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ECONOMIC EVALUATION OF MINERAL EXTRACTION PROJECTS FROM FIELDS OF EXPLOITATION DURING OPERATIONAL PERIODS

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Abstract
The exploitation of minerals from fields of exploitation can be treated as a separate investment project. Three stages of such a project should be considered during the decision-making process, the preparation of a field for exploitation, the acquisition of raw materials and the liquidation of the field following mining activities. During the implementation of these various stages, the evaluation of the economic efficiency of static and dynamic methods are taken into account in each of the stages. An essential element is also the evaluation of risks connected with the investment, this is a quantitative measure of the uncertainty of achieving specific objectives. The bases for the correct calculation of economic efficiency include: proper input data, including economic and technological aspects. This article highlights the necessity of an economic evaluation concerning the exploitation of fields during operational periods due to their recognition in higher categories and the ever changing mining and economic conditions. Such changes are analysed with economic efficiency of exploitation systems. The initial value of the project takes into consideration the time value of money proposed as a criterion of economic evaluation. Income and expenditure, which correspond to the liquidity of the company, are assumed as a basis for calculation. Net present value is presented as a sum of values regarding preparation period, exploitation and field liquidation.

Key words
minerals; exploitation; extraction; project; economic evaluation; calculation

1. INTRODUCTION

The order of exploiting and classifying mineral resources (i.e. recognising whether they are industrial or nonindustrial) are described in the field development project (Article, 2001). During the operational period, i.e. during the period of deposit exploitation, natural conditions may change (e.g. through more precise diagnosis of deposits) and mining conditions (i.e. due to a change in exploitation orders), and economic circumstances, resulting from fluctuations in prices and costs.

As a result, the exploitation of every field during the operational period should be preceded by an economic evaluation. Field exploitation may be treated as a separate investment project which would to a large extent involve assets. Under this assumption, obtaining raw materials from a field can be analysed in a variety of exploitation systems, selecting the option which is most preferred. If there are no limits of mining and relevant data is available, some variables characterizing the field can be sometimes optimized, in particular, the size and the layer intended for exploitation.

Net present value (NPV) was proposed for the economic evaluation of field exploitation in the form of updated values from the period of preparing for the exploitation, operating at full capacity, and the liquidation period. NPV is proposed because the time factor (time value of money) must be taken into account during the evaluation of the calculation of cash inflow and expenditure (and not income and expenses) and used to correspond to the company's financial liquidity.

2. ALGORITHM OF ECONOMIC EVALUATION OF FIELD EXPLOITATION PROJECT

Economic efficiency regarding the exploitation of a field can be described by the formula (Wanielista 1995; Butra 2001)

$$NPV = NPV_r + NPV_e + NPV_l \tag{1}$$

where:

- NPV – net present value from the period of preparation, exploitation, and liquidation of the field in zloty (zł);
- NPV_r – net present value from the period required for the preparation of the field, zł;
- NPV_e – net present value from the period of the exploitation of the field, zł;
- NPV_l – net present value from the period of the liquidation of the field, zł.

Net present value from the period of the preparation of the field can be described by the formula

$$NPV_r = \sum_{t=0}^{T_r} \frac{NCF_{rt}}{(1+RADR)^t} \tag{2}$$

wherein

$$NCF_{rt} = CIF_{rt} - COF_{rt} \tag{3}$$

where:

- T_r – a period of field preparation for exploitation, years;
- NCF_{rt} – balance of flow of funds in the *t*-th year, zł;
- $RADR$ – discount rate of risk;
- CIF_{rt} – cash inflow in the *t*-th year zł/year;
- COF_{rt} – expenditure (not to be confused with expenses) in the *t*-th year, zł.

For mining projects which exploit raw materials, a subaccount for the intermediate product or raw materials can be used for the calculation of cash inflow and expenditure, and for rolling costs in relation to the final products. A selling formula is used in the first case, usually negotiated on an external or internal market. A general selling formula for minerals, of which the value does not depend on the contained useful raw materials, can be approximately derived from the profits equation

$$W_k(p_k - c_k) = W_f(p_f - c_f)r_z \tag{4}$$

where

$$p_k = \frac{W_f}{W_k}(p_f - c_f)r_z + c_k \tag{5}$$

or

$$p_k = \gamma_f(p_f - c_f)r_z + c_k \tag{6}$$

where:

- W_k – mineral extraction, Mg/year;
- W_f – final product from the extracted mineral, Mg/year;
- p_k – conventional price of extracted mineral, zł/Mg;
- p_f – market price of the final product, zł/Mg;
- c_k – mineral extraction costs, zł/Mg;
- c_f – rolling costs of producing the final product, zł/Mg;
- γ_f – the final product yield, Mg/Mg;
- r_z – coefficient determining the portion of the profit attributable to mining processes or mining companies ($r_z < 1$).

If the value of minerals depends on the contained useful raw materials, the approximate value of the minerals can be calculated from the formula

$$p_k = 0{,}01\alpha\varepsilon(p - c)r_z \tag{7}$$

where:

- α – content of useful ingredients in the mineral, %;
- ε – total yield of useful ingredient in the final process;
- pf – market price of the final product, zł/Mg;
- cf – rolling costs of producing the final product, zł/Mg.

Given the above, cash inflow during the preparation of the field for exploitation are determined by the formula

$$CIF_{rt} = W_{rt}p_k \tag{8}$$

where:

W_{rt} – mineral extraction in the period of field preparation for the exploitation in the *t*-th year, Mg/year.

Expenditure during the preparation of the field for exploitation in the *t*-th year can be represented by the formula

$$COF_{rt} = \sum_{i=1}^{n} IC_{rti} + \sum_{j=1}^{m} WC_{rtj} + CO_{rt} + v_{rt}W_{rt} + (F_{kt} - DEP_{kt})\frac{W_{rt}}{W_{kt}} \tag{9}$$

where:

- n – fixed assets involved in exploitation, pc.;
- IC_{rti} – the price of fixed assets including expenditure on their transport and installation in the exploitation field in the *t*-th year, zł/j.n. (lm., pc.);
- WC_{rtj} – price of the *j*-th current asset (or groups of assets) and the expenditure required for the transportation and eventual installation in the exploitation field in the *t*-th year, zł/j.n.;
- CO_{rt} – other operating expenses to prepare the field for exploitation not included in the expenditure for the purchase of fixed assets and current assets, zł/year;
- v_{rt} – unit variable costs regarding the extraction of ore in the period of preparing a field for exploitation and its possible throughput in the processes not connected with mining, zł/j.n.;
- W_{kt} – total mineral extraction in the *t*-th year, Mg/year;
- F_{kt} – standing costs of the mineral extraction in *t*-th year, zł/year;
- DEP_{kt} – depreciation costs of fixed assets in the *t*-th year, zł/year.

The discount rate can be represented by the formula

$$RADR = WACC + PR \tag{10}$$

where:

- $RADR$ – discount rate of risk;
- $WACC$ – the weighted average cost of capital;
- PR – risk premium.

Net present value from the period of the exploitation of a field can be described by the formula

$$NPV_e = \sum_{t=T_r+1}^{T_e} \frac{NCF_{et}}{(1+RADR)^t} \tag{11}$$

where

$$NCF_{et} = CIF_{et} - COF_{et} \tag{12}$$

where:

- T_e – a period of field exploitation, years;
- CF_{et} – balance of the flow of funds in the *t*-th year, in the period of field exploitation zł/year;
- CIF_{et} – cash inflow in the t-th year from the field exploitation, zł/year;
- COF_{et} – expenditure in the *t*-th year from the field exploitation, zł/year.