The Application of Digital Technologies in the Investment Analysis of Promising Deposits of Ore and Mineral Raw Materials of the Kola Peninsula

Asia Giliarova[a]
Mining Institute Kola Science Centre RAS, 184210, Fersman st.24, Apatity, Russia
a.giliariva@ksc.ru

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Abstract: The sustainable development of mining enterprises is currently constrained by a number of significant geological and mining restrictions. Overcoming the above limitations is possible, among other things, by involving promising ore deposits of the Kola Peninsula in economic turnover. The aim of the work was to modernize the investment assessment of promising ore deposits in terms of the use of digital technologies. The research methods adopted static and dynamic methods for determining investment attractiveness indicators, as well as digital technologies, parametric and scenario modeling. The paper modernizes the methodological approach to assessing the investment attractiveness of promising ore deposits, which, unlike those used earlier, both directly uses digital technologies and takes into account the effects of their application in mining. A distinctive feature of the proposed modernization of the assessment of the investment attractiveness of mining projects is the multivariate, parametric and scenario modeling of the initial parameters and influencing factors, which minimizes the influence of uncertainty and subjectivity factors. The investment assessment of promising deposits of the Kola Peninsula was carried out. Scenarios of involvement of investment-attractive deposits in economic turnover by types of mineral raw materials (titanium, rare earth elements, lithium, vanadium) are considered.

1 INTRODUCTION

The development of mining enterprises is currently constrained by a number of signifcant geological and mining restrictions: the most accessible ore mineral reserves have been mostly extracted; the quality of the mineral is declining; mining operations are carried out at deeper horizons; operating costs are rising; mining production is still quite conservative (digital technologies, automation of mechanisms and robotization of machinery and equipment are being introduced at enterprises slowly, with a signif-icant lag behind global trends) (Lukichev, 2021; Marklund, 2017; Gilyarova, 2020; Rylnikov et al, 2020).

Overcoming the above limitations is possible, among other things, by involving promising ore deposits in the western part of the Arctic, in particular, the Kola Peninsula, into the economic turnover (Lukichev et al, 2019; Churkin et al, 2017; Lukichev et al, 2022).

On the Kola Peninsula (Murmansk region) there are a large number of promising ore mineral deposits (Lukichev et al, 2019; Bortnikov et al, 2015; Kostjuchenko, 2017; Mashkovcev et al, 2019). The Murmansk region is a developed mining region, and the relative proximity of large mining enterprises plays a positive role when consider-ing potential mining investment projects. The activities of these enterprises are characterized by the active introduction of innovative developments and digital tech-nologies (Lukichev, 2021; Churkin et al, 2017).

The undoubted advantages of promising deposits, ore mineral raw materials of Murmansk include: reserves of more than 10 million tons (individual - up to 70-90 million tons) of high-quality minerals; relatively small distance (30-180 km) from large operating mining enterprises, as well as from railways and roads; available developments and scientific and technical substantiations of technologies for the extraction and processing of ores; intensively developed digital technologies for mining. The table

[a]https://orcid.org/0000-0002-9655-5486

shows geological and economic data on the most promising deposits of the Kola region.

Examples of the use of digital technologies at mining enterprises in the Murmansk region are described in (Lukichev, 2021; Gilyarova, 2020; Melnikov et al, 2017). They testify that this meets the requirements of industry digitalization, and, at the same time, allows you to automate operations, equipment and mining mechanisms used, and reduce operating costs in the development of ore deposits.

In view of the foregoing, the main goal of this study was to modernize the investment assessment of promising deposits of ore and mineral raw materials in the context of the use of digital technologies.

Table 1: Geological data on promising ore mineral deposits of the Kola region.

No	Deposit	Ore	Reserves, mln t	Valuable components
1	Kolmozerskoye	Pegmatites	>70	Li_2O; BeO, Ta_2O_5, Nb_2O_5
2	Polmostundrovskoe	Pegmatites	~30	Li_2O, BeO, Ta_2O_5, Nb_2O_5
3	Vasin-Mylk	Pegmatites	>10	Cs_2O, Li_2O, BeO, Ta_2O_5
4	Neske Vara	Carbonatites	>90	Ta_2O_5, Nb_2O_5
5	Saharyokoe	Yttrium-zirconium	~15	ZrO_2, Y_2O_3
6	Lovozerskoye (Alluive section)	Eudialyte	>70	ZrO_2, Y_2O_3
7	Sopcheozerskoe	Chromites	>10	Cr_2O_3
8	Afrikandskoe	Perovskite-titanomagnetite	>190	TiO_2, Fe,$(Nb,Ta)_2O_5$, TR_2O_3
9	Fedorovo-Panskaya tundra	Platinum group metals	>20	Pd, Pt,Au, Ni, Cu
10	South-Eastern Gremyakha	Ilmenite-titanomagnetie	>10	TiO_2 Fe
11	Tsaginskoe	Ilmenite-titanomagnetite	>50	Fe, TiO_2 , V_2O_3
12	Kolvitsky	Ilmenite-titanomagnetite	>90	Fe вал. TiO_2 V_2O_5
13	Sallanlatva	Vermiculite, Niobium	>70	Nb_2O_5

2 METHODS

The work uses static (in which cash receipts and payments arising at different points in time are evaluated as equivalent) and dynamic (based on the concept of discounting) methods for evaluating investment projects (International, 2020; Guide, 2014; Nunes et al, 2017; Behrens et al, 1991). Mining projects are characterized by high capital intensity and duration of implementation, so for them it is clearly necessary to take into account the time factor, since static methods will give incorrect results (Lukichev et al, 2022; Gilyarova, 2017). Therefore, in the investment assessment of promising ore mineral deposits, the main attention was paid to dynamic methods aimed at complex calculations: Net Present Value is Discounted (NPV_D); Internal Rate of Return is Discounted (IRR_D); Payback Period of Investments is Discounted (PBP_D); Profit-ability Index is Discounted, (PI_D). For these purposes, multivariate calculations were used.

Parametric modeling was used to assess the influence of the variability of geological and mining engineering factors. Scenario modeling was used to study the influence of external and internal factors.

For the analysis and interpretation of the results obtained, the following methods were used: information-analytical, system analysis, algorithmic, logical, analogy.

3 RESULTS

The methodological approach to assessing the investment attractiveness of promising ore deposits has been modernized, in which, unlike those previously used, both digital technologies are directly used and the effects of their use in mining are taken into account (Figure 1). A distinctive feature of the modernization of the investment attractiveness assessment proposed by us mining projects is multivariate, parametric and scenario modeling of initial parameters and influencing factors, which allows minimizing uncertainty and subjectivity factors.

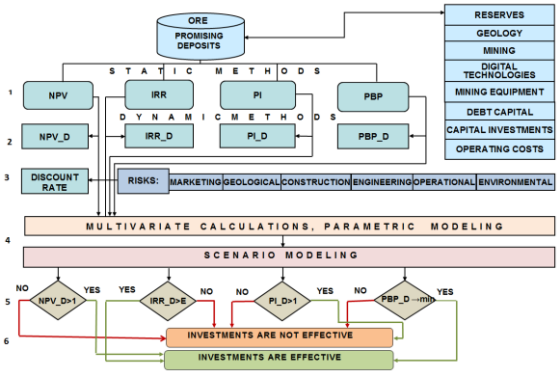

Figure 1: The proposed methodological approach to the investment assessment of promising ore mineral deposits.

To implement the methodical approach, an algorithm has been developed that includes the implementation of 6 main steps (indicated in Figure 1 by numbering):

1. A feasibility study of a mining project is carried out, the result of which is the calculation of Net Present Value (NPV), Internal Rate of Return (IRR), Profitability Index (PI) and Pay Back Period (PBP).

2. Multivariate calculations using the values of influencing parameters, factors and risks determine the discounted cash flows NPV_D, IRR_D, PI_D, PBP_D, characterizing the investment project under consideration throughout its entire life cycle.

3. An assessment is made of risks of various nature that affect the value of the discount rate.

4. Parametric and scenario modeling of the implementation of the mining project is being carried out. Here parametrization is understood as modeling with the use of mining and geological information systems ((Lukichev et al, 2022; Churkin et al, 2019) using numerical, geometric and variational parameters of the elements of a mining project, as well as the relation-ships between these parameters. Scenario modeling takes into account various market-forming and influencing external and internal factors.

5. The fulfillment of the logical conditions for the commercial efficiency of the project is checked: NPV_D>1, IRR_D>E, PI_D>1, PBP_D →min. It is proposed to accept that a promising field can be considered investment-attractive with the simultaneous achievement of all 4 conditions.

6. The resulting assessment of a promising deposit as a mining project is formed: investments are effective or investments are not effective.

Based on the proposed method, an investment assessment of 13 promising ore mineral deposits of ore mineral in the Murmansk region as mining projects was carried out. In our assessment of investment attractiveness, we do not include the Afrikandskoye and Fedorovo-Panskaya tundra deposits, for which positive investment decisions have already been made (Arkmineral Service Mining Company LLC and Fedorovo Resources JSC, respectively).

Nine deposits with investment attractiveness have been identified. For them, the payback period is from 4 to 8 years, and the discounted yield index is from 1.4 to 3. At the same time, it was determined that even taking into account digital technologies and robotic technology, investments for the Neske Vara and Sallanlatva fields will not pay off.

For the selected deposits, a classification was made and histograms were constructed according to PI_D and PBP_D by types of ore mineral raw materials (Figure 2).

To obtain titanium products, the Tsaginskoye, South-Eastern Gremyakha and Kolvitskoye deposits were identified (Figure 2a), which are ranked according to the Profitability Index: from 2.8 to 2.29. The payback period of investments will be 4.6, 5.2 and 6 years, respectively.

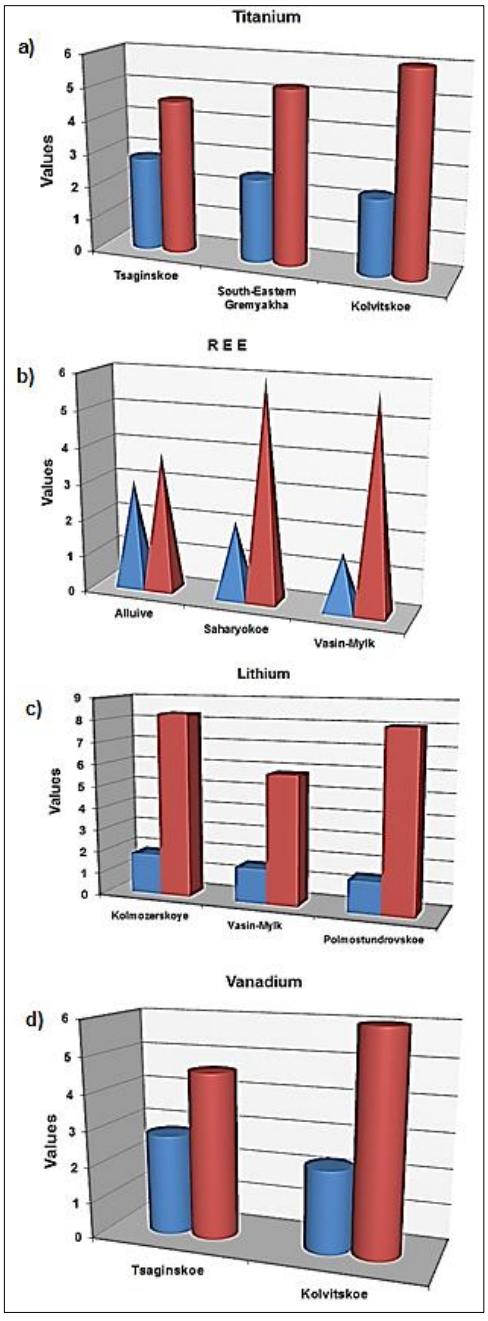

Figure 2: Investment-attractive promising deposits of the Murmansk region by types of ore minerals: a) Titanium, b) Rare Earth Elements (REE), c) Lithium, d) Vanadium.

For the development of mining enterprises in terms of rare earth production, it is advisable to consider scenarios for involving the Alluive, Sakharjokskoye, Vasin-Mylk deposits into commercial operation (Figure 2b). The payback period for investments in the development of these fields is projected to be up to 6 years with a profit-ability index of 3 to 1.5, respectively.

To obtain lithium-containing products, the Kolmozerskoe, VasinMylk, and Polmostundrovskoe deposits were identified (Figure 2c). IDI for them is estimated to be significantly higher than 1 with a payback period of investments up to 8 years.

For the production of vanadium, the Tsaginskoye and Kolvitskoye deposits have been identified (Figure 2d), for which the payback period of investments can be 5-6 years with a Profitability Index above 2.

4 RESULTS DISCUSSION

All selected promising deposits are multicomponent (the only exception is the Sopcheozero chromium deposit), which provides the opportunity for both mono and integrated development, in various combinations of recoverable useful components and the production of the corresponding commercial product.

A significant positive circumstance for the selected deposits is the relative proximity of existing mining and metallurgical enterprises.

The mining and geological advantages of these deposits include the proximity to the day surface of the mineral, which makes it possible to apply a more cost-effective open-pit mining method.

For the development of promising fields located in relatively remote but undeveloped territories, scenarios using modular equipment and a rotational method can be considered. Such scenarios are most applicable at the Vasin-Mylk, Sakharjok and other fields.

5 CONCLUSION

The modernization of the investment assessment of promising ore mineral deposits as mining projects has been completed, which allows, on the one hand, to take into account the potential of digital modeling of mining technology created in scientific institutes of the mining profile, and, on the other hand, to apply digital technologies in determining indicators of investment attractiveness. The proposed methodological approach is based on parametric and scenario modeling, which allows minimizing the influence of uncertainty factors and increasing the efficiency of assessing the investment attractiveness of promising ore deposits. An algorithm for the practical implementation of the investment evaluation of promising ore deposits is proposed.

Based on the proposed methodological approach, an integrated investment assessment of 13 promising fields in the Murmansk region was carried out, and nine of them were selected as the most investment-attractive. Scenarios are proposed for involving investment-attractive deposits into the economic turnover by types of ore minerals (Titanium, Rare Earth Elements, Lithium, Vanadium).

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