ON THE CALCULATION OF THE SUCCESS RATE IN MINING

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Abstract: *Mankind has always relied on resources. The mineral resources represent an important part of the resources required by the society. But mining has its own specificities, not only from technical point of view, but from economic point of view, tool. Therefore, we consider that calculating the success rate is on special significance in the context of exploiting natural resources.*
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KEY WORDS: *success rate, "bonitaet", raw materials, output efficiency, cost rate.*

JEL CLASSIFICATION: *Q30.*

1. GENERAL COMMENTS ON THE SPECIFICITY OF MINING

Mining concerns the primary sector of the economy, just like agriculture, silviculture and fishing. The mission of this domain is the primary production of raw materials and food, based on the factors of production nature, labour and capital; this feature is causing a slightly different approach compared to other production units.

The natural mineral deposits represent concentrations of mineral raw materials located in the Earth's crust, containing substances necessary for the society (usage value), possible to be exploited and successfully used from economic point of view (economically exploitable).

The most important criteria for the determination of the availability of certain located reserves are (Slaby & Wilke, 2005):

- geological conditions and substance contained
- technical and technological conditions
- economic conditions
- ecological conditions
- political and legal conditions

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The economic conditions mean that the deposit must comply the conditions of profitability, i.e. the exploitation and the subsequent processing of the raw materials must be possible under economic conditions. The economic objectives of the company (e.g. maximum allowable costs, minimum allowable effectiveness etc) are accompanied by regional economic criteria (e.g. the influence of mining on the development of the region and, if applicable, requirements of land use that are in contradiction with mining) and by criteria of political economics (e.g. the assurance of of supply, economic frame-conditions etc).

2. QUALITY, QUANTIY AND "BONITÄT"

When approaching the exploration of the solid raw materials, only quality and quantity of the deposits are usually assessed. But there are also other characteristics of the deposits, i.e. other factors that influence significantly the technologies employed and subsequently the costs. In the German written literature these factors are named by the general term "*bonität / bonitaet*". In the German language this term has been in use in other branches of the primary production, such as agriculture and forestry, for characterizing the production factor "land" (Fettweis, et al., 1986).

Bonitaet refers to the whole of the geological conditions of the deposit, which influence the costs for each quantity unit of solid raw mineral, such as (Slaby & Wilke, 2005):

- depth, horizontal and vertical extension, thickness and inclination of the deposit
- tectonic conditions, rock mechanics, hydrologic and geothermal conditions, risk of occurrence for mine gas in the deposit and the surrounding rocks
- stability and exploitability of the raw material deposit
- geographical location and location of the deposit

Bonitaet influences mainly influences the work procedures, the works for geological prospection, exploration, opening, equipments to be used, extraction and valuation.

Starting out from a presentation of economic relationships, especially the effect of the factor "quality" of the production factors, we'll try to discuss a mathematical expression valid for the mining of all minerals for describing the economic success of mines.

The factors that determine the "bonitaet" are presented in the following table:

Table 1. Compilation of the factors of the *bonitaet* of the coal deposits

No.	Compilation of the factors representing the Bonitaet of the coal deposits
1.	Geometrical conditions of the deposits, such as extent, number, depth, displacement, thickness, inclination and strike of the deposit; territorial place of the major structure elements; small scale tectonic, rock wall, crumbling risk, washout, intrusions, masking, erosion and other narrowing of the deposit; data about lithostratigraphy; regularity of the above described deposit conditions

2.	Geomechanical conditions of the coal deposit and the relevant surroundings from the mining point of view (covering, roof and base of the deposit) a) data from monitoring of the exploration drilling suc as drilling progress, mud loss, deterioration of the drilling tools, core recovery, value of RQD (rock quality designation) b) petrographical data, such as content of mineral, natural concentration, porosity, permeability of the rocks, inclusively the coal c) data regarding the mechanics of the soil and the mountain, consistency of the pressure, splitting strength, module of elasticity, creep properties, hardness, abrasiveness d) data about common content, such as bedding, cleavage, jointing, formation of irregularities, deformations, collapse behaviour e) mountain pressure f) regularity/irregularity of the mentioned factors
3.	Hydrological conditions regarding the deposit suc as inlet horizon, subsidence and recovery, direction of water flow, dynamics of the groundwater, chemistry, gas direction and temperature of the horizon waters etc.
4.	Geothermal conditions of the deposit in a broader sense, regarding the gas conduct of the mountain, risk for autoignition of the coal, particles in the rock that present risk for causing pneumoconiosis, risk for weathering etc.
5.	Geothermal conditions regarding the deposit such as specific heat, coefficient of thermal conductivity, thermal expansion coefficient of the rocks, constant temperature of the mountain, geothermal gradient etc.

3. SUCCESS RATE IN MINING INDUSTRY

The economic result of the production enterprise (profit or loss) is expressed in monetary unit per time unit [MU/TU] or in monetary unit per quantity unit [MU/QU] (Fettweis, et al., 1986):

$$SR = \frac{It}{P} - \frac{CC}{P} = Iq - CR \quad \left[\frac{MU}{QU}\right] \tag{1}$$

in which:
CC – chapter costs [MU/TU]
P – production (quantity produced) [QU/TU]
SR – success rate [MU/QU]
CR – cost rate [MU/QU]
It – income [MU/TU]
Iq – income [MU/QU]

The success rate of a company (It, respectively Iq) represent either revenues – selling prices for marketable products – or internal prices.

The Iq also depends on the characteristics of the products, which means a correction factor must be used ($q \gtreqless 1$). The value 1 of the factor is meant for the products with standard quality.

We can accordingly write that:

$$Iq = q \cdot PR - CR_T \qquad [MU/QU] \qquad (2)$$

in which:
PR – market price [MU/QU]
CR_T – cost rate for transport [MU/QU]
q – quality factor [-]

The costs of a production enterprise represent the price for the use of the production factors. The chapter costs CC are produced according to the following basic equation (Fettweis, et al., 1986):

$$CC = Q_1 \cdot p_1 + Q_2 \cdot p_2 + \dots + Q_n \cdot p_n = \sum_{i=1}^{n} Q_i \cdot p_i \qquad [^{MU}/_{TU}] \qquad (3)$$

in which:
Q_i – quantity of necessary *n* production factor [FQU/TU], i=(1,2,...,n)
p_i – price of the necessary production factor [MU/FQU], i=(1,2,...,n)
FU – quantity unit of the necessary factor

Accordingly, the costs represent a function of the quantity structure depending on the factor type and factor quantity as well as on the factor price. For further analysis it is important to estimate the costs level and their evolution caused by various influence factors.

The prices p_i for the production factors depend on the supply sector. The size of the influence factors x_{ij} in relation with the kind and quantity of the production factors are, besides the size of the enterprise and the use of the capacities, a great number of variables of importance which determin together the factor quality and play a decisive role in the context. The pattern of influences is very complex. It can be described by the the following:

$$Q_{ij}=f(x_{ij}),\ i=(1,2,...,n),\ j=(1,2,...,m) \qquad (4)$$

The influence factors are very important for cost calculation showing the impact of various production factors individually and on each other. For example, in a drifting, for the drilling it is necessary to use electric power Q_1, cutting bits Q_2, explosive substances Q_3. Further we have the cross section x_{i1}, the type of the drilling tool x_{i2}, the rock solidity x_{i3}. In this case, Q_1, Q_2, Q_3 are influenced by x_{i1}, x_{i2}, x_{i3}. So, the eystem of equations (4) becomes:

$$\begin{array}{c} Q_1=f(x_{11}, x_{12}, ..., x_{1m}, Q_2, Q_3, ..., Q_n) \\ Q_2=f(x_{21}, x_{22}, ..., x_{2m}, Q_1, Q_3, ..., Q_n) \\ . \\ . \\ . \\ Q_n=f(x_{n1}, x_{n2}, ..., x_{nm}, Q_1, Q_2, ..., Q_{n-1}) \end{array} \qquad (5)$$

According to Oberhofer (Oberhofer, 1984), the difficulty is due to the necessity to identify the variables of influence, their values and estimate the right values for the coefficients. To solve that in practice it is necessary to use methods of statistics and logic analysis.

As a result, the equation (1) can be re-written as follows:

$$SR = q \cdot PR - CR_T - \frac{CC}{P} = q \cdot PR - CR_T - \frac{1}{P} \cdot \sum_{i=1}^{n} M_i \cdot p_i \quad \left[{}^{MU}/_{(QU]}\right) \qquad (6)$$

Mining is about exploration and exploitation of the mineral deposits, but also processing of the content of the deposit in order to make it marketable. I.e. deposits and their contents represent the object of three processes (G.B. Fettweis&al, 1986).

The exploration corresponds to the land acquisition phase. The exploration costs will be included in the price for the production factor “deposit”.

The exploitation represents the primary production in mining. Fix materials in the nature become mobile goods.

The processing is necessary because with some exceptions (such as natural ballast used for road construction) the exploited material has no value on the market as such. It often requires an even further processing, such as in the case of ore mining, as the ore itself has market value only when transformed in metals.

The quantity and quality alone are not enough to calculate the explotation costs. There are factors that cause variations of the operating costs, and even cause variations in investments.

It is necessary to describe the “quality of the factors”. This “quality of the factors” is described by the term “bonitaet”.

The context described is synthesized in the following equation:

$$ER = (g_P \cdot g \cdot PR - CR_V - CR_T) - \left[\frac{1}{P_H \cdot g_R \cdot (1-d)} \cdot \left(\sum_{i=1}^{n} F_{Ai} \cdot p_i\right) \cdot \frac{g_P}{m}\right] - \left\{\frac{1}{v} \cdot \frac{Y}{R \cdot \left(\frac{1-l}{1-d}\right)} \cdot \sum_{i=1}^{n} F_{Gi} \cdot p_i\right\} \quad \left[{}^{MU}/_{PU}\right] \qquad (7)$$

in which:

$$P_H = \frac{R \cdot \left(\frac{1-l}{1-d}\right)}{Y} \quad \left[{}^{QU}/_{TU}\right] \qquad (7a)$$

$$g_P \cdot q \cdot PR - CR_V - CR_T = Iq \quad \left[{}^{MU}/_{QU}\right] \qquad (7b)$$

(7c)

(7d)

The formula symbols are explained in the following (Table 2) (according to Fettweis, et al., 1986):

Table 2. Symbols used and their meaning

	Symbols	Meaning	Dimension	Context and comments
Units		Factor quantity unit	[FQU]	e.g. tons, pcs, kWh etc
		Monetary unit	[MU]	
		Quantity unit	[QU]	
		Product unit	[PU]	The quantity unit for the minig product (e.g. concentrate) is named [PU]
		Usefull material unit	[WU]	e.g.: tons of concentrate of metals, thermal power of the power plant coal [J]
		Time unit	[TU]	Period
Rates	SR	Success	[MU/PU]	Efficiency in monetary unit per product unit
	CR_j Indexes j: A G T V	Cost rate Processing Extraction Transport Manufacturing	[MU/PU]	Costs in monetary unit per product unit
	PR	Market price	[MU/WU]	Price for the standard quality raw materials
	p	Factor price	[MU/FQU]	
	Iq	Income	[MU/PU]	Income in monetary unit per product unit
Factors related to time periods	It	Income	[MU/TU]	Income in monetary unit per time unit
	CC_j Indexes j: A G	Chapter costs Processing Exploitation	[MU/TU]	
	P_j Indexes j: D H L P R	Production Dilution Material Excavated material Loss Mining Product Upcomming reserve	 [QU/TU] [QU/TU] [QU/TU] [PU/TU] [QU/TU]	$P_H=P_R-P_L+P_D$

	F_j Indexes j: A G	Quantity of factors Processing Exploitation	[FQU/TU]	
	d	Dilution	[-]	$d = \frac{D}{R - L - D}$ respectively $d = \frac{P_D}{P_R - P_L - P_D} = \frac{P_D}{P_H}$
	g_j Indexes j: H L P R	 Excavated material Loss Mining Product Upcomming reserve	 [WU/TU] [WU/TU] [WU/TU] [WU/TU]	 $g_H = g_R (1 – d)$ $g_L = g_R$ $g_P = [g_R (1 – d) m] / v$
	l	Extraction loss	[-]	l = L/R, respectively l = P_L/P_R
	m	Useful materials obtained after preparation	[WU/WU]	
	q	Factor	[-]	Correction factor for higher or lowe quality
	v	Mass obtained after preparation	[PU/QU]	
	D	Sterile dilution material	[QU]	Sum of sterile dilution material during the lifetime of the mine Y
	L	Production loss	[QU]	Sum of production losses during the lifetime of the mine Y
	R	Upcoming reserve	[QU]	Quantity
	Y	Lifetime of the mine	[TU]	

3. CONCLUSIONS

The correct and complete assessment of the costs in mining is a complex activity. There are a lot of factors and variables that influence the final costs and influence one another. This is why we did not use the simple term of variable costs, but we used the term of chapter costs instead. Estimating the correct values for the variables and for the coefficients represent the real challenge.

This cost calculation is appropriate not only for underground coal mining, as in Romania there is a tendency to associate it with the word „mining". Mining refers to the exploitation of a wide range of mineral resources in various conditions and locations. But they all need a correct cost calculation as a condition to be profitable.

The term “bonitaet” comes to give a more accurate description of the deposits. But all the factors that give the bonitaet of the deposit must be carefully determined and valued in order to have a correct cost calculation. Furthermore, it is not a constant over the time, it changes together with the concrete conditions of exploitation.

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