Cost-ratio model proposal and consequential evaluation of model solutions of manufacturing process in mining company

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In this article, the issues of cost-ratio of the production process in a mining company are addressed. To understand the issue a theoretical basis and consequently cost ratio of a particular company and its plant were drafted. The analysis of issues solved was based on the current status of the plant and therefore the existing technological processes, manufacturing processes and costs to individual processes. The cost-ratio indicator of the production process is the fundamental workings of the mining company and is an important part of management in the mining company. In the design cycle, the cost models were developed, which shows the various factors affecting the operating cost-ratio and the importance of these indicators in practice of mining companies. The contribution of the paper represents three models, considering the 100 % of production volume with different kind of overhead costs in the production process of each one. This could be very helpful for small and medium extractive, and mining enterprises in the way of optimisation of their own cost management, based on the output of analyses contained. In summary, the first model provides the best results of the cost-ratio, so the combined overheads seem to be the most suitable suggest for this kind of the company.

Keywords: Cost-ratio, Mining company, Extractive industry, Manufacturing process, Management, Cost-ratio model

Introduction

The mining industry is quite unique when compared with other typical production industries. The volume of funds required for a new project is immense, depending on the commodity type, extraction method, mine size, annual extraction, location and a large number of other parameters.

Success in business today stands or falls on the ability of the manager to analyse, monitor and decide on measures for cost-ratio. These measures apply to all levels, from operational to executive. Correct manager's decision and the subsequent consideration of all factors help to improve business efficiency and eliminate the risks and potential impacts. Tracking and predicting the cost-ratio is the basis for acquiring the correct investors for a relatively volatile market.

Economic result is the most important aspect of any business. Making a profit at the lowest possible cost is the primary objective an enterprise any focused. Therefore, the economic result is the main goal of everyday concern. Based on the comparison between the costs and benefits, it is possible to calculate the economic efficiency of the economic process. The difference between revenues and costs gives us the economic result:

$$Economic\ result = \ Revenues - Costs \tag{1}$$

Company returns are a monetary amount, received by the company from its operations for a certain accounting period, regardless of whether during that period they were collected (Gavurová, 2011). The main group of production company revenues are Revenues from the sale of merchandise.

Company costs are monetary amounts that the enterprise purposefully incurred in obtaining income. In case that the revenue exceeds the costs, it is profit. If the costs exceed the revenue, it is a loss.

Theoretical background

The cost is something that will be given up to achieve a future benefit. It states that it is an abstract concept, and we can not touch it because it is something that we have arranged for the prospect of future success (Stanek, 2003). Usually, we consider the price at which we purchased the source. Costs can be measured by the amount of money we have "sacrificed" or paid, respectively not yet paid for obtaining future benefits (Hontyová, 2016).

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Costs are an important synthetic indicator of the quality of business activity. An important task of management is to manage and guide them. Cost management requires their detailed classification (Štangová 2000).

Generic classification of costs means their grouping into homogenous groups associated with the activity of individual factors of production (materials, fixed assets, labour, etc.). This kind of sorting offers answers to the question: "What is consumed?" (Da Silva, 2014)

The basic cost types are (source):
- Consumption of raw materials, materials, energy and fuel,
- Financial expenses (interest paid, insurance costs, other charges and other),
- Amortization of buildings, machinery, production equipment, intangible fixed assets, tools,
- Wages and salaries, other personnel expenses (social and health insurance, commissions),
- Costs for external services (rent, transportation, travel, repair and maintenance).

The costs are divided into several levels according to business size and complexity of the production (Synek et al., 2003):

Costs of production activity:
- Main costs,
- Ancillary costs,
- Incidental costs,
- Associated production costs.

Costs of non-production activity:
- Costs of sales,
- Administration costs,
- Costs of supply.

Main groups of costs for managers are:
- Fixed costs,
- Variable costs,
- Total costs,
- Average costs for 1 piece/ton and other.

Tab. 1. Relations between types of costs.

Production volume [ton]	Fixed costs [€]	Variable costs [€]	Total cost [€]	Average costs of 1 ton [€]
1	20	0,9	20,9	20,9
2	20	1,8	21,7	10,85
3	20	2,7	22,4	7,47
4	20	3,6	23	5,75
5	20	4,5	23,8	4,76
6	20	5,4	24,8	4,13

Source: (Synek, 2003)

Cost-ratio specifications for preparation of mining, extraction and processing of minerals

Preparation of extraction, mining and mineral processing represent three basic processes of technical mining planning. All these processes are creating the object of manufacture, where the use of special mining equipment and technology is necessary (Cehlár, 2016). In the most of the enterprises, this means the use of a heavy machinery and vehicles, which have to perform uncovering with subsequent release of minerals. Obtained minerals have to be prepared and transported for further processing. Finishing the final product depends on the extracted mineral resource; from the method of mining to the actual processing.

Preparation of extraction, mining and processing are also processes that often require a considerable financial cost for the company or plant (Blištan, 2015). These costs are influenced by various factors and goal of any company is their reduction. It is essential to identify factors that influence and divide the total cost into the variable costs and fixed costs. Consequently, it is important to calculate the total cost per tonne of finished product and try to reduce this amount.

Furthermore, we stated the basic specifications with the impact on costs in implementing the three basic processes. These specifics affect the variable and fixed costs of the mining company and also the total costs per

tonne of finished product, which is one of the most important indicators in evaluating cost-ratio of the enterprise (Cehlár, 2006).

We have thoroughly analysed gravel deposits on the plant in terms of its origin. Then we described its current state, the hydrogeological conditions of the deposit and estimated mineral reserves. Then, we described in detail the plant production process consisting (Kajanová, 2005) of:
- Technological process for uncovering,
- Technological process for mining and extraction,
- Technological process for processing.

Subsequently, we focused on the financial side of the plant and proceeded to analyse the costs of the plant. We divided the cost with priority according to the manufacturing process as follows:
- Costs of uncovering,
- Costs of mining and extraction,
- Costs of processing.

We also divided the individual costs on variable and fixed costs and calculated the cost of 1 tonne of gravel. Then, we calculated the actual cost-ratio, cost-effectiveness and cost-profitability in the particular plant (Despodov, 2014). The following shows the relationship to cost-ratio (h in %), cost-effectiveness (Nu in %) and cost-profitability (RN in %), which we have used to achieve results:

$$h = N/V \ x \ 100 \tag{2}$$

where:
N – costs, V – revenue, h – cost-ratio indicator

$$Nu = T/N \ x \ 100 \tag{3}$$

where:
T – sales, N – cost, Nu – cost-effectiveness

$$RN = Z/N \ x \ 100 \tag{4}$$

where:
N – costs, Z – profit, while $Z = T-N$, RN – cost-profitability

Production costs of the plant

We equally divided production costs of the plant as the technological process, (Schejbalová and Muchová, 2013) which takes into account the classification of the fixed and variable costs, as shown below:
- Costs of mining preparation,
- Costs of mining,
- Costs of processing.

Production costs of mining preparation included the variable as well as fixed costs. Variable costs represent, for example, costs for diesel, gasoline and other fuel, electricity costs, distribution of materials, mining fees and other external activities. (Tab. 2).

Tab. 2. Variable costs of mining preparation [EUR/ tonne].

Costs/ tonne of gravel	2012	2013	2014	2015 FC
Diesel/ Gasoline	0,05	0,06	0,05	0,05
Electricity - variable	0,00	0,00	0,00	0,00
Production and distribution of materials	-0,01	0,00	0,00	0,00
External activities for gravel mining	0,02	0,03	0,03	0,02
Mining fees and licence charges	0,02	0,02	0,01	0,01
Total variable costs	**0,07**	**0,11**	**0,09**	**0,09**

Source: own processing from internal documents of mining company

Fixed costs of mining preparation represented the cost of production, machinery maintenance, costs of materials and other expenses of a cost centre. They are stable costs necessary to carry out the work in technological progress.

Tab. 3. Fixed costs of mining preparation [EUR/ tonne].

Costs/ tonne of gravel	2012	2013	2014	2015 FC
Working cost of production	0,14	0,19	0,18	0,28
Working cost of maintenance	0,00	0,00	0,00	0,00
Other personnel costs	0,02	0,00	0,01	0,01
Third party service	0,00	0,02	0,00	0,00
Third party service for maintenance	0,00	0,00	0,00	0,00
Material for maintenance	0,01	0,00	0,01	0,01
Other costs of cost centre	0,00	0,00	0,00	0,00
Products and other revenues	0,00	0,00	0,00	0,00
Total fixed costs	**0,17**	**0,22**	**0,20**	**0,31**

Source: own processing from internal documents of mining company

Production costs for mining and extraction included variable and fixed costs. Variable costs are also the costs of diesel and gasoline, electricity costs, distribution of materials, mining fees and other external activities.

Tab. 4. Variable costs of mining and extraction [EUR/ tonne].

Costs/ tonne of gravel	2012	2013	2014	2015 FC
Diesel/ Gasoline	0,23	0,20	0,24	0,24
Electricity - variable	0,00	0,00	0,00	0,00
Production and distribution of materials	0,01	0,00	0,00	0,00
External activities for gravel mining	0,60	0,34	0,29	0,29
Mining fees and licence charges	0,00	0,00	0,00	0,00
Total variable costs	**0,84**	**0,54**	**0,54**	**0,54**

Source: own processing from internal documents of mining company

Fixed costs of mining and extraction represented the costs of production, maintenance of machines, costs of materials and other expenses of the cost centre. They are stable costs necessary to carry out the work in technological progress.

Tab. 5. Fixed costs of mining and extraction [EUR/ tonne].

Costs/ tonne of gravel	2012	2013	2014	2015 FC
Working cost of production	0,37	0,47	0,42	0,65
Working cost of maintenance	0,00	0,00	0,00	0,00
Other personnel costs	0,02	0,03	0,03	0,04
Third party service	0,02	0,01	0,02	0,04
Third party service for maintenance	0,01	0,01	0,01	0,02
Material for maintenance	0,07	0,06	0,02	0,03
Other costs of cost centre	0,02	0,04	0,03	0,04
Products and other revenues	0,00	0,00	0,00	0,00
Total fixed costs	**0,51**	**0,61**	**0,52**	**0,81**

Source: own processing from internal documents of mining company

Production costs for processing included variable and fixed costs. Variable costs are also the costs of diesel and gasoline, electricity costs, distribution of materials, mining fees and other external activities.

Tab. 6. Variable costs of processing [EUR/ tonne].

Costs/ tonne of gravel	2012	2013	2014	2015 FC
Diesel/ Gasoline	0,10	0,09	0,12	0,12
Electricity - variable	0,41	0,44	0,39	0,39
Production and distribution of materials	0,01	0,00	0,01	0,01
External activities for gravel mining	0,00	0,04	0,00	0,00
Mining fees and licence charges	0,00	0,00	0,00	0,00
Total variable costs	**0,52**	**0,57**	**0,51**	**0,51**

Source: own processing from internal documents of mining company

Fixed costs of the processing represented the costs of production, maintenance of machines, costs of materials and other expenses of the cost centre. They are stable costs necessary to carry out the work in technological progress.

Tab. 7. Fixed costs of processing [EUR/ tonne].

Costs/ tonne of gravel	2012	2013	2014	2015 FC
Working cost of production	0,82	0,76	0,91	1,13
Working cost of maintenance	0,07	0,00	0,00	0,00
Other personnel costs	-0,03	0,02	0,05	0,07
Third party service	0,05	0,07	0,06	0,09
Third party service for maintenance	0,03	0,04	0,02	0,03
Material for maintenance	0,36	0,23	0,12	0,19
Other costs of cost center	0,08	0,08	0,06	0,09
Products and other revenues	0,00	0,00	0,00	0,00
Total fixed costs	**1,38**	**1,18**	**1,21**	**1,61**

Source: own processing from internal documents of mining company

Currently, the most important indicator for managers is the total cost indicator per tonne of finished product. Total costs are the sum of the total of variable and fixed costs. These are shown in Tab. 8 and are classified according to the cost of mining preparation, extraction and processing.

Tab. 8. Total costs of mining preparation, extraction and processing [EUR/ tonne].

Mining preparation				
Costs/ tonne of gravel	**2012**	**2013**	**2014**	**2015**
Total variable costs	0,07	0,11	0,10	0,09
Total fixed costs	0,17	0,22	0,21	0,31
Total costs	0,24	0,33	0,29	0,39
Extraction				
Total variable costs	0,84	0,54	0,54	0,54
Total fixed costs	0,51	0,52	0,52	0,81
Total costs	1,35	1,15	1,05	1,35
Processing				
Total variable costs	0,52	0,57	0,51	0,51
Total fixed costs	1,38	1,18	1,20	1,61
Total costs	1,90	1,75	1,72	2,11

Source: own processing from internal documents of mining company

In the following tables, we stated the number of costs, revenues, sales and profits for the last three years (Tab. 9). Based on these values, we calculated the cost-ratio indicator, cost-effectiveness and cost-profitability indicator (Tab. 10).

Tab. 9. Yearly costs, revenues, sales and profits for the last three years.

Year	2012	2013	2014
Costs [EUR]	395 000	414 000	506 000
Revenues [EUR]	596 000	636 000	905 000
Sales [EUR]	660 000	719 000	996 000
Profits [EUR]	265 000	305 000	490 000
EBITDA [EUR]	201 000	222 000	399 000

Source: own processing from internal documents of mining company

Tab. 10. Basic indicators of cost-ratio for the last three years.

Year	2012	2013	2014
h – cost-ratio [%]	66	65	56
Nu – cost-effectiveness [%]	167	174	197
RN – cost-profitability [%]	67	74	97

Source: own processing based on internal documents of mining company

Proposal of model solutions for cost-ratio of production process in mining company

Model 1: Combining the use of overheads and suppliers assistance in the production process. Transporting the material from the point of mining to the technological line is the responsibility of the external contractor. The distance between mentioned points is 4 km.

Extracting and processing remain in the overheads of the plant. The main indicators represent variable costs and therefore electricity, diesel and services of an external supplier. Then there are fixed costs, e.g., wages and salaries, costs of materials, maintenance of machinery and equipment and others. Total costs indicator indicated per tonne represented the 100 % of production volume (Tab. 11) in this model:

- Fixed costs – 1,69 €
- Variable costs – 1,61 €
- Total costs – 3,30 €

Tab. 11. Costs of production by 100 % production volume and combined production overheads.

Gravel plant - 100%	[EUR]
Wages and salaries	168 488,00
Other personnel	7 348,00
Third party service	12 000,00
Third party service for maintenance	10 000,00
Material for maintenance	17 500,00
Other costs of cost centre	3 000,00
Products and other revenues	-7 000,00
Total	**211 336,00**
Electricity	0,50
Diesel	0,46
External services	0,65
Total	**1,61**
Production per year 100 % [tonne]	125 000,00
Fixed costs per tonne	1,690688
Variable costs per tonne	1,61
Total costs per tonne	3,30

Source: own processing based on internal documents of mining company

Model 2: The second model represents an opportunity to keep the entire production process in overheads. In short, the plant shall provide their own machinery and equipment, employs own staff for operating and maintenance of machines. This could be the possibility to avoid the costs for external services.

The main indicators of change are variable costs per tonne fixed costs per tonne and the total cost per tonne. We also added a certain percentage of the costs and the wages and salaries, material and services for the maintenance of machinery and equipment and a certain percentage of the other costs of the cost centre. Because of increase, the number of own machines and equipment compared to the current situation, the cost of diesel will increase by 0,30 €.

Total costs indicator indicated per tonne represented in this model the 100 % of production volume (Tab. 12):

- Fixed costs – 2,25 €
- Variable costs – 1,26 €
- Total costs – 3,51 €

Tab. 12. Costs of production by 100% production volume and own production overheads.

Gravel plant - 100%	[EUR]	Note
Wages and salaries	230 890,96	137%
Other personnel	7 348,00	-
Third party service	12 000,00	-
Third party service for maintenance	12 500,00	+25%
Material for maintenance	21 875,00	+25%
Other costs of cost centre	3 450,00	+15%
Products and other revenues	-7 000,00	-
Total	**281 063,96**	-
Electricity	0,50	-
Diesel	0,76	+0,30
External services	0,00	-
Total	**1,26**	-
Production per year 100 % [tonne]	125 000,00	-
Fixed costs per tonne	2,2485117	-
Variable costs per tonne	2,2485117	-
Total costs per tonne	3,51	-

Source: own processing based on internal documents of mining company

Model 3: The third model represented the opportunity of the manager to transmit the mining preparation, extraction and transport to the production line on external suppliers by outsourcing. In this case, we disregard investment in machinery and also the cost of diesel will decrease. The economic advantage would be, that there is no needed to employ the six employees, which will be reflected in declining of personnel expenses. With machinery and equipment, it is also related to their service and maintenance, where there was also a visible decline in costs. On the other side, the costs for external services and the external contractor will increase naturally.

Total costs behave as follows (100 % of production volume, Tab. 13):

- Fixed costs – 0,98 €
- Variable costs – 2,43 €
- Total costs – 3,42 €

Tab. 13. Costs of production by 100 % production volume and an external supplier overheads.

Gravel Plant - 100%	[EUR]	Note
Wages and salaries	87 364,15	52%
Other personnel	7 348,00	
Third party service	12 000,00	
Third party service for maintenance	7 500,00	-25%
Material for maintenance	13 125,00	-25%
Other costs of cost centre	3 000,00	
Products and other revenues	-7 000,00	
Total	**123 337,15**	
Electricity	0,50	
Diesel	0,16	-0,30
External services	1,77	
Total	**2,43**	
Production per year 100 % [tonne]	125 000,00	
Fixed costs per tonne	0,9866972	
Variable costs per tonne	2,43	
Total costs per tonne	3,42	

Source: own processing based on internal documents of mining company

Discussion

The cost of the production process of the final products in a mining company is influenced by primary, secondary, and tertiary determinants of both internal and external environments. They influence the production capacity and also the elasticity of the production process in close interaction with the development of demand and managerial decision-making on the extent to which production performed in its own direction and directed by external suppliers, i.e. subcontracted.

The determinants mentioned above significantly affect the total cost of production that we have explicitly quantified in the three cost models mentioned above, taking into account the different combinations of the production process costs and external suppliers. A comparison of model solutions of costs for the production process of the mining company involved in the surface mining of gravel pointed to the following partial conclusions:

- if the external contractor carries out the transport of the raw material to the technological line and the mining and subsequent processing of the extracted raw material is carried out by the company, the total production costs will be 3.30 Eur/t; fixed costs 1.69 Eur /t; and variable costs 1.61 Eur / t (Model 1).
- If the complex production process is carried out by the mining company, the total production costs will be 3.51 Eur/t; fixed costs 2.25 Eur/t; and variable costs 1.26 Eur/t (Model 2).
- Moreover, if the entire manufacturing process, i.e. the preparation of mining, mining, and transport to the processing line, is carried out by an external contractor, the total cost of production will be 3.42 Eur/t; fixed costs 0.98Eur/t; and variable costs 2.43 Eur/t (Model 3).

These facts revealed that the use of an external supplier throughout the production process eliminated investments related to the machinery, its servicing and maintenance. However, it increased the costs of external supplies, leading to a drop in fixed costs of 1.27 Eur/t and an increase in the variable costs of 1.17 Eur/t tonne compared to the implementation of the production process by the mining company, which ultimately resulted in a decrease in total production costs of 0.09 Eur/t. However, comparing the monitored costs with the combined production process (general expenses and external contractor), fixed costs declined by only 0.71 Eur/t and variable costs increased by 0.82 Eur/t, resulting in an increase in total production costs of 0.12 Eur/t.

It can be stated that the most suitable way of realising the production process in the mining company is the combined realisation of the production process (Model 1) when the raw material load will be realised by external suppliers.

Conclusion

By the individual models, we observed the development and changes of individual items of fixed, variable and total costs. Along with this financial indicator, we monitored the effect of other factors such as the ratios of demand/ supply, quality/ price, market development and so on.

The models specified in this paper operated with data on the available level. However, by this approach, it is possible to analyse each cost item, simulate the development of various factors, and based on the results take adequate decisions, both on the production and sales, as they are closely linked. This model (in case of gravel plant) should be further enhanced at least by grading curve of feedstock and by its impact on the structure and production capacity and, of course, by the impact on the market as the envisaged structure of demand and average selling price of products. After the process of application, the accounting legislation is thus possible

modelling of revenue, inventory and cash flows and thus the profitability of the operation, which is necessary for calculating the return of past and planned investments.

In summary, the first model provides the best results of the cost-ratio with the value of 3,30 € of total costs, so the combined overheads seem to be the most suitable suggest for this kind of the company. On the other side, the worst results are found in the second model with own production overhead costs, at the level of 3,51 € of total costs.

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