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COST ESTIMATION IN COAL MINING: THE EVOLUTION OF QUICK EVALUATION METHODS

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COST ESTIMATION IN COAL MINING: THE EVOLUTION OF QUICK EVALUATION METHODS

ABSTRACT

New developments in mining involve many uncertainties from reserve estimation, technological characterization of the ore, and local, economic, and political factors. Such developments rely on large amounts of resources and have long maturation periods. These factors highlight the necessity to periodically reassess projects throughout each phase of their operation from a technical and economic point of view. The decision to start the investment or continue investing time and resources in a mine needs to be revised in light of new information that will be aggregated throughout the course of its development. For such revision to be possible, especially in the earliest stages of the project there is the need to use quick evaluation methods which, although less accurate, may confirm the whether or not to continue more demanding studies and project implementation. The paper presents and discusses the method termed "Quick Evaluations", and discusses in a special way the use of techniques originally proposed by O'Hara and Stebbins in coal projects.

KEYWORDS

Mineral Evaluations, Coal Mining, Parametric Method

INTRODUCTION

The first feasibility studies for a given mining project are initiated after an evaluation of mineral reserves generates interest. The purpose of such studies is to determine whether further geologic investigation, mine planning, metallurgical studies and other studies will recompense their investment.

As these studies are only preliminary, many characteristics within them lack sufficient details to safely define the mine layout, process flowchart, final product quality, and many other important aspects for the development of the project. Therefore, these factors rely on the experience and skill of the engineers and qualified persons which perform the study.

Many proposals for classification systems or project planning exist. Their authors, in general, propose an expected level of accuracy of the cost estimates calculated during every step. The models (Reynolds and Frew), presented below, exemplify two different project phase classification systems or studies.

Reynolds (1990) proposes the following project classification phases or studies during the related engineering development levels with the indicated precision in investment values:

Table 1 - Accuracy of mining studies during different phases (Reynolds, 1990)

Project Phase	% Engineering Concluded	Precision (%)
Conceptual	0	± 50
Pre-Feasability	0 – 30	25 – 30
Feasability	30 +	10 – 15
Detailed Study	60	± 5

Note that by Reynolds' proposition the term "conceptual" corresponds to a phase which is very preliminary to the project, where practically speaking no proper engineering studies exist and the calculated costs reflect only the order of magnitude expected. By the term "engineering", Reynolds' implies the dimensions or scale, although preliminary, of the facilities or equipment required for the project.

The same term "conceptual", as defined by Frew (presented in 1990), corresponds to a more advanced stage of evaluation, providing therefore values, expectedly, more accurate.

Table 2 – Description of different mining estimates (Frew, 1990)

Type of Estimate	Description	Precision (%)
Indicative	Based on imperical data from other projects	± 30
Preliminary	Based on conceptual projects and price/cost estimations	± 20
Workable	Based on flowcharts, sizes of known equipment, and arrangements and estimated prices for equipment and materials	± 10
Definitive	Based on constructive engineering drawings and final price	± 5

QUICK EVALUATIONS

For assessments at the initial stage, most authors propose empirical rules, sometimes called "rules of thumb" with the rule of six-tenths being the most used, as described by Mular (1978) as in Equation 1:

$$\text{Cost 1/Cost 2} = (\text{Capacity 1/Capacity 2})^{0,6} \qquad (1)$$

This simple rule compares the investment that should be analyzed for a stipulated production capacity, with another known and existing investment of similar operation and physical and political environment, stating that: the relationship between costs (investments) is proportional to the 0.6 power of capacity ratio.

Many other "rules of thumb" have been proposed, many of which are applicable for only one specific type of mineral (Metal, Coal, Gold, etc.).

To assist in this initial phase of the project there are several published papers based on empirical formulas from actual operational statistics, mostly in the form of tables, graphs or formulas for the purpose of establishing purchasing values and operating costs for equipment, facilities and services, as well as the costs for design and planning of equipment and facilities. Normally, these papers define the acquisition and operating costs according to predetermined type and size of equipment or facilities quickly. Such definitions are termed "quick evaluations" within the technical literature.

The "Comparison Method" proposed by Stebbins and Schumacher (SME 2011) is based on comparison of similar projects with adjustments to balance differences. To facilitate understanding, within this article are presented tables and graphs that provide indications for acquisition values, operating costs, equipment sizing, facilities and services. The background information includes: listing of operations, supplies and equipment, deposit information, and proposed development. A good example, for reference, is the "Mine and Mill Equipment Costs - An Estimator's Guide, Western Mine Engineering Inc" (2015). The background information is combined with labor costs, productivity, supply costs, and equipment prices (Stebbins, 2011). Accuracy of the method depends on the basis of the information available from published works, empirical formulas, and statistics of actual operations.

In the other hand, the so-called "Parametric Methods" estimate derived costs through generalized algorithms. Most present the following relationship: "Cost = x (parameter)y". The variable "parameter" can represent many design characteristics (length, mass, etc.), and most often represents a production rate.

The variables x and y are values derived from known data of statistical evaluations or estimated from field operations. Examples of this methodology may be found in the U. S. Bureau of Mining Cost Estimating System (CES USBM 1987) and the O'Hara Model (1980).

The publication of the USGS (Circular 9298 Simplified Cost Models For Prefeasibility Mineral Evaluations) contains: models for well drilling, models of underground mines, models for milling, cost equations for access roads, power lines, tailings dams and also adjustment factors to the variation in transport distances for open pit models and variation in depth of mining to underground models.

Another known parametric method, the O'Hara model, proposes costs derived from general parameterization algorithms. Using this method, T. Alan O'Hara in 1980 developed mathematical models to estimate mining costs. From O'Hara's formulas MAFMO software - Modele d'Analyse Financière sur Micro-Ordinateur was developed at the Centre of GEOTECHNIQUE et d'Exploitation du Sous-sol of the Ecole Nationale Superieure des Mines de Paris, which effected estimates of CAPEX and OPEX in addition to financial risk analysis. Currently, a group of researchers from the Federal University of Rio Grande do Sul is developing software called MAFMINE which is based on MAFMO and the O'Hara formulations with adjustments made to capture modern mining technology costs.

THE MAFMINE SOFTWARE

Development of MAFMINE software involved the use of a computer model known as client-server. Clements (2003) client-server is a computational model which separates clients and server which are interconnected usually using a computer network. Each instance of a client can send data requests to the connected server and wait for an answer. In turn, the server can accept these requests, process them and return the result to the client.

In the case of the software MAFMINE, the server is running one or more programs that share their resources with customers. The client does not share their resources, but requests the contents of a server or service function. Clients therefore initiate communication sessions with the server which waits for incoming requests. All data are stored on the server, which typically has much higher safety controls that most customers. Servers can better control access and resources to ensure that only clients with the appropriate permissions can access and change data.

Some features present in MAFMINE software:

- Investment Cost Estimation
- Operating Cost Estimation
- Export of Data for Risk Analysis (in the implementation phase)
- Save project settings
- Change of base year and country estimates
- Print report data
- Model Customization for different users (in the implementation phase)

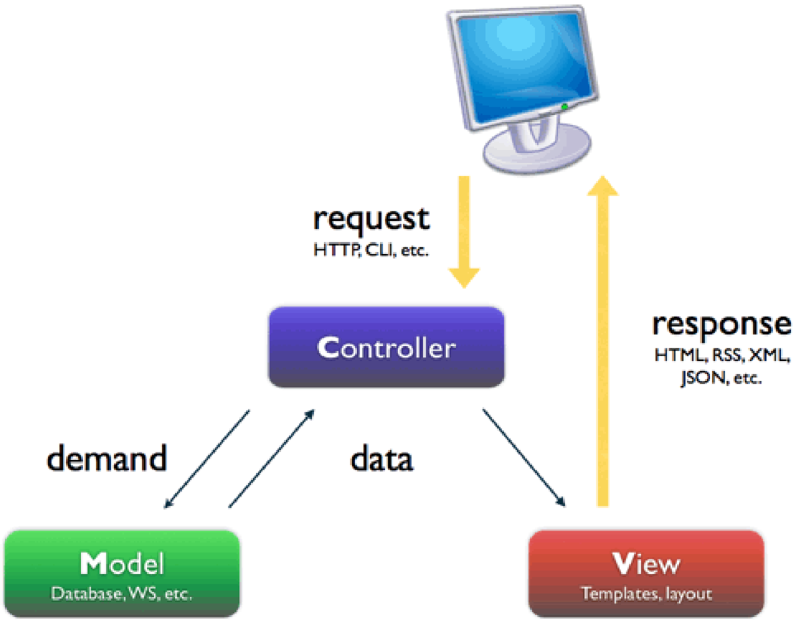

Figure 1 – Operating Software Architecture of MAFMINE

RESULTS AND DISCUSSION

Below are shown the results obtained with the O'Hara model through the MAFMINE software. The results are compared in two distinct situations both in terms of mineralization and in mining technique. In the first operation (CASE 1), the conceptual study of an open pit copper mine (performed by a consulting firm) is tested by comparing the CAPEX between the consultant and MAFMINE. Then (CASE 2) compares the OPEX from MAFMINE to the result obtained by applying Stebbins methodology (SHERPA) and the actual OPEX from an underground coal mine. Both Cases 1 and 2 are focused on operations in Brazil.

CASE 1

- Daily ore production: 12,000 t
- Daily waste production: 48,000 t
- Initial stripping: 12,126 Mt, 80% w / o use of explosives and 20% w / use of explosives
- Ground conditions of beneficiation plant: flat with less than 3 m of earthmoving.
- Ground support of building foundations: resistant soil with low humidity
- Climatic characteristics: tropical
- Processing plant capacity: 10,224 t / day
- Work Index - Wi = 16
- Electricity: high voltage provided by the existing system located 50 km away
- Water availability: it was assumed that the water supply sources are rare. The new water intake (not recycled) will be located 20 km from the plant.

Table 3 – Values proposed by case 1 investment consulting firm (Carriconde, 2010)

ITEM	CHARACTERISTICS	VALUE (USD)
Mining Equipment		59.185.860
Initial Stripping	4.575.000 m³	10.982.000

Crushing Circuit		18.093.636
Grinding Circuit		19.467.865
Flotation Circuit		6.391.176
Thickening and Filtration		6.452.010
Substation	15000 KVA	3.000.000
HV Line	50 km	2.750.000
Water Catchment	10.000 m³ / dia a 20 km	10.000.000
Water Tank	50.000 m³	700.000
Pumps	600 m³/h	2.676.000
Tailings Dam	(initial dam)	1.500.000
Land Acquisition	120 hectares	600.000
Laboratory		600.000
Auxiliary Buildings		1.800.000
Machinery and Tools (workshops)		900.000
Shipping/Transport	(balances, scales, chargers, etc)	1.200.000
Environmental Studies		350.000
Project (implementation/deployment)		17.483.826
Contingency	10 %	16.413.237
TOTAL INVESTMENT		180.545.610

Table 4, below, shows the results of the MAFMINE estimation. The overall results obtained by the application are very similar to those obtained by the conceptual study. The total value of investments made by MAFMINE exceeds the conceptual study by 10.85%.

Table 4 – Report generated by MAFMINE

Investment Costs	M U$ (2008)
Open Pit Mine	
Land Preparation	1,54
Pre Stripping	24,85
Equipment	402,303
Maintenance Facilities	117,637
Viability Studies	49,587
Project Supervision and Provisional Costs	70,539
Pre-production	39,188
Total	94,315
Beneficiation Plant	
Land Preparation	18,448
Foundations	107,299
Crushing facilities, Storage and Transfer	134,126
Buildings	89,416
Grinding Equipment and Stockpiling of Fines	246,554
Concentration Unit	57,791
Thickening and Filtration Unit	14,903
Concentrate Storage Unit	0,9738
Sedimentation basins	23,844

Viability studies	58,049
Project Supervision	78,165
Pre-production	43,425
Total	88,176
Infrastructure	
Electricity	72,948
Water Tanks	52,168
Auxiliary services	27,698
Access routes	21,913
Staff Accommodations	0,2
Total	17,673
Total Investment	200,164

Some individual values suffer a bit more difference, such as pre-stripping and mining equipment. These are items that should be investigated in the model. As the model becomes old, items such as electricity and pumping can also be updated for greater precision in the results.

CASE 2

Year – 2013
Underground Coal Mine
Method- Room and Pillar
Country – Brazil/Santa Catarina State/ Criciúma City

Table 5 – Case 2 value comparison, Stebbins, MAFMINE, and Actual

Mining Method	Project	Production ROM (t/year)	Actual OPEX (US$ 2013)	Stebbins (US$ 2011)	MAFMINE (US$ 2012)
Room and Pillar	Verdinho	1,047,568	19,74	20,18	19,80

CONCLUSION

Although the results are less accurate than those obtained with a conventional design, the so-called "Quick Evaluations" are less accurate but easier and applied faster. They require little information but when combined with experience can provide good results. In addition, the results can be evaluated and adjusted with each compilation by documenting all assumptions and calculations of the sources of the estimated costs.

Reliability is proportional to the quality of information available on the specific nature of the orebody. Reliability also increases with the level of effort involved in evaluating the information. The more there is information available to be evaluated, the greater the reliability of the estimated costs. So cost estimation constitutes an interactive process design and assessment throughout the mining project's development process.

At this point it should be noted that reliable results can only be achieved with good understanding of the specific characteristics of the deposit and diligent work.

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