Technical and economic assessment of existing and projected enterprises for the development of placer mines

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Abstract. The development of placer mines is a significant source of replenishment of Russian reserves with precious stones and precious metals. Currently, the development of placers is carried out in the vast territory of the Far East, Transbaikal, Eastern and Western Siberia, Altai, Ural. The efficiency of mining operations is significantly influenced by geological, mine engineering, climatic factors, the physical and mechanical properties of rocks, the physical state of placers (frozen, thawed), location (distance from settlements and communication routes), the percentage of clay material, etc. Based on these factors, the technical and economic indicators of the same-type mining machines (for example, drag diggers) often differ significantly (sometimes several times). In this regard, the method of complex technical and economic assessment of operating and projected mining enterprises for the development of placer mines has been developed. The method includes the evaluation of the mines according to the following technical and economic indicators. 1. Indicators characterizing operating conditions. 2. Indicators characterizing the potential of an enterprise. 3. Indicators characterizing the enterprise work results. Mathematical processing of all groups of factors in natural units of measurement is not possible due to the difference in units of measurement and a large amount of variation. Therefore, it is necessary to bring all the indicators in the appropriate form. These requirements coincide with the system of indexing (coding) of the source data, in compliance with the necessary principles. The article provides an example of coding. Further, the classification of the enterprises using the Euclidean metric is carried out. The proposed criteria are the basis for a comprehensive assessment of mines, as well as for obtaining linear regression techniques, a simple regulatory function that establishes the reciprocity between the calculated values of the economic results from the conditions and capabilities of the enterprises. The deviation of the calculated value from the actual value allows to judge how effectively (or not effectively) an enterprise operates under the appropriate conditions and opportunities. The article provides examples of determining the results of the activities of particular Transbaikal enterprises by this method.

Keywords: development of placers, assessment of the mines, groups of factors, Euclidean metric, criteria, regulatory function, deviation indices.

1. Introduction
One of the priorities of the mining industry is the extraction of precious stones and precious metals, a significant part of which is extracted with less labor inputs and at the lowest cost from placer mines. Development of placers is carried out in the vast territory of the Far East, Yakutia, Transbaikal, Eastern Siberia, Altai, Western Siberia and Ural.
A feature of currently developed mine fields is that most of them (80–90 %) are difficult to develop and the sands included in them are difficult to reach because of their location in geographic and climatic zones with severe climate, where perennial and deep seasonal permafrost is almost universally distributed (with the exception of the southern regions of Western Siberia, Altai and Ural). About 30–40 % of placers are characterized by a high content of clay and cemented material. In addition to deep-seated Lensky placers, today the similar mines have been explored in the Far East, Yakutia, Transbaikal and other areas, which for the most part have a relatively small capacity of the productive formation and a powerful thickness of dirt rocks (up to 50–70 m and more). All of it greatly complicates the development of placers, is the reason of low productivity, loss of valuable components, reduction of technical and economic performance in general. Most placer mines can be worked out by economical and highly productive dredge, as well as hydromechanized (bulldo-grain-scraper, excavator) methods.

Today the main gold mining areas have a sufficient amount of reserves of explored placer mines, which for a long period of time will retain its importance as a supplier of relatively cheap precious metal that does not require large capital expenses for extraction and enrichment, compared with the ore one. About 70–75 % of these mines (equal to the volume of rock mass) are suitable for the development of the dredge method, which is, as a rule, the most effective of the currently known methods for the development of placers. The prime cost of the metals production from the gold-bearing placers by the dredge method is 1.3–2.5 times lower than the competing hydromechanical method. Modern dredge fleet consists mainly of 80, 150, 250, 380-liter dredges.

The distribution of dredges (for a total scoops capacity) of the total amount is characterized by approximately the following: 50–80 L. (7.5 %); 150–180 L. (9.5 %); 210–250 L. (62 %); 380 h (21 %). The largest dredging fleet in terms of the number of dredges and the total capacity of buckets (over 20 %) develops the placers of Amur region. The dredging fleet of Transbaikal and the Far East for 76 % consists of 250-liter dredges. The duration of the washing season varies widely from 80–90 to 290 days, with the average duration of the dredge work of 180–190 days per year. It depends on many reasons: climatic conditions of the area; availability of sufficient amount of water, especially in spring and autumn periods; the degree of preparedness of landfills and the dredges for winter works; duration and quality of capital repairs, qualification of the dredge crews. Dredges usually start working in April or May finish working at the end of October or in November. Some dredges, when successfully solving issues of peat overburden, thawing and protection of landfills, water supply of the cut and repair works, start working at the beginning or in the middle of March up to the middle or the end December. Capital (winter) repairs pf dredges lasts from 1 to 4 months, begins in January-February and ends usually in April or May, sometimes in March or June. Seasonal performance of a single 250-gallon dredge is 200–500 thousand m³ thousand with the projected 750–800 m³ at the same time at landfills where overburden works, thawing and frost protection were carried out qualitatively, under the similar conditions, the dredges can wash up to 1.3–1.6 million m³ (dredges of Amur region, the Yenisei pool). [14]

As a result, the technical and economic performance of many of the same-type dredges at work, due to the above stated reasons, differ significantly (sometimes several times). Hydromechanized development of placers faces similar challenges. When projecting the development of placer mines for the same reasons, it is difficult to choose a development method, a mining technology, overburden and mining techniques and an enrichment method.

2. Study Relevance
Resulting from the above stated problems, the developing of a methodology for a comprehensive technical and economic assessment of existing and projected enterprises for the development of placer mines was set as the main task of the study. In addition, the possibility of applying a comprehensive assessment of mines was taken into account:

1. When setting the starting prices of mines at auctions. Currently, the starting price is determined on the basis of gold reserves and prevailing prices for it. This does not take into account But the factors that complicate the development of the field (such as distance from the station base, the presence of permafrost, peat capacity and a number of other factors) are not taken into account.
2. In determining the investment attractiveness of mines. A comprehensive assessment will reveal all the negative and positive factors of the development of a particular field in the search for a potential investor.

3. For facilitating the procedure of determining the size of the subsoil fee. Currently, the fixed intra-industry mining rent in the form of a tax on the extraction of minerals does not fully reflect the conditions of exploitation of mines.

4. To establish tax benefits for mining enterprises, especially when paying the land tax and other taxes.

5. When determining the performance of a mining enterprise in terms of its place among the enterprises of the industry, within the industry or within the region, from the national economic point of view, based on a comparison with the performance of other mining enterprises and primarily with the accumulated best practices.

Previously, the works of various authors were studied. Consideration of theoretical issues of subsoil value appraisal, in solving current problems of subsoil use management (determination of one-time starting payments during auctions (tenders), ranking of mines by degree of attractiveness), was based on the works of: B. I. Benevolsky [6], S. A. Emelyanova [12], A. Y. Katz [13], G. N. Kornev [15], N. K. Nikitina [22], E. A. Podturkina [24] and others. When considering the tax issues in the mining industry, the works of the following scientists were used: V. A. Kurushkin [16], G. S. Mirzakhanov [20], R. K. Sadykov [25], A. E. Cherepovitsyn [26], Y. I. Yukhimov [28] and others. Consideration of the issues of economic efficiency of mining enterprises was based on the fundamental scientific works of Russian scientists: M. I. Agoshkov [1], Arens V. Zh. [2], A. S. Astakhov [3,4], Y. P. Belov [5], J. K. Galiev [7,8,9], S. N. Goncharenko [10], F. D. Larichkin [17], V. K. Maximov [18, 19], Y. V. Mossakovsky [21], I. M. Shchadov [27], M. A. Yastrebinsky [29] and others.

For all the importance of research by these scientists, it should be noted that insufficient attention is paid to a comprehensive assessment of mineral mines, in particular, placer gold mines, which would take into account the constantly changing technical and economic conditions for their development and thereby allow to establish the level of efficiency of mining enterprises.

3. Statement of the Problem
The stated aspects of the lack of the problem development led to the setting of goals and objectives of the study on the development of a methodological approach to solving problems in the field of a comprehensive technical and economic assessment of placer gold mines and determining on this basis the effectiveness of their development.

The main objectives of the study are the following:
- to assess the current state of the theoretical foundations of a comprehensive technical and economic assessment of mineral mines;
- to clarify the specifics of open mining works and the nature of technical and economic indicators of mining enterprises;
- to determine the possibility of a comprehensive technical and economic assessment of the development of placer gold mines;
- to substantiate the mechanism of comparison of the initial quantitative and qualitative information of the developed placer gold mines;
- to develop and test the methods of complex technical and economic assessment of placer gold mines in the Transbaikal territory;
- to evaluate the effectiveness of the implementation of the methodology.

4. Theoretical part
The methodology provides for the evaluation of placer gold mines in the following groups of technical and economic indicators:
1. Indicators characterizing the operating conditions that include: 1) the distance to the nearest railway station (L \( r. \ s. \)), km; 2) the category of the road from the mines to the train station (CR); 3) the amount of sand mineral mines (Vsnd), thousand of m\(^3\); 4) volume of overburden (V overb.), thousand of m\(^3\); 5) the average power of peat (PP), m; 6) length of the placer (Lp), m; 7) the width of the placer (Wp), m; 8) coefficient of overburden (C overb.), m\(^3\)/m\(^3\); 9) the average power of the sand formation (PSF), m; 10) gold reserves (RAu), kg; 11) content (C), mg/m\(^3\); 12) damage by permafrost (Pf), %.

The most important factor characterizing the conditions is the price of minerals. Therefore, it is recommended to exclude it from the study because the impact of prices on the economic results of enterprises economic activity will be overwhelming.

2. Indicators characterizing the potential of an enterprise: 1) the capacity of the site for the extraction and washing of sand in one season (Qc), thousand/m\(^3\); 2) performance of the site for stripping peat in one season (Qst.p.), thousand m\(^3\); 3) specific capital investments (Kud), rub/m\(^3\); 4) floating assets (f.a.), rub; 5) coefficient of equipment deterioration (C eq.d.); 6) coefficient of equipment use (C eq.u.); 7) reserve ratio (r.r.).

3. Results indicators: 1) the cost of producing one gram of gold (P. c.), rub/gram; 2) a blank disc-kotirovalnyj income (NPV), RUB; 3) net present value (NPV), rub.

It should be noted that the belonging of some indicators to this or another group is not certain. And the selection of information does not imply the receipt of the only correct grouping. Another successful combination of indicators in each of these groups is not excluded.

The use of all groups of factors for mathematical processing in natural units is impossible because of the difference in units of measurement, a significant scope of variation. For example, the distance from the station base is measured in km, mineral reserves in thousand tons, the production capacity of an enterprise in thousand m\(^3\) / year, so the indicators are not comparable. This makes it necessary to bring all the parameters into a comparable form, so it is proposed to use the indexing system (coding) of the source data. The following principles must be observed here:

1. Indices (codes) must correspond to the intervals of statistical grouping carried out for indicators in natural units. Only in this case, the indices will reflect the true characteristics of an enterprise, as well as be used for the subsequent calculation of functional dependencies.

2. The need to comply with the direction of the indices involves coding in such a way that it reflects the qualitative characteristics of the studied parameter.

The principle underlying it assumes the assignment of code 1 to the enterprises in better conditions, with the deterioration of conditions, a code of 2, 3, 4, 5, etc. is assigned, and vice versa. For example, the distance from the station base varies from 1 to 500 km, the enterprises are grouped first with the division of the range into groups, then each group is assigned its own index. An example of indexing is shown in the table. 1 [23].

Table 1. The distance to the substation base in an (indexed) encoded form (developed by the author)

| Indicator Name                      | "from" | Distance, km  | "to" | Assignable Index (code) |
|-------------------------------------|--------|---------------|------|-------------------------|
| Distance to the Nearest Railway     | 0      | 50            | 100  | 1                       |
| Station (L r. s.)                   | 50     | 100           | 150  | 2                       |
|                                     | 100    | 150           | 200  | 3                       |
|                                     | 150    | 200           | 250  | 4                       |
|                                     | 200    | 250           | 300  | 5                       |
|                                     | 250    | 300           | and more | 6 |
|                                     | 300    | and more      | and more | 7 |

Classification of the enterprises is carried out using the Euclidean metrics [11].

\[
d(x_i, x_j) = \left[ \sum_{k=1}^{h} (x_{ki} - x_{kj})^2 \right]^{\frac{1}{2}},
\] (1)
where \( x_{ik} \) and \( x_{kj} \) – the quantitative values of an attribute for the \( i \) and \( j \) enterprises.

It should be noted that the Euclidean distance retains denotative meaning only when all parameters fluctuate in relatively equal ranges. To use the selected metric, it is necessary to normalize the quantitative values of all the features according to formulas 2 and 3.

\[
X_{HK} = \frac{X_K - X_{OK}}{S_K}
\]

(2)

\[
S_K = \left[ \sum_{i=1}^{m} \frac{(X_{ki} - X_{ok})^2}{m-1} \right]^{\frac{1}{2}}
\]

(3)

where \( X_{HK} \) – the normalized value; \( X_K \) – value of an attribute; \( X_{OK} \) – the sectoral value; \( S_K \) – the mean square deviation of an attribute; \( m \) – the number of compared mines.

The proposed criteria are the basis for a comprehensive assessment of mines, as well as for obtaining linear regression techniques, a simple regulatory function that establishes the reciprocity between the calculated value of economic results from the conditions and capabilities of an enterprise.

\[
F = f(Ry_i; Rp_i)
\]

(4)

Deviation (\( \Delta_1 \)) of the calculated value (\( F \)) from the actual one (\( Rp_i \)) allows to judge how effectively (not effectively) an enterprise works under the corresponding conditions and opportunities. The deviation is calculated by the following formula:

\[
(\Delta_1 = F - Rp_i)
\]

(5)

In the case of a deviation with a positive value, it can be judged that an enterprise is not working efficiently, does not use internal reserves and favorable operating conditions, in addition, the more the absolute value of the deviation is (\( \Delta_1 \)), the lower performance rates an enterprise gets.

A negative value of \( \Delta_1 \) indicates that an enterprise makes full use of its own capabilities and favorable operating conditions.

The deviation of the average intra-industry value from the actual value is calculated by the formula:

\[
\Delta_2 = Rp_{cp} - Rp_i
\]

(6)

where \( \Delta_2 \) – a deviation of the intra-industry value from the actual; \( Rp_{cp} \) – a comprehensive assessment of intra-industry average value of economic indicators (for a particular region).

The calculated value of the deviation index of the results of the \( i \) enterprise works (\( K_i \)) shows the deviation in fractions of the units of work results of the average intra-industry value:

\[
K_i = \frac{Rp_{cp}}{Rp_i}
\]

(7)

If the value of the deviation index is greater than one, it can be judged from the fact that an enterprise operates with indicators below the intra-industry ones, and vice versa.

5. Practical Significance, Implementation Results

A comprehensive technical and economic assessment of the efficiency results of the mining enterprises was carried out for 30 placer gold mines of the Transbaikal territory.

For example, during the developing of a placer of the Undra river \( K_i = 0,6 \), which means that the enterprise operates with the rates that are 40 % higher than the intra-industry rates, and during the developing of a placer of the Zurgun (\( K_i = 1,28 \)), the enterprise works with technical and economic indicators that are 28 % lower than the intra-industry rates. To simplify the analysis of the enterprise, it is advisable to rank for \( \Delta_1 \), \( \Delta_2 \), and rank the \( K_i \) calculation results in a table.
The developed method was tested: with a comprehensive technical and economic assessment of the placer gold mines Klyuch Talıy, in order to find a potential investor for the development of the mines; upon receipt of a bank loan when working out the placer of the river Shunduya; when proving the profitability, it was put into the category of the perspective ones, and the subsoil user received a license for its development. The calculations made it possible to justify the expediency of investing in the development of the Klyuch Talıy field. The deviation of the calculated values from the actual ones is \( \Delta_1 = -1.002 \), the deviation of the medium regional value from the actual ones \( \Delta_2 = -1.220 \) and the estimated index value of the deviation of the enterprise results is \( K_i = 0.64 \). Thus, it is possible to speak about good opportunities of the enterprise, favorable operating conditions and potentially high technical and economic results that are 22 % higher than the average in the region. At the cost of 215 rubles/gram and the 2008 price for gold of 310 rubles/gram, the net present value of the enterprise will be 4.8 million rubles. As a result, LLC "Aginskaya gold and industrial company" settled the receiving of the investment to $ 38 million in JSC "Sberbank".

The estimated indicators for mining and geological company LLC "Kazakovskoye" that develops a Shunduya placer: the deviation \( \Delta_1 = -0.656 \), the deviation \( \Delta_2 = -0.398 \) and the calculated index value of the deviation \( K_i = 0.81 \), it says that the enterprise has good reserves, but the calculated indicators are slightly worse than the industry average rates. At a cost equal to 274 rub/gram, NPV is 3.6 million rubles. On the basis of the calculations performed by the proposed technique JSC "Sberbank" has implemented lending LLC "Kazakovskoye" in the amount of 5 million.

Also, for the Nelinda placer gold mines that are still not developed, owned by the subsoil user of LLC "Raduga", the deviation of the calculated value from the actual \( \Delta_1 = -0.835 \), the deviation of the regional average from the actual \( \Delta_2 = -1.037 \), they indicate that its mining enterprise that develops it will have good reserves, and the results of its work will be 3.7 % higher than the regional average. With a prime cost of 974.3 rub/gram and a gold price in 2015 of 1700 rubles/gram, the net present value will be 36114 thousand rubles, a payback period will be 1.1 year, capital investments will amount to 52 341 thousand rubles, internal rate of return will be 37 %, index of return – 1.1 %. The negative factors are: the location of the mines is in the North of the Transbaikal territory, the lack of transport communications and infrastructure, a large capacity of permafrost. The starting price of the mines of placer gold "Nelinda" was 576 000 rubles. A comprehensive technical and economic assessment has put the mines in a number of promising and highly profitable ones. As a result, the subsoil user found it possible to raise the price of the mines to 12 038 000 rubles.

6. Conclusion

The introduction of the methodology in a number of placer mines of the Transbaikal territory confirmed its practical significance. The study has shown that it can be used to assess both existing and projected enterprises and to identify their investment attractiveness. The method of technical and economic assessment with some changes and additions to the initial data can be used in the development of other mines (ore, coal, etc.).

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