

ECONOMIC MODELLING UNDER CONDITIONS OF EXPLOITATION OF COHESIVE CONSTRUCTION MINERALS

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Abstract

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Managers of mining companies use for decision-making on optimization of manufacturing processes advanced modelling methods and simulations on computers. The article proposes and analyses the model of a mining company production cycle consisting of a three-dimensional quarry model, technology model and economic-mathematical model. Based on the latter model an economic simulation model of a quarry has been created in the MS Excel program currently available on all personal computers, which measures outputs in the form of changes in total and unit costs according to the generic classification of costs in response to changes in inputs in the form of parameters of technology equipment and other operating parameters. Managers use the economic simulation model of quarry as decision support to increase profitability or improve competitiveness of their product from the sector of construction minerals.

decision-making, simulation methods, economic modelling, construction minerals

Modelling, simulation models, analytical models are concepts that are now often found in discussions and work of experts in all areas of management (Malindžák, 2010). The reason can be found mainly in the fact that in a dynamic and turbulent environment (Drucker, 2001) it is not easy to make the right decision. Especially when we realize that the results of decision-making processes (especially at the strategic level of management) significantly affect the effective operation and future prosperity of these organizations (Fotr, 1997).

Information plays a key role in decision-making processes. The quality of decision-making processes depends to a large extent on availability of information and knowledge in terms of their scope and quality (Fotr, 1997). However, information is not the only thing that matters in decision-making. Apart from personal qualities of decision-makers, the outcome of decisions is affected by the use of appropriate forms of decision-making and decision-making methods. In particular, the chosen decision-making method may be important strategic support

of the manager (decision-maker) for selecting optimal variants or alternatives.

One of the decision-making methods is just a method based on modelling and simulations. Modelling can be defined as material or intellectual reproduction and investigation of a real existing object by means of another, usually artificially constructed object, in which only selected properties, features and relations of the original object are expressed (Fiala, 2008). Modelling can be understood as creating models and simulations, then as calculations and experiments with the model created (Malindžák, 2010).

Currently the model is interpreted differently depending on the author, intention, science or engineering field of study, etc. A model usually means any entity M that for some purposes, represents another entity O (understood as the source and therefore often referred to as an original or artwork) (Křemen, 2007). In this article, we understand the model as simplified reproduction of a real object where some compliance in the

structure or function with the object examined exists (Fiala, 2008). A model is then the result of modelling and as an artwork we use the process of the mining of construction minerals. The article aims at presenting the modelling as a tool applicable by managers of mining enterprises operating in the mining sector of construction minerals.

MATERIALS AND METHODS

Exploitation of cohesive construction minerals

The exploitation of mineral resources is an important industrial sector, which gives interesting business opportunities, despite the number of specifics associated with acquiring the mineral resources. From a long-term view the mining production process is of a cyclical nature and its ups and downs are mainly influenced by the level of prices and conditions of procurement of the raw materials either by own production or by importation (Dvořáček, 1999).

The current face of the Czech mining is significantly affected by economic transformation that took place in the last decade of the 20th century. It was a period of time marked by privatization, liberalization and restructuring. The result of these changes is a decrease in importance of mining in the GDP creation. In 1993 this proportion was 3.7%, in 1998 the proportion fell to 1.8%. The decrease continued even in subsequent years, in 2001 the proportion of the mining of construction minerals in the Sector Classification of Business Activities (OKEČ) was 1.1% and in 2007 only 0.94%. In the following year, 2008, the proportion increased to 1.03%.

Besides reducing the importance of mining as a sector of the national economy also the importance of individual raw material groups changed. While previously, the extraction of energy resources unambiguously prevailed, today non-metallic minerals are up the importance and in some years (e.g. 2008) the construction materials were dominating by volume and value. The data from the Czech Geological Survey – Geofond shows that in 2009 the proportion of energy resources in the energy sector sales was 49.69%, the proportion of construction minerals was 28.43% and other raw materials then 21.88%.

Construction minerals are considered to be a group of four raw materials, which inherently belongs to non-ore raw materials. These are decorative stone, building stone, gravel and sand and brick raw materials. The extraction of these raw materials in the Czech Republic is promising even in the future, since as at 31 December 2009, in geological reserves 183,752 thousand m³ of decorative stone, 2,346,363 thousand m³ of building stone, 2,112,759 thousand m³ of gravel and sand and 548,769 thousand m³ of brick raw materials were reported. Lifetime of industrial supplies of brick raw materials and decorative stone is estimated at more

than 100 years. The industrial supplies of building stone are for around 77 years and gravel and sand then 97 years [Raw-Material Yearbook].

It is interesting that some forest enterprises (e.g. Lesostavby Frýdek-Místek, a. s.) operates quarries.

The whole process of the exploitation of mineral resources and thus construction minerals consists of four basic phases: (1) opening and preparation of the deposit to mining, (2) mining itself, (3) treatment of extracted raw materials, (4) elimination of effects of mining (Kryl, 1997).

Considering the volumes of mining and technological difference in exploiting decorative stone we further focus in this article on building stone. The principles of modelling and the model itself, which is to be described below, can be applied to other groups of construction minerals after some adjustments.

The inherent mining process begins with disintegration, which in case of the extraction of building stone means that we use blasting operations to separate the rock from massive. In the bulk extraction the method of mining in degrees (bench mining) is applied. It is used wherever the quarry wall is steeper than 60 degrees and the height of the bench in the range of 10 to 25 meters (Kryl, 1997).

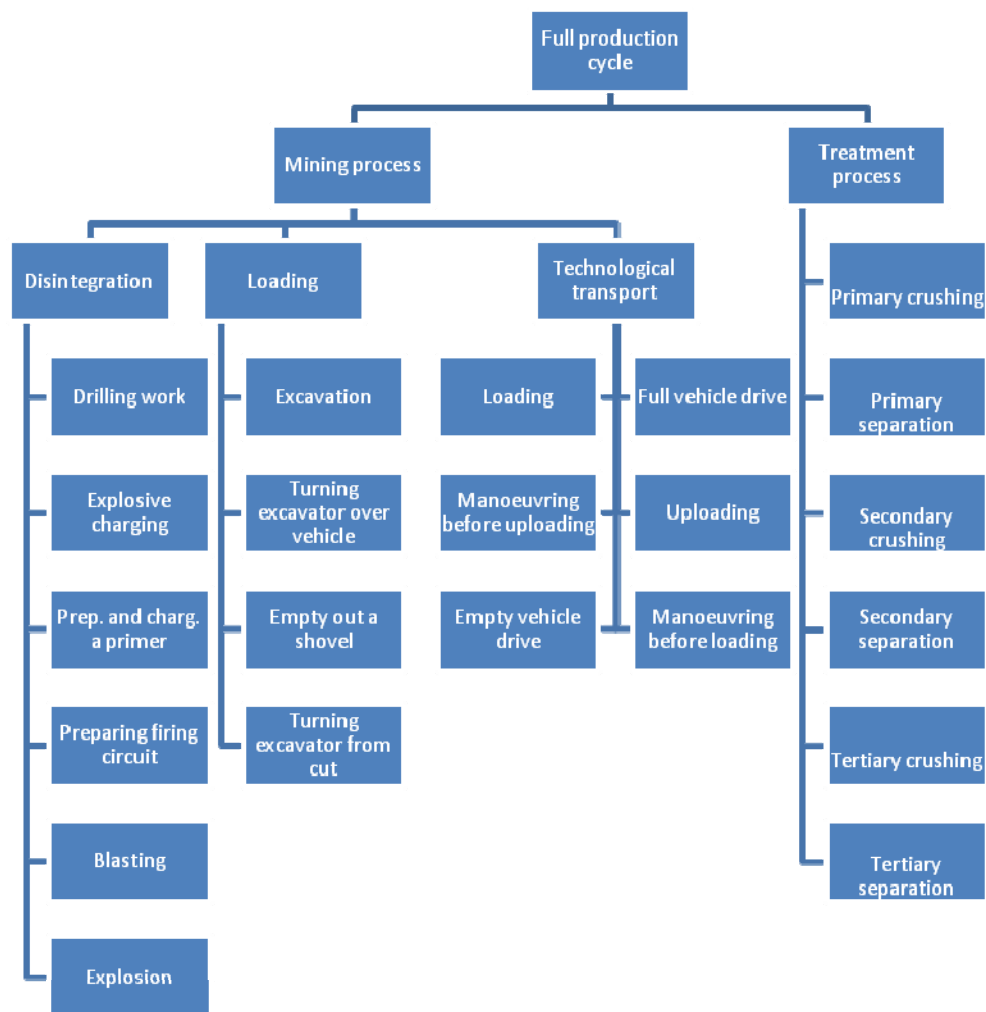
If we examine in detail the entire process of acquiring cohesive raw materials, then we can decompose it into two production processes (mining process, treatment process), which are further decomposed into individual technological processes and operations (see Fig. 1).

Methodology of creation of an economic model under conditions of a mining enterprise

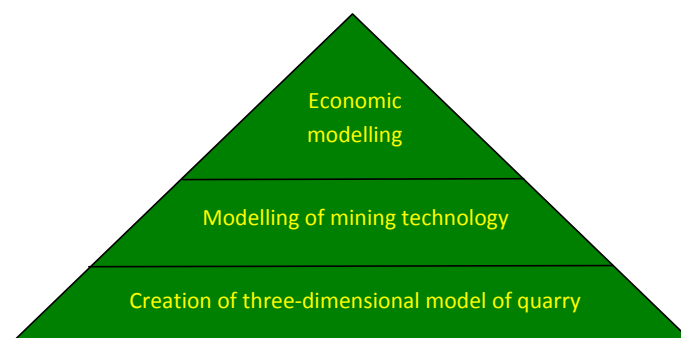
Many theoretical studies and practical applications are dedicated to the issues of economic modelling (e.g. Hušek, 1987; Rabová, 1992; Fiala, 2008).

The model building process is a kind of abstraction. The basic division of the models depending on their construction and means of reproduction of phenomena, is into material (technical) and ideal (mental) models (Fiala, 2008). The first method of modelling consists in the modelling of enlarged or reduced objects that by their properties and behaviour faithfully represent the objective reality of interest. The crucial from the ideal models are mathematical models (Fiala, 2008), when we work with mathematical means of expression (input and output variables, constants, parameters, equations, inequalities, etc.).

Our objective reality of interest is the exploitation of cohesive mineral resources. We intend to describe this exploitation in an economic way, which we will do using an economic-mathematical model. Economic-mathematical modelling, however, stands on the imaginary top of a model pyramid (see Fig. 2).



1: Decomposition of the complete production cycle in the exploitation of building stone



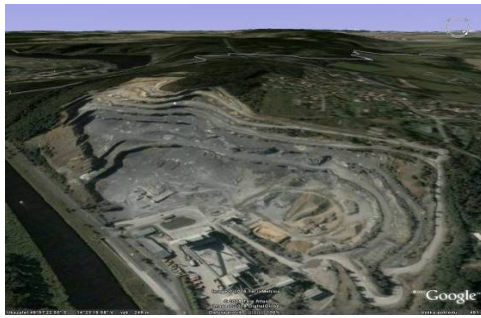
2: Pyramid model

We have no choice therefore than to deal with its various levels.

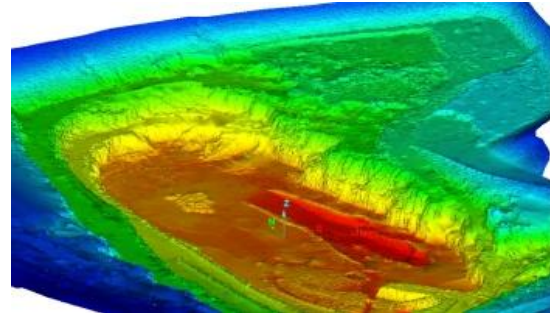
Three-dimensional modelling of quarry

In creating a three-dimensional model of quarry (see Fig. 3 and 4) it is a necessary first to clarify how detailed model for subsequent modelling we need. If we make do only with basic knowledge of the

quarry area of interest, or a “site layout”, then we can use a colour orthophoto map (Hanzl, 2001). The orthophoto map of the area of interest can be obtained, for example using Google Earth. If a simple three-dimensional model will not satisfy us, we have the laserscanning available, which allows to create 3D-model of the quarry operation of interest.



3: Zbraslav Quarry the Google Earth application



4: Illustration of three-dimensional in model of Railton, the Australian limestone quarry, Tasmania

The three-dimensional model needs to be completed with the data on minerals mined at the deposit. In particular, it is their occurrence at the deposit, including geo-mechanical and technological properties.

If we only need a very simple representation of a quarry operation, we can create a model in a matrix whose number of rows corresponds to the number of benches and the number of columns then the number of working sections (see Tab. I). In the working section the appropriate technological operations are performed and its size is determined by the parameters of the blasting operation. It is clear that the “matrix” three-dimensional model must be adapted to specific conditions of the quarry. Also the figures reported for each working section can be modified according to the needs of the creator or user of the model.

In our sample model section indication, section parameters, total transport distance in the individual working sections (WS) are recorded and by the colour of the section then the extracted mineral is indicated.

Modelling technologies

Despite many specifics the mining and processing of minerals is (Dvořáček, 1999) a standard business sector and mining companies are places, where input factors are transformed into outputs.

The transformation process cannot be imagined without necessary technology, the miner uses to

acquire minerals at a certain deposit. And that is the subject of modelling. Various types, numbers and characteristics of the technology equipment deployed reflect the capacity requirements to be met by the quarry operation. The starting point for modelling is then the decomposition of the complete production cycle, shown in Fig. 1.

In general, the capacity of a production unit is defined as a result of its performance and the period of time for which it is in operation (Synek, 2007). In case of a mining company a production unit is understood the entire company, its production organizational units (plant, operation), or individual technology equipment (loader, industrial vehicle, crusher, etc.). The production capacity is then understood as the maximum amount of a commercial mineral that can be extracted under certain conditions over time (Dvořáček, 1997). We express the capacity in physical units (in the area of construction minerals usually t or m³) and calculate it using the following formula:

$$Q_p = F_p \times V_p \quad [\text{t} \cdot \text{year}^{-1}], [\text{m}^3 \cdot \text{year}^{-1}], \quad (1)$$

where:

Q_p ... theoretical production capacity [t·year⁻¹], [m³·year⁻¹]

F_p ... usable (available) time fund [h·year⁻¹]

V_p ... theoretical technical performance [t·h⁻¹], [m³·h⁻¹].

I: Simplified three-dimensional model of quarry

		Order in the working cut					
		1	2	3	4	....	n
Working cut	1	WS ₁₁ par ₁₁ Sc ₁₁	WS ₁₂ par ₁₂ Sc ₁₂	WS ₁₃ par ₁₃ Sc ₁₃	WS ₁₄ par ₁₄ Sc ₁₄	....	WS _{1n} par _{1n} Sc _{1n}
	2	WS ₂₁ par ₂₁ Sc ₂₁	WS ₂₂ par ₂₂ Sc ₂₂	WS ₂₃ par ₂₃ Sc ₂₃	WS ₂₄ par ₂₄ Sc ₂₄	....	WS _{2n} par _{2n} Sc _{2n}
	3	WS ₃₁ par ₃₁ Sc ₃₁	WS ₃₂ par ₃₂ Sc ₃₂	WS ₃₃ par ₃₃ Sc ₃₃	WS ₃₄ par ₃₄ Sc ₃₄	....	WS _{3n} par _{3n} Sc _{3n}
	4	WS ₄₁ par ₄₁ Sc ₄₁	WS ₄₂ par ₄₂ Sc ₄₂	WS ₄₃ par ₄₃ Sc ₄₃	WS ₄₄ par ₄₄ Sc ₄₄	....	WS _{4n} par _{4n} Sc _{4n}

Real operating conditions as a rule do not allow to use the performance advantages of the technology equipment deployed and in particular to use fully the time fund. Therefore, the actually achieved volume of production is always less than or the same as the theoretical production capacity (Synek, 2007).

In determining the production capacity within technological modelling, we do not focus only on the own technological devices, but the attention is paid to the production capacity of the whole technological process, or the entire production process. The production capacity of higher production units is influenced by both the interaction of individual technological devices and the relationship of these units.

Generally, the individual production units are arranged in parallel or in series. If this is the *parallel arrangement*, then the production capacity is given by the sum of partial production capacities. If the transformation process is solved using the *serial arrangement* of the technology equipment, the production capacity is given by the capacity of the so-called main production member.

The main production member is meant such operation, where a major part of production machinery is concentrated and where the largest proportion of the overall work is spent (Synek, 2007). It is also obvious that in the serial arrangement of production units the smallest performance of a technological device is a limiting factor in the technological or manufacturing process. Therefore, when selecting the equipment, we should follow the principle of capacity reconciliation, which we can ensure in that the following process is stronger in capacity than the previous one¹.

Which arrangement of technological processes or technology equipment for the exploitation of construction minerals will predominate depends on the size of quarry operation. For small quarries net serial arrangement can be expected. With increased volumes of exploitation the required capacity is ensured by adding the technology equipment arranged in parallel. For example, to transport muck from a ruin three industrial vehicles are used. Another example is the simultaneous existence of two ruins, where the much is currently transported from. According to the properties of the mineral it can be transported to two different places, where will be further treated (fixed + mobile treatment line). It can be assumed that in medium and large quarry operations we find rather a hybrid arrangement, which means a serial organization of technological processes and a possible parallel arrangement of technology equipment.

Economic modelling

Only if the technology solution of the mineral exploitation is known, we can proceed to economic modelling. This modelling means to search for an economic model, or economic-mathematical model describing the technological process of mining and processing of cohesive mineral resources.

The inherent process of modelling consists of five following stages (Hušek, 1989; Vlček, 1999; Fiala, 2008):

1. Problem analysis

- Investigated object (complex system) is analysed;
- Substantial parts and relationships between them are identified;
- Specific data is acquired.

2. Development of the mathematical (abstract) model

- System of equations or inequalities.

3. Solving the model (creating a simulation model)

- Algorithmization and recording the abstract model using a computer program.

4. Experiments with the model – simulation

5. Implementation of the solution in practice

When we examine entrepreneurship in the area of the exploitation of mineral resources through the prism of Act No. 513/1991 Coll., the Commercial Code, as amended, we find that the business activity is the activity conducted in own name on own responsibility for the purpose of getting profit. A positive income from operations thus becomes an important aim of the company and its management.

The income is an economic variable that can measure the performance of transformation process (Fiala, 2002). The inputs and transformation itself, in our case the exploitation and treatment of a mineral, can be expressed as the total costs and the outcomes as the total revenue (Fiala, 2002).

$$HV = V_C - N_C \quad [\text{CZK}], \quad (2)$$

where:

HV ... income [CZK]

V_C ... total revenue (sales) [CZK]

N_C ... total costs [CZK].

One of the reasons why we use in the economic model just the income is the availability of the information concerning economic variables needed to perform the calculation. Under the provisions of Article 4 of Act No. 563/1991 Coll., the Accounting Act, as amended, the accounting entities (business entities) are required to keep accounts. Under Article 7 of the Act, the accounting entities shall keep accounts so that the financial statements compiled under the Act give a true and fair view

¹ In the mining sector of mineral resources the following technological processes are sized by 10% to 15% more than the previous ones.

of the accounting and financial situation. For our purposes the key is just such financial statements, which consist mainly of the balance sheet and profit and loss statement. Just the profit and loss statement provides the information necessary to calculate the income, as the costs and revenues achieved during the period are recorded in this statement.

We will focus further only on cost modelling. The reason is that the costs are at the forefront the interests of operational managers. It will be of vital interest for many extraction companies to introduce optimum measures based on minimising of production costs.

The model will be based on the generic classification of costs, whereas the focus of interest will be in the key cost types, which can be expressed:

$$N_C = N_{VS} + N_{ON} + N_{OD} + N_{OS} \text{ [CZK]}, \quad (3)$$

where:

N_C total costs [CZK]

N_{VS} ...performance consumption [CZK]

N_{ON} ...personal expenses [CZK]

N_{OD} ...depreciation [CZK]

N_{OS} ...other costs [CZK].

Performance consumption is given by:

$$N_{VS} = N_M + N_E + N_S \text{ [CZK]}, \quad (4)$$

where:

N_{VS} ...total costs [CZK]

N_M ...material consumption [CZK].

N_E ...energy consumption [CZK]

N_S ...services [CZK].

Personal expenses we express as follows:

$$N_{ON} = N_{MN} + N_{ZP} + N_{SP} + N_{SN} \text{ [CZK]}, \quad (5)$$

where:

N_{ON} ...personal expenses [CZK]

N_{MN} ...labour costs [CZK]

N_{ZP} ...health insurance [CZK]

N_{SP} ...social security [CZK]

N_{SN} ...social expenditures [CZK].

Other costs are operationally understood to be less important types of costs such as taxes and fees, financial costs, other operating expenses and extraordinary expenses.

For managerial decision-making it is useful to model also the relative cost expression. We mean unit costs, or costs, which are expressed as a percentage of the costs per value unit of production (hellers of costs per CZK 1 of revenues and or a crown of costs per CZK 100 of revenues). The indicator of unit costs is therefore known as a heller indicator (Dvořáček, 1997).

However, for subsequent considerations and calculations it will be preferable to use a cost indicator of the physical volume of production. In this case the volume of production is expressed in physical units, which in the area of construction minerals is t and m^3 .

$$n_j = \frac{N_C}{Q} \text{ [CZK.t}^{-1}\text{] [CZK.m}^{-3}\text{]}, \quad (6)$$

where:

n_j mean total costs (unit costs) [CZK.t⁻¹] [CZK.m⁻³]

N_C total costs [CZK]

Q volume of production [t], [m³].

The model is created to support the decision-making of a miner, or a mining company manager. Therefore, it may be valuable for the decision-maker, if the economic model reflects manufacturing and technological processes exploiting minerals. If the model will be able to describe the exploitation of muck of a certain working section, such model will be more interesting for decision-makers. If we model the costs in terms of these considerations, then the total costs of a working section can be expressed as follows:

$$N_{CU} = N_{RU} + N_{NU} + N_{DU} + N_{UU} \text{ [CZK]}, \quad (7)$$

where:

N_{CU} ...total costs on mining and treatment of muck of the working section [CZK]

N_{RU} ...total costs on disintegration of the muck in the working section [CZK]

N_{NU} ...total costs on loading the muck in the working section [CZK]

N_{DU} ...total costs on transportation of the muck from the working section [CZK]

N_{UU} ...total costs on treatment of the muck from the working section [CZK].

Within each manufacturing or technological processes inputs are consumed whose consumption of money is reflected by costs. In our mathematical model it is expressed in the relations (3)–(5), but with a sole exception of depreciations, or costs having a fixed nature (e.g., lease payments, insurance).

Depreciations and other fixed costs, due to their nature in a given time period (e.g. year, month) are fixed, but the processes in the given working section are usually of significantly shorter duration. It is therefore necessary to determine the amount of fixed costs of items for the duration of the exploitation and treatment of the muck coming from the working section.

Since it is materially the costs that are associated with the technological equipment deployed, the basis for determining this amount is the effective time fund of the technology equipment and its performance.

For simplicity, let us further consider the depreciation. The depreciation of the technology equipment may be determined by the relationship:

$$N_{ODi} = \frac{PC_i}{t_i} \text{ [CZK.year}^{-1}\text{]}, \quad (8)$$

where:

N_{ODi} ...depreciation of the i -th technological device [CZK.year⁻¹]

PC_i ...purchase price of the i -th technological device [CZK]

t_i expected amortization period of the i -th technological device [years]

i index of the technological device.

The amount of depreciation attributable to an operating hour of the technological device then is:

$$N_{ODhi} = \frac{N_{ODi}}{Fefs_i} \quad [\text{CZK.h}^{-1}], \quad (9)$$

where:

N_{ODhi} ...depreciation per hour of the i -th technological device [CZK.year⁻¹]

N_{ODi} ...depreciation of the i -th technological device [CZK.year⁻¹]

$Fefs_i$ effective time fund of the i -th technological device under the given shifts determination [h.year⁻¹]

i index of the technological device

s index of shifts (1–3).

Since the performance of the deployed technological devices is usually known, it is not difficult to determine the equipment depreciation per unit of performance. In modelling we will work with expected actual performance, which reflects the specific conditions of deployment.

$$N_{ODji} = \frac{N_{ODhi}}{Vs_i} \quad [\text{CZK.j}^{-1}], \quad (10)$$

where:

N_{ODji} depreciation of the i -th technological device per unit of work performed² [CZK.j⁻¹]

N_{ODhi} ...depreciation per hour of the i -th technological device [CZK.year⁻¹]

Vs_i the anticipated actual performance of the i -th technological device [j.h⁻¹]

i index of the technological device.

Once known the technology equipment depreciation per unit of work performed, it is easy to determine the amount of depreciation attributable to a working section.

$$N_{OD\dot{U}i} = N_{ODji} \times RP_i \quad [\text{CZK}], \quad (11)$$

where:

$N_{OD\dot{U}i}$...depreciation of the i -th technological device attributable to the working section [CZK]

N_{ODji} depreciation of the i -th technological device per unit of work performed [CZK.j⁻¹]

RP_i scope of work performed using the i -th technological device [j]

i index of the technological device.

The total depreciation is then the sum of depreciations of single technological devices.

$$N_{OD\dot{U}} = \sum_{i=1}^p N_{OD\dot{U}i} \quad [\text{CZK}], \quad (12)$$

where:

$N_{OD\dot{U}}$...depreciations of all the technological devices attributable to the working section [CZK]

$N_{OD\dot{U}i}$...depreciation of the i -th technological device attributable to the working section [CZK]

i index of the technological device

p number of deployed own technological devices in the working section [pieces].

Relationships (8)–(12), apply by analogy to lease payments or additional fixed cost items.

When assigning numbers to the processes under consideration (1 – disintegration, 2 – loading, 3 – technological transport, 4 – treatment), the total costs may be expressed as follows:

$$N_{C\dot{U}} = \left(\sum_{j=1}^4 N_{VS\dot{U}j} + N_{ON\dot{U}j} + N_{OD\dot{U}j} + N_{OS\dot{U}j} \right) \quad [\text{CZK}], \quad (13)$$

where:

$N_{C\dot{U}}$ total costs attributable to the working section [CZK]

$N_{VS\dot{U}j}$...performance consumption of the i -th process attributable to the working section [CZK]

$N_{ON\dot{U}j}$...personal expenses of the i -th process attributable to the working section [CZK]

$N_{OD\dot{U}j}$...depreciation of the i -th process attributable to the working section [CZK]

$N_{OS\dot{U}j}$...other expenses of the i -th process attributable to the working section [CZK]

j index of the process.

The above abstract model can then be refined as necessary considering other input variables affecting the level of individual cost items (e.g., the prices of items consumed, technical parameters of technological devices, rock characteristics, staffing, work organization).

Creating a simulation model

A simulation model means an abstract model typed in the form of a program in a programming language (Rábová, 1992). If we are proficient in programming several standard programming environments are available (like Visual Basic, COM, C + +, NET, Java). If we want to create a dynamic model then we can use successfully special simulation programs (e.g. Powersim Studio, Vensim, Stella). A simulation model can also be made in a spreadsheet (e.g. MS Excel).

Managers and technical and administrative staff in the role of decision-makers are the ones who are the most frequent users of the simulation model, and therefore the spreadsheet environment is the most appropriate. It is undisputed that Microsoft Office, which involves as an integral part also the Excel spreadsheet, is a widespread, if not the most popular software product, which can be found on the computers of managers and technical and administrative staff. Other advantages of this environment are availability and easy manageability.

2 The unit of work is understood e.g. drilled meters, kilograms of explosive charged, m³ of ruin

Since the spreadsheet is really a standard tool, let us only say that the working surface is made up of a large table of 65,536 rows and 250 columns. The user sees and works as a rule with a small part only. The field in the table is called a cell and each cell has an address designated by a column and row (e.g., B3). The individual cells can be treated as variables. Using absolute and relative cell references and mathematical relationships we create a simulation model. In creating this, also mathematical functions and constants are used.

For the above reasons, the simulation modelling was performed in the Microsoft Excel 2007 spreadsheet calculator. In order to work with the model in earlier versions of the calculator it is saved in the compatibility mode.

RESULTS

The result of simulation modelling is the economic model of quarry (EML), which was enrolled as the applied software³. One of the conditions for enrolling the software was to confirm the deployment of EML under operating conditions. EML is used for example by a major mining company KÁMEN Zbráslav, spol. s r. o.

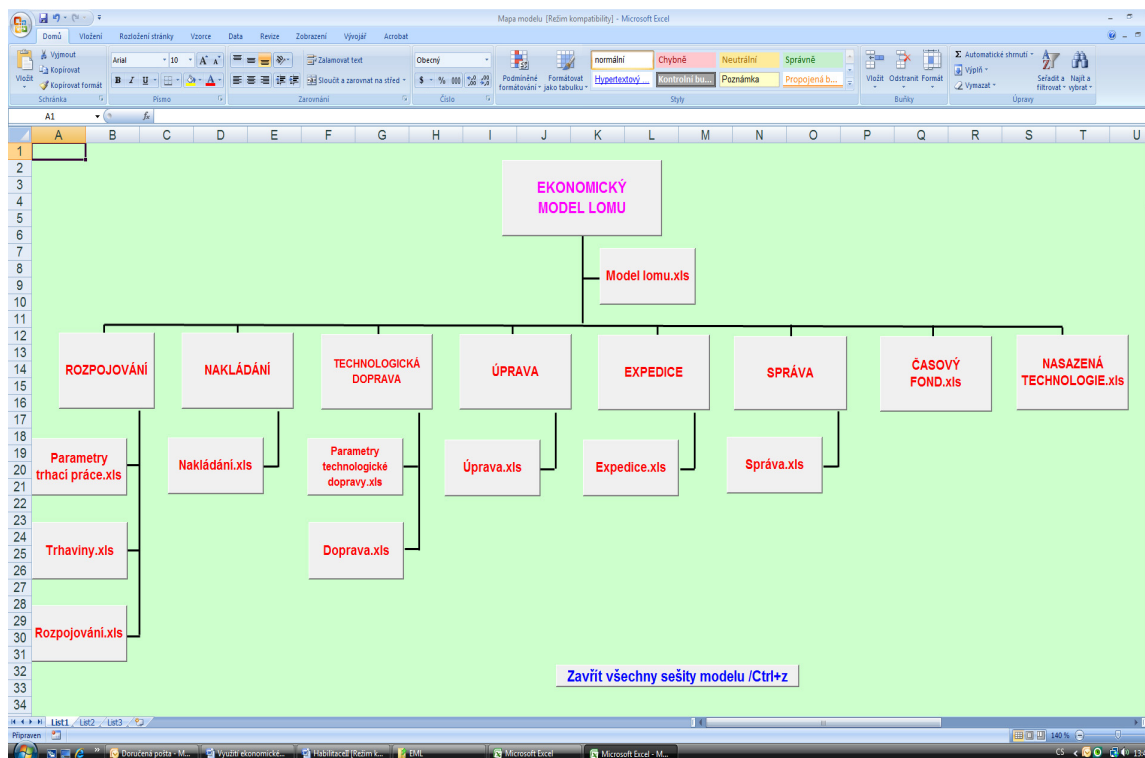
The EML economic model of quarry is a support tool for managerial decision-making under conditions of a mining company. EML models the

mining and treatment process. It also deals with dispatch and administration. The model is set up so that it respects the internal structure of the mining process, which means that also single technological processes and operations (disintegration – drilling, blasting, loading, technology transport) are modelled.

The model consists of a total of 13 inter-related workbooks. In order the user (manager) can easily work with the model, the model involves the workbook “Map of model.xls” (see Fig. 5), which is used to control the model, during the creation of which the form “Buttons” was used.

The workbook “*Model of quarry.xls*” is an imaginary peak of the simulation pyramid. The workbook covers the individual modules (disintegration, loading, technology transport, treatment, dispatch, administration) and provides comprehensive economic information about the individual modules (processes) and the quarry as a whole. The last sheet in the workbook **Work section Total**, Fig. 6, essentially summarizes the results in transparent tables and graphs. The workbook provides:

- Structure of total costs of mining and treatment of muck;
- Structure of total costs of mining and treatment of muck in relation to production volume;
- Unit costs of individual technological processes;



5: Model map

3 In the Centre of Technology Transfer of the VSB - TU Ostrava it is registered under the number 036/25-11-2010_SW. EML is freely available at: <http://homen.vsb.cz/~van74/sw/EML/>.

- Cost structure by processes;
- The total costs by processes.

The simulation model in the spreadsheet calculator is in the form of tables, whose output cells are connected with the input cells through relative or absolute links. In a comprehensive view of the tables, these links are hidden, and therefore if they are not inserted into the model of value, the accuracy and completeness of the simulation model cannot be verified. So the functional verification of the model is the key phase of simulation modelling.

Simulation

Creating a simulation model (see Fig. 6) completes the modelling process and opens the space to use the model in own simulations, which are actually the real objective of the whole modelling process. Creating a model without the assumption of its use in simulations is indeed possible, but completely useless.

The actual simulation can be performed at two levels. The first level is insertion of input items into a simulation model (e.g. EML), and determining the costs of mineral acquisition. The second level of the economic simulations is experiments with different input variables, while using the principle of a sensitivity analysis.

The sensitivity analysis determines the sensitivity of the output variable of the model to a change of a certain input. The sensitivity is determined by gradually changing the values of selected input variables while maintaining outstanding values. This procedure can repeat in a number of simulation steps (Hlinica, 2009). For example, we change

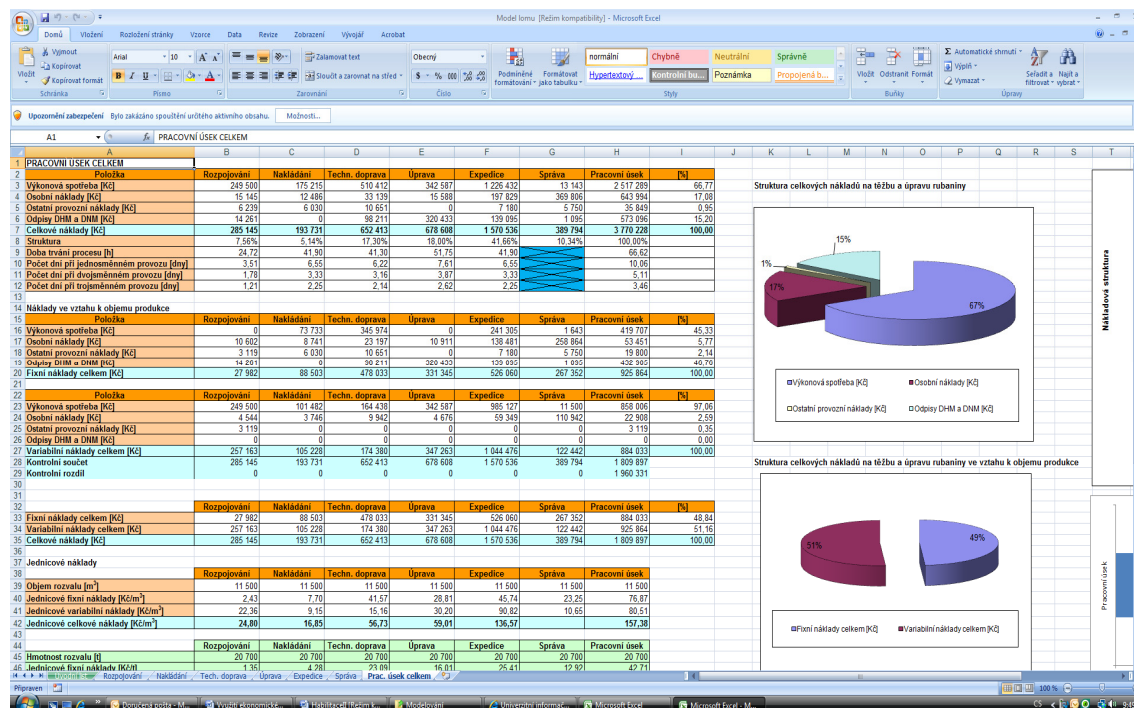
gradually the selected input variable by 2, 4, 6 and 8%, and observe the response of the output variable. In those cases where the number of input variables is in the order of tens, we must take into account some difficulty in the organization of computations even when using the computer technology. It is not essential to change gradually all input variables. It depends of course on the purpose of the conducted simulations, or the volume of the performed simulations depends on the own decision-making process.

DISCUSSION

These are several experiments we can do. We can change the input data (e.g. the use of technological devices, their performance characteristics, prices, consumption) and monitor how these changes are reflected in the total and unit costs of the relevant processes, and therefore in the costs per entire working section. In addition, it is possible to simulate changes in mining days, changes in downtimes in the mining and treatment process or changes in the number of shifts.

We illustrate the use of the model on the simulation of a change in the number of mining days, which reflects the current climatic conditions in winter. If the winter is mild and construction activities take place, the mining production is not stopped, which is obviously reflected in the economy of the mining plant, or in the total costs of the phases in question of the building stone exploitation, as the following simulation shows.

Due to the limited maximum number of pages that the authors have got available, it is not possible



6: Sheet "Working section Total" Note Figures are for illustrative purposes only

II: Unit total costs when changing mining days in [CZK.t⁻¹]

The number of mining days	Disintegration	Loading	Technology transport	Treatment	Operating division
190	13.73	9.36	33.18	44.35	100.62
195	13.69	9.24	32.96	43.92	99.82
200	13.66	9.14	32.74	43.52	99.06
205	13.63	9.03	32.54	43.13	98.34
210	13.60	8.93	32.35	42.76	97.65

III: Sensitivity of unit total costs to change in mining days in [%]

Item	Disintegration	Loading	Technology transport	Treatment	Operating division
Sensitivity for 195 days of mining	-0.24	-1.22	-0.67	-0.96	-0.79
Sensitivity for 200 days of mining	-0.47	-2.38	-1.31	-1.88	-1.55
Sensitivity for 205 days of mining	-0.69	-3.48	-1.92	-2.75	-2.27
Sensitivity for 210 days of mining	-0.89	-4.53	-2.50	-3.58	-2.95

to specify all the input values. In total there are 244 of them in EML. The results of the simulation performed are shown in Tab. II and III.

In the case of an increase in the number of mining days from original 190 to 200 a decrease in unit costs occurs. The reason is that the increasing number of mining days causes a rise in the effective time fund, thereby allowing loosening more the fixed costs. Due to mild winter, there is a greater use of long-term tangible assets, which has a positive economic effect in reducing the unit costs. It is therefore clearly recommended to the management of the mining firm to prolong the period, when the quarry produces crushed stone. However, it is clear that this period cannot be prolonged, despite the climatic conditions.

CONCLUSION

Mining and treatment of mineral resources is from the economic view a standard business activity. If a mining enterprise would like to survive in the market it cannot do without the implementation of a number of measures for cost optimisation based

on their minimization. Practically, this is search for savings. It ensures either greater profitability while maintaining prices, or lower prices, which will be appreciated by customers of the mining company.

The created business model provides its users with more possibilities of application. It can find its application in the creation of internal prices, which may also serve as the basis of economic evaluation of a considered technological or manufacturing process. Identifying significant deviations can become the beginning of analytical work at the end of which there is the knowledge of the quarry managers which direction to fix the attention to achieve the set out objectives.

Decision-making is an integral part of managerial work. When searching for the right decisions, the managers can rely on a variety of techniques, tools and methods. The economic modelling and simulation is one of the supporting and valuable instruments. The proper use of this instrument can contribute to improve the quality and level of the decision-making process and thus the managing process as a whole. It depends only on decision-makers to decide.

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