different indicators of production capacities. To determine the amount of capital expenditures of a gold mining enterprise, one can apply a method based on the dependence of capital investments on reserves of the deposit. This approach is convenient in that it ties the size of investment in the field development to key characteristic of the field itself – its reserves. The method has received some distribution in scientific literature, in particular, on its basis, a relationship is established between the field value and its reserves [10].

Polymetal company used this method to calculate specific cost of developing several gold ore deposits (Table 2). The average specific indicator $I_{un.av}$ is equal to 1 million US dollars per ton of reserves. Thus, this indicator is a guideline when planning the amount of initial capital investments to launch a field in operation. Then capital expenditures for development of the field can be calculated by formula

$$C = I_{un.av} R, \quad (4)$$

where $I_{un.av}$ – specific capital costs for development of the field, $I_{un.av} = 1$ million dollars per ton; R – field reserves, tons.

Table 2

Polymetal specific capital investment ratio			
Deposit	Reserves, t	Capital investments, million dollars	Specific capital investments, million dollars per ton
Majskoe	151	205	1.36
Kubaka	55	55	1.00
Ol'cha	22	15	0.68
Sopka Kvarcevaya	43	42	0.98
Svetloe	34	51	1.50
Varvarinskoye	113	81	0.72
Kyzyl	349	320	0.92
The average	767	769	1.00

Deviation of I_{un} from $I_{un.av}$ at Mayskoye and Svetloye deposits can be explained by a considerable distance from the existing infrastructure. At the same time, the Varvinskoye and Kyzyl deposits, on the contrary, are in a more favorable position and have not only a connection to power system of the Republic of Kazakhstan, but also automobile and railway communications. Thus, inevitable deviations of actual values of specific capital expenditures from the standard value of \$ 1 million per ton that we've established have an objective reason for themselves. The data in Table 2 allows to adjust standard values of specific capital costs, taking into account real characteristics of the field (Table 3).

Table 3

Classification of deposits by specific cost		
Category	Specific capital investments, million dollars per ton	Type of deposits
1	0.7-1	Deposits of low capital intensity with accessible infrastructure
2	1-1.2	Deposits of medium capital intensity requiring investment in infrastructure
3	1.2-1.5	Deposits with high infrastructure costs
4	>1.5	Deposits with very high infrastructure costs, development decision of which requires additional justification

Based on the data in Table 3, one can calculate values of four correction coefficients A_i . For the fourth category of deposits, value of the coefficient A_4 is set normatively; for deposits of the first three categories, values are $A_1 = 1$, $A_2 = 1.2$ и $A_3 = 1.5$. They will make it possible to establish limit normative values of specific capital expenditures taking into account category of the field. For the fourth category of deposits, formula (1) must be used in its entirety, taking into account component C_5 .

Results. Based on the foregoing, the following condition for feasibility of developing the field can be introduced:

$$C_1 + C_2 + C_3 + C_4 \leq (1 \text{ mill dollars/t}) A_i R.$$

Finally, we can assess balance B of capital investments in development of deposits. For this, we suggest using the following formula:

$$B = \frac{\sum_{i=1}^n C_i I_{un.i}}{\sum_{i=1}^n I_i}, \quad (5)$$

where C_i is the capital cost of developing the i -th field; $I_{un.i}$ – actual unit (specific) costs for development of the i -th field; n is the number of fields in the company's investment portfolio.

Using formula (5), it is possible to determine the average value of specific capital costs, taking into account distribution of investments between different fields. Obviously, the value of B should tend to unity, i.e. to the normative value of specific capital costs. Deviations upward will indicate that company's investment portfolio is shifted towards deposits with higher specific capital costs, which may create additional risks for it. On the contrary, a downward shift suggests that company invests primarily in fields with low capital intensity.

If we apply formula (5) to Polymetal, i.e. substitute the values from Table 2 into it, then we will get $B = 1.06$, while the average value of specific capital costs for this company is equal, as was said above, to one. This means that investments in development of Polymetal's fields are shifted towards those with higher unit capital costs.

A limitation for our model is the fact that it was built on the basis of data from only one company. Perhaps attracting information about other enterprises will make it possible to correct the standard value of specific capital costs that we have proposed.

Conclusion. The presented model on the basis of unit costs makes it relatively easy to estimate initial capital investments in development of gold ore deposit, taking into account the degree of its infrastructure development. Based on the obtained formula (5), we can assess the balance of capital investments in development of a particular field, taking into account already existing in the company's portfolio.

We believe that this result will be useful for everyone involved in the development of feasibility studies.

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