
ASPECTS OF EVALUATING MINING PROJECTS

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ABSTRACT

Economic evaluations of mining projects incorporate the examination and assessment of the technical, financial, social and political aspects of the environment in which the mineral deposit is situated.

This paper outlines some technical inputs that form the basis for financial evaluation. These include estimates of mineable ore, production rates, performance of production systems, capital and operating costs and the revenue. The financial assessment, set within the fiscal regime of the host country, will generate standard project evaluation criteria such as NPV and IRR. The paper emphasises the re-iterative process of evaluation and the need to avoid costly detailed engineering until such time as proposal to mine has been approved.

ÖZET

Madencilik projelerinin ekonomik değerlendirmesi, cevher yatağının içinde bulunduğu çevrenin teknik, mali, sosyal ve politik yönlerinin incelenmesi ve değerlendirilmesi ile koşuttur.

Bu çalışma finansal değerlendirmeye temel teşkil eden bazı teknik girdileri ortaya koyar. Bunlar çalışılabilir rezervlerin, üretim kapasitelerinin, üretim sistemleri performanslarının, sermaye ve işletme maliyetlerinin ve gelirlerin yaklaşımını kapsar. Ülkenin mali politikalarına göre şekillenecek mali değerlendirme net bugünkü değer ve iç kârlılık oranı gibi standart proje değerlendirme kriterlerini üretir. Bildiri, değerlendirmenin zaman içerisinde tekrar eden yapısını ve madencilikte yapılacak yatırımın onaylanmasına kadar yapılacak masraflı detay mühendislik işlemlerinden kaçınma gereğini belirtmektedir.

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1. INTRODUCTION

A mine project is the scheme of facilities needed to mine and extract minerals from defined orebodies: it normally requires a special investment or allocation of resources such as capital and completion within a specified time period. Mine projects are different from 'exploration' projects which usually have the definition of mineralisation or mineral deposits as their objective.

The evaluations should:

- a) provide a base on which economic decisions are made,
- b) identify and quantify risk, and
- c) establish project priority.

At least four aspects of the environment in which the project is evaluated may be identified — technical, financial, social and political. To a certain extent they overlap. Together they form the economic base for an evaluation:

a) Technical aspects. These include the geological setting of the deposit and technology that determines the production system.

b) Financial aspects. The amount, type and cost of capital available for a mining project will depend partly upon the financial environment at the time the investment is undertaken.

c) Social aspects. These involve the social costs and benefits derived from a mining project. The development of infrastructure, the utilisation of local labour and material resources can provide positive contributions to society. On the other hand mines produce tailings and effluents that may have a negative impact on the natural environment, and.

d) Political aspects. By political aspects are meant the mineral, fiscal, foreign exchange and employment policies of the local and national governments where the deposit is situated. They are particularly important to governments participating in mineral projects.

The investigation of a mineral resource involves considering a number of technical factors — the ore, its location, the mining and extraction systems and the market. Estimated costs and revenues form the input to a basic project model that indicates possible cash flows over the period of developing and operating a mine (the model's output). Provided all non-negotiable costs, revenues and, possibly, inflation and taxes are included, the basic model can reflect the actual value of the ore. This might be an adequate end-point for the evaluation of an internal or company project.

When a project interfaces with other parties — host governments, lenders or joint-venturers — it is necessary to expand the basic model to incorporate negotiable monetary, financial and fiscal aspects and, possibly, a value for social and political benefits deriving from

the project as a whole. The economic model of a mining project should allow further information to be incorporated and evaluated as it becomes available.

Figure 1 is a simplified model of a mining system showing the main inputs of geology, market and investor. The number of loops' in the system implies that various technical scenarios should be tested.

The advantage of developing models for mining projects is that they can be used to vary one or more inputs and examine the effect on different evaluation criteria — the procedure known as sensitivity analysis

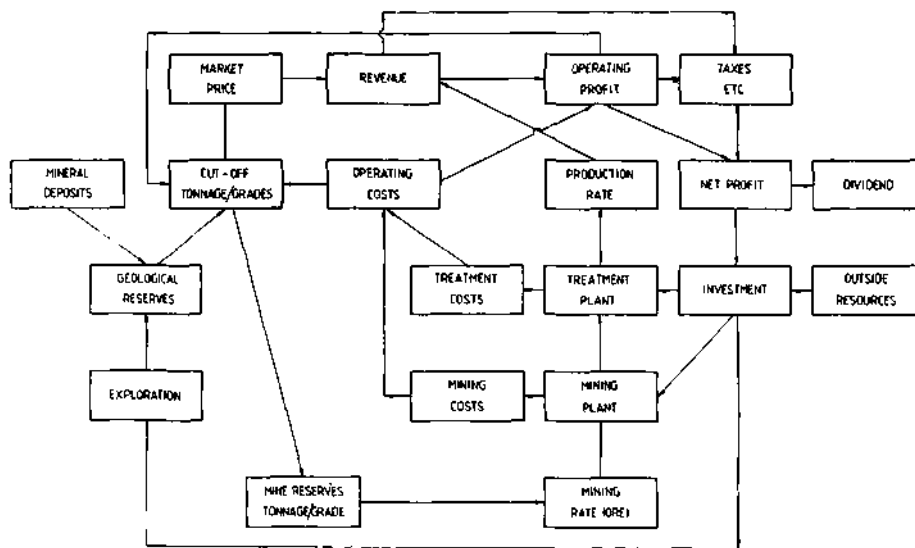


Figure 1 — Simplified model of a mining system

2. TECHNICAL INPUTS TO EVALUATION

2.1. The Mineable Reserves

In a mining project it is the ore that forms the major resource input to the mining process. The mining method will be determined mainly by estimates of the size, shape, strength, depth and orientation of the orebody and its geological environment. It is relevant to note that mining will usually recover only part of the mineable ore and that the ore will be diluted by internal or external waste. The production rates and life of the operation will depend upon the

quantity and quality of mineable reserves. Run of mine ore, consisting of rocks and minerals of varying density, quality and grade, feeds the process plant that will recover only part of the valuable mineral content. A model of the orebody is pre-requisite for modelling and evaluating a mining system.

As soon as an exploration programme delineates a zone of mineralisation and attributes a grade or value to its content, conceptual studies for a mining project can commence and a simple evaluation model formulated. This can be constructed in such a way that it can grow in complexity as more information is acquired.

Mineral resources and ore reserves have been classified in various ways and phrases such as 'possible', 'probable', and 'proven' or 'measured', 'indicated' and 'inferred'.have been used for many years (U.S. Bureau of Mines, 1980).

Evaluations will normally be undertaken on indicated and inferred 'reserves'. The indication of continuity between samples allows the evaluator to estimate quantities of the resource, often at varying cut-off grades. These form the basis for feasibility studies. The main purpose of measured or proven reserves is for detailed planning of one to five year stopping or mining operations.

It is useful if exploration and mining geologists can indicate statistically the accuracy of their estimates. The initial problem for the project evaluator is to extract global estimates of the reserves and variances at agreed confidence levels. The author uses grade-tonnage curves that give an estimate of the average grades of the material above various cut-off grades. Great care has to be taken However to ensure that if such material is to form a reserve it is in fact extractable using known mining methods.

2.2. Production Rates

The selection of possible production rates for mining projects forms part of early decision making. It might be assumed that the production rate (s) should be found to optimise a financial criterion such a Net Present Value or the Internal Rate of Return. However other factors have to be taken into account also. The life of the mine (LOM), the average production rate (APR) and the total mineable reserve or the 'expected ore tonnage' (EOT) are related as follows:

$$\text{APR} = \frac{\text{EOT}}{\text{LOM}} \quad (1)$$

As a mine develops it is usual for further mineable reserves to be discovered. Thus APR and LOM will be modified as time passes.

Factors relating to the life of the mine include:

- a) Legal limitations. Mining leases are often granted for periods of 15-25 years with the possibility of extensions,
- b) Market or product life, In the early 1970s it was recognised that the demand for uranium as a primary source of radio-active fuel for nuclear power would drop off within 15-20 years,
- c) Political stability. Changes of government might result in a change in ownership or changes in the taxation laws,
- d) Strategic objectives. The reality of the many mining situations is that they create economic and social development that is difficult to stop.

Factors that relate to the production rate include:

- a) The accessibility of the ore. Shaft dimensions limit the ability to hoist rock and ore. Morgan (1986) investigated nine underground mines and found that the average rate at which they deepened was 27m per year,
- b) Economies of scale. Many authors indicate that both capital and operating costs per unit of production tend to decrease as the production rate increases (O'Hara (1980), Straam (1978) etc),
- c) The ability to transport or sell the planned production at the rate being proposed,
- d) Limitations to the capital available may well limit the size of a mining operation This often leads to a strategy of starting at one rate and then financing increases from profits.

Taylor (1980) addressed this problem and derived an empirical guide which he called 'Taylor's Rule'. This is as follows:

$$\text{LOM} = 0.2(\text{EOT})^{0.25} \quad (2)$$

The average production rate can be derived from equations 1 and 2:

$$\text{APR} = 5(\text{KOT})^{0.5} \quad (3)$$

Taylor (1986) found that the production rates for a wide range of mines were within 20% of the 'rule' figure.

As the project moves from the 'conceptual' to 'feasibility' stage it is often found that the alternative production rates centre around the capacities of the shafts or major processing units such as a primary crusher. Early mining of higher grade material is one way of improving returns on investment.

2.3. The Production System

Once a range of feasible production rates has been selected the major capital equipment can be sized and the main services requirements established. Indeed, as inferred earlier, some equipment and services may have already determined the throughput.

It is not the purpose of this paper to outline the numerous mining and processing methods and systems available for converting the 'ore' into a saleable product. The evaluator of a mining project will need to know that these are realistic. This could involve engineering in a wide range of disciplines — mining, processing, mechanical, electrical and electronic, civil, architectural etc. Each facility will need to meet the production or service needs of the project at least during the critical early years. The following aspects are important:

a) capacity. There is a temptation for engineers to over-design as this outcome is less serious than that resulting from plant being under capacity. This problem can be overcome by establishing an acceptable range of production rates for any system,

b) mining dilution, recovery and efficiencies of the systems,

c) appropriateness. It is normally not good practice to develop innovative and relatively untried technology at a new mine nor is it sensible to rely on sophisticated processes and equipment at a mine that is unlikely to have sufficient technical support close at hand,

d) safety and health. The mine may well be planned for an area where there are limited safety and environmental regulations. These may need to be imposed on the project,

e) resources. Provision must be made not only for the initial investment and operating requirements but also for the replacement of equipment and for improvements to the systems as time passes,

f) time. A realistic schedule is needed covering investigations, negotiations and permissions, detailed design, procurement, construction, commissioning and operation.

The development of the proposed production system will depend upon the information available for preliminary and eventual detailed design. The evaluation process needs to be managed so that the interaction between differing technical areas is coordinated.

2.4. Cost Estimation

The design basis for a project is probably the most important technical criterion for the accurate estimate of the cost of the outcome. A major purpose of a conceptual study is to identify 'the' optimum design for an eventual project. To change the scope of a project during the construction phase can be exceedingly costly.

The project will involve a number of types of expenditures that will be incorporated in a forecasted cashflow. Generally they can be classified into two categories, ie capital and operating or working costs. Capital costs usually refer to expenditure on major equipment and facilities and authorised by the company's directors. Operating or working costs provide the resources for the ongoing production and are under the control of the operating manager. How they are handled in the cashflow will depend upon the fiscal regime of the country in which the mine is situated and any special agreements negotiated. The following types of cost are typical:

- a) Preproduction Capital: the investment needed to bring a mine into production.
- b) Working Capital: the funds to provide for stocks of consumable materials and spares, funds for salaries and wages etc. both at the start of and during production operations,
- c) Replacement Capital: the predetermined expenditure needed to replace plant and equipment worn out or becoming obsolete during the operating phase.
- d) Improvements Capital: needed for ongoing significant improvements to the mine, plant or infrastructure. It can be justified by technical, financial, social or political reasoning.
- e) Operating Costs: identified by function — mining, treatment, engineering, administration, etc; or by resource — labour, supplies, equipment, services, overheads etc.

Forecasting the cost of the resources needed for a project is time consuming. However there are a number of standard approaches that can give estimated costs at varying accuracies for project evaluation. There seems to be a lack of publications that record estimating performance and little justification for the accuracy assigned to the various methods. The author has used the following:

- a) Proration of historical estimated or actual costs using linear or power factors to handle changes in scale. This approach is well described by Straam (1978) and O'Hara (1980). The relationship between the costs can be expressed as follows:

$$\text{Cost of facility} = \text{constant X (production rate) 'power'}$$

The traditional cost estimation 'power' is 0.6 ("sixtenths rule"). However Straam and O'Hara use a wider range for different types of facility, equipment or operating cost. These can lie between 0.4 and 1.0.

- b) Factored Estimates based on the (sometimes installed) equipment cost. A quotation (or 'prorated' estimate) is obtained for the equipment. The cost of installation may then be estimated in hours

at known labour costs. Factors are then used to calculate the associated costs of construction. These would include site preparation, foundations, buildings and steelwork, cladding piping and insulation, electrical, instrumentation and control, painting, design and management.

c) Unit costs are often developed for engineering construction materials such as concrete, pipework, for excavation work such as tunnels (by cubic metre or metre advance) and for labour. Books, such as Spon's Engineering and Equipment price books, list unit costs for different sizes of equipment, pipes, buildings etc). This form of estimating is very appropriate for operating costs.

d) Cost adjustments are necessary to convert estimates at one place and time to that of the project. These include-

- location differences such as infrastructure, availability of off-site utilities, wages, transport, travelling distances and terrain;
- technical and scope changes; technology may improve as time passes and even at an early stage there may well be significant scope differences;
- financial adjustments such as exchange rates that differ from year to year, import taxes, inflation (normally handled by published indices);
- economic climate changes result in different competitive quotations for contract work or prices for equipment.

e) Detailed estimates involve the detailed engineering of facilities and equipment as well as labour, consumables and services for operating costs. The quantities of material are 'taken off drawings and estimated. Exact specifications of equipment are developed to the stage that suppliers can give either budget or actual quotations. Labour hours are based on previous experience and costed usually at unit (all-in) rates.

The evaluator's strategy in cost estimation can be directed at identifying the relatively few major cost items that account for a major part of the total equipment, facility or project cost. For example in preparing a preliminary cost estimate for an open cast coal mine and washing plant it was found that 7 out of 33 (about 22%) of the major cost centres accounted for 70% of the capital requirements. It included an accurate estimate of the dragline consisting of a quoted price for the machine, a factored estimate for transportation, a unit price for ballast and a currency adjustment for the date of the estimate. This a combination of estimating methods gave an estimate that was intended to fall within 3% of the expected actual cost (AAC 1978).

The difference between the estimated and actual outcome of a project in terms of productive capacity, quality of work, time and

cost will depend upon a number of factors. Lock (1978) identified the following: design errors, construction mistakes, material or component, failure, cost escalation, changes in scope and omissions.

In order to bring the cost (s) to a 'best estimate' value an 'allowance' is normally added to provide for omitted items that the estimator from experience knows will be identified later (foreseeable). However it is still necessary to provide for unforeseeable elements of cost within the defined scope of work. These are known as a 'contingencies' and estimated by the design engineers for each item or facility.

Detailed engineering design and cost estimating can account for 5-10% of a project cost. Cost estimating for a conceptual or pre-feasibility study should be undertaken at a level that is appropriate for the remainder of the study where ore 'reserves', recoveries, product specifications and product prices may well be only partially known. In the case of an apparently marginal proposition, time need to be spent on those elements that will be critical to the next stage. As the project moves towards feasibility so more accurate estimates of the various components will be needed, including a few detailed estimates of major components. However the bulk of the detailed design and estimating for the whole project should not be undertaken until a project go-ahead is given.

2.5. Revenue Estimation

Estimating the costs for a mining project may seem difficult but estimating the revenues that may accrue can be very risky. There is the problem of the selling price of the product a few years after the decision to commence construction. Although it may be possible to negotiate initial contracts for the sale of the product at prices based on various formulae, the operation will eventually have to be able to cope with the normal commodity supply and demand within the context of substitution, competition and economic cycles.

Secondly, many mines produce mineral products that require further processing and the transportation to the processing plants. The costs of these additional activities can account for over 50% of the saleable mineral or metal cost of production. Lewis (1980) analysed the smelter terms over a decade for copper, lead, zinc and tin concentrates.

In making decisions regarding the continued exploration and investigation or the development of a mineral deposit the evaluator may consider different revenue scenarios. Crowson (1986) suggested that a mineral project should at least be able to break even at the lowest predicted price regime.

3. TAXATION

It is possible to compare two similar internal projects within a company without taking taxation into account. However when comparing international ventures the tax regimes of the host countries add a critical component to the evaluation Walrond and Kumar (1986) compare the fiscal arrangements in six developing countries with two 'developed' ones. They found that the tax system in some countries could cause all but the richest deposits to stay unmined.

A number of means by which a government can gain direct benefit from a project can be considered.

- a) Taxes on Revenue — Royalties.
- b) Taxes on Resources — Import Taxes, Value added tax.
- c) Taxes on operating profits less allowances.
- d) Withholding taxes.
- e) 'Free' ownership where the host country does not finance the equity but still has a share of the ownership and dividends from the project.
- f) Lease payments for land and mineral rights.

It is wise to understand the main implications of the taxation systems in setting exploration targets for potential ventures. This is especially so where there is limited scope for negotiating mining agreements.

4. EVALUATION

The basis for a financial assessment is the estimated annual cashflow of the project over its life. The inputs to the cashflow have been discussed with the exception of loans, repayment and interest. Spencer (1987) gives an equation for the cashflow as follows:

Annual cashflow = Capital Expenditure + Revenue — Operating Costs — taxes — increases in working capital + loans — loan repayment — interest.

Spencer also mentions a number of values and indices that can be used in financial evaluation. These include:

- a) Maximum cash exposure,
- b) Payback period,
- c) Net Present Value (NPV) at a predetermined discount rate and,
- d) Internal Rate of Return (IRR).

Another value measurement that could be used is the Present Value Ratio (PVR).

A decision has to be made regarding the need to escalate the annual cashflow in line with forecasted cost inflation and product

price increases. In the author's opinion cashflows should reflect estimates of the annual inflation and the price of the product at the time it is sold. One reason for this is that costs and product prices may increase or decrease at different rates. Another reason is that tax allowances are usually based on the expenditure at the time it is and can not be inflated annually.

As intimated earlier it is best to examine a number of technical scenarios and production rates. The change in a value, such as the IRR, resulting from a change of an input parameter, such as price, can be plotted on a graph to show how sensitive the project is to a particular parameter.

5. CONCLUSIONS

The evaluation of potential mining systems requires the calculation of a number of technical inputs, such as mineable reserves, production rates, recoveries, costs and revenues. These, together with the tax regime, form the basis for an evaluations based on projected cashflows. Although not discussed at length in this paper further investigations in the social and political spheres can not be neglected.

The paper has underlined the need for continuing low cost evaluation of mineral deposits during the feasibility stage. Before each stage of the development of the deposit a conceptual assessment of the technical, financial and possibly the social and political environments should be made. These should give direction to further in formation gathering and research.

Proving extensive ore reserves, detailed engineering and costing should not form part the project investigation phase. They should be avoided until a feasibility study indicates that such work is necessary in order to develop a mine.

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