ECONOMIC MODELLING AND ITS APPLICATION IN STRATEGIC PLANNING

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Abstract
Mining executives often have a difficult task determining what the strategic objective of the business should be as this can be impacted by the prevailing market conditions. In addition, they have no mechanism to quantitatively ‘test’ the impact of this strategic decision on the business and understand the underlying dynamics. During the commodities bull run of 2003 to 2008 the strategic objective may have been to grow the long term value of the business (NPV) through increased tonnage, acquisition and finding new reserves, which all came with an increasing fixed cost base. Now with the financial crisis upon us and the collapse of commodity prices and demand, executives have adjusted their strategies as ‘cash is king’ and short-term cash flow, in some instances at the expense of long term value, is the order of the day. For many mining companies, mine closures, reductions in production and cost cutting exercises are now the focus. In many instances, management do not have an ability to rapidly test different strategic alternatives to ‘test’ the impact on value, unit costs, reserves and profitability at the operational level and optimise the underlying trade-off variables. Economic modelling of the complete business value chain is a means of linking the operational ‘reality’ and strategic choices, so that the full impact can be assessed. This paper describes some of the challenges facing mining executives and how economic modelling can be applied to make decision making more rigorous.

1. Introduction
For detailed operational planning to be effective and meet the company’s strategic objective, the executive must give planning guidelines which gives the ‘objective’ for the operational planning. In the current financial crisis this ‘objective function’ may be to reduce production, reduce unit costs and capital spend and maximise short-term profitability. In fact, without a full understanding of the impact of these strategic options, these may not be possible, as each individual objective may yield a different operational plan. A trade-off that always seems to appear in tough economic times is to reduce development as this will lead to reduced unit cost of production but without a full understanding of the longer term impact. Strategically it may make sense to reduce development to ensure short-term survival but at the same time an understanding of the long-term impact is required and when is the latest that development must be ramped up again to ensure sustainable of long term production. This is often not understood due to fragmented planning and the turnaround time to ‘test’ different strategic alternatives.

An economic model integrates strategic planning and the reality of the operations and allows scenario planning and ‘what-if’ analysis to be done which will enhance the strategic decision making process.
An economic model is a mathematical representation of the real world. In the mining context it is a model of the complete business, operation or shaft and integrates all production, labour and financial metrics into a holistic representation (Lane et al., 2007)

2. Why Economic Modelling

Effective mine planning that meets the strategic objectives requires an integrated view of all mining disciplines (Finance, Mining, MRM, Engineering, HR) across the full mining value chain so that the underlying trade-offs can be clearly understood and optimised. Mining companies need to maximise value from a finite, non-renewable asset, whilst operating in a market environment characterised by variable metal prices (G I. Smith et al., 2007). This is particularly challenging in the mining industry because of the following.

2.1 Fragmented Planning in Mining

The mining environment is especially prone to the dangers of fragmented planning because of its inherent technical detail and complexity, combined with a high degree of operational and market uncertainty.

Several factors combine to make operational and strategic planning in the mining industry particularly challenging:

- Mining involves the exploitation of a finite resource in order to create value. Therefore significant capital is required at regular intervals through the life of the mine not only to increase production or improve efficiencies but also just to maintain the current production levels.
- Mining involves uncertainty with regards grade, geology, geotechnical and hydrogeology which makes it difficult to predict production output and operational cost with certainty.
- Generally mining companies are price takers with price driven by speculation and supply and demand dynamics. This makes the planning of revenue also difficult.
- As mines age and grow in physical size and depth, operational costs generally trend upwards over time, which puts additional pressure on margins. This is counteracted by improvement in technology for mining and processing that requires capital investment.

Planning is therefore fragmented along the following two dimensions:

- Scale and Time – detailed operational plans are usually short-term (1-3 years) and are performed by the mine personnel on a monthly and annual basis, whereas large capital projects are the realm of project teams constituted as required. Most often the personnel responsible for these two planning horizons are not integrated resulting in a mismatch of project and operational parameters and objectives.
- **Functional Scope**—Whilst there is a degree of co-operation between engineers (Mining) and accountants (Finance), they do not operate as a single team. Generally the more operational and short-term the focus, the more technical the orientation at the expense of in-depth consideration of issues relating to commercial risk. Evidence of this is seen in the deployment of sophisticated graphical mine planning software where economic functionality (costing, labour, revenue) is limited and in most instances applies as average unit cost. The short-term labour and cost budget is done by the finance and HR functions and is a consequence of the mine scheduling choices made with limited regard for the trade-offs. The costing for long-term planning is often done by the mining engineering function and pays minimal respect to the short-term budget.

This generally results in the following three planning worlds (Figure 1 below).

- **Operational Planning**—This is the detailed planning done at the operation and deals with the reality on the ground with regards geology, mine design and scheduling and labour and cost budgets within a given mine capital configuration or footprint (for example capacity constraints). The business plan is the output of this planning realm.

- **Capital Planning**—Whilst operational planning focuses on planning within the given configuration, capital planning looks at planning the capital configuration. Planning activities involve planning individual capital projects to the portfolio of projects.

- **Strategic Planning**—this is the most macro, long-term and externally focused and involves strategic decisions with regards capital projects, an understanding of external market dynamics regarding supply and demand and competitors. This strategic planning realm provides the objective for all other planning and is probably the least tangible and most difficult to quantify.

The business planning functions and timetable are therefore designed as an integrating process to ensure alignment of all three planning realms. The challenge being that this is a long drawn out process as no mechanism exists to test the impact of decisions in one realm and the impact on the other planning realms. For example a strategic decision can be made at a high level but the impact on the operations is only really understood once the detailed operational planning has been done. Therefore, in many instances there is a mismatch between the strategic objective and the operational planning. This results in a drawn out planning cycle that loses its rigour as plans are manipulated and costs cut uniformly, as deadlines looms, without understanding the true drivers of cost.
2.2 The Mining Executives Dilemma

In addition to planning being particularly challenging in the mining industry for the reasons just mentioned, the mining executive has a dilemma – “What should the strategic objective be” and how will this be impacted by the current market conditions. Figure 2 below shows four very feasible strategies but each requires a strategic trade-off and would result in different operational plan.
### Desirable Objective Functions

<table>
<thead>
<tr>
<th>Objective</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase Tonnage</td>
<td>But this will involve spending more capital (and perhaps reducing capital efficiency)</td>
</tr>
<tr>
<td>Maximize Capital Efficiency</td>
<td>Selecting only highly efficient capital projects will reduce the life and perhaps even value</td>
</tr>
<tr>
<td>Maximize Value</td>
<td>Maximum value may sacrifice tonnage and mine life</td>
</tr>
<tr>
<td>Short-term Profitability</td>
<td>But may destroy long-term value</td>
</tr>
</tbody>
</table>

**Figure 2** – All Desirable Objective Functions but require operational trade-offs.

#### 2.3 Strategic Decisions can lock in future Operational Performance

Figure 3 below demonstrates that strategic and capital planning decisions made at the time of developing the mine will in fact determine in many instances the actual operational performance parameters possible during operation. For example, once the shaft capacity has been decided this will constrain the operation to a maximum tonnage.

**Figure 3** – Cascading choices that determine operational performance
2.4 Optimising the Whole Value Chain

Due to their inherent complexity, safety issues and accountability, mining companies are generally operated as 'silos' across the complete value chain often with each mine and processing division managed as a separate entity. Operational KPIs are aligned with these objectives without a full understanding of the impact up or down the full value chain. A particular operation may be maximising a certain ore type as this impacts their unit cost KPI, but this may be at the expense of processing efficiency and therefore decrease overall group value. Maximising the value of each individual component of the business may not yield the maximum value for the group (Lane et al., 2007).

The complexity around alternative ore sources, routings, processing options and different products becomes even more complex to optimise without a model of the complete business value chain.

3. Economic modelling Links Strategic Planning and Operational Reality

Due to this inherent complexity of mine planning, the task of quantifying different strategic objectives or "what-if" scenarios is onerous. The ability of the mine planning system to do this effectively is determined by its level of detail, extent that all financial and production variable relationships are linked and turnaround time to generate scenarios. Ideally different 'what-if' strategic alternatives need to be generated and compared with regards to value, unit cost, production profile and stress tested against changes in commodity prices.

An appropriate constructed and calibrated economic model of the business would allow different scenarios of strategic options or 'what if' scenarios to be generated to test the impact on the operational parameters. Likewise the impact of changes to operational parameters can be assessed in terms of strategic fit. This model can be a standalone calculator or integrated into the mine planning and financial systems allowing monthly updating of the budget.

An economic model is a mathematical representation of the real world. In the mining context it is a model of the complete business, operation or shaft and integrates all production, labour and financial metrics into a holistic representation (Lane et al., 2007).

The foundation of an economic model is its mechanism to translate complex technical input data, company business rules and assumptions as well as Macro Economic assumptions into credible financial outputs (Hudson et al., 2008).

It is important that the 'drivers' under the control of management are modelled appropriately so that the outcome can be linked to tangible initiatives. For example if the strategic objective is to reduce unit cost, then the model cannot simply reduce unit cost. The dynamics and relationships between panel efficiency, blasts per month, production output, no of teams and absolute costs need to be modelled so that actual driver of unit cost reduction can be determined appropriately.
4. Application of Economic Modelling

4.1 What is a Economic Model

An economic model integrates all the relationships between the physical (shaft, operation), operational (efficiencies, constraints, advance, tonnes) and economic variables (costs, revenue, capital). In essence, thousands of individual relationships with inputs and outputs could make up a complete economic model as depicted in Figure 4.

![Economic Model Diagram](image)

Figure 4 – An Economic model integrates all aspects of the business value chain

4.2 Model Designs for Different Business Problem Applications

Depending on the business application (strategic objective), different economic model structures exist to satisfy the model output and trade-off requirements. This will determine the level of detail, the focus, visual representation, data requirements, trade-off variables and output variables required in the model.

For example different model designs could be (figure 5 below):

- **Driver Tree** – this type of model clearly links up the ‘root cause’ or detailed drivers of why the output variable is changing. This is a good way to understand what drivers are under the control of management and how they influence the outcome.

- **Portfolio Model** – these types of models consolidate the complete business in terms of all underlying operations/mines and often all future capital projects and allows at a strategic level, trade-offs around project selection and scheduling, closing of mines or operations and/or changes in commodity prices.

- **Value Chain/Process Model** – the focus of this type of model is to represent all the relationships in each and between each activity through the complete value chain of the business. This would allow trade-offs between activities, to understand the impact on the overall business. For example a change in the
blasting pattern may increase unit cost of blasting but will increase plant recovery resulting in far greater value add.

**Geological/Area Model** – this type of model is critical for mine optimisation relating to decisions around where to mine and schedule and the impact on unit costs and value.

**First Principle Model** – this is a very detailed model of the actual dynamics underlying an activity and is used for detailed operational performance and optimisation and OPEX cost determination. For example, a mechanised mining model of the machine moves and utilisation by face. Outputs being machine hours, utilisation, spotting time etc.

**Market Model** – this is the typical supply demand type models that look at determining commodity price through supply and demand dynamics. Some of the outputs beside price would be industry cost curves etc.

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**Figure 5 – Different Economic Model Designs**

4.3 **Optimisation Using an Economic Model**

Any planning activity, even if not explicit, is in fact optimisation, as there are often opposing effects or consequences that planners will have to trade-off. Optimisation involves the maximisation of an objective function (NPV, profit, tonnes, unit cost etc) through the trade-off of the underlying variables (resources, capital, ore type, schedule etc).

For optimisation to be effective an integrated view of all economic and production variables with ‘realistic’ relationships and business logic is required so that the underlying variables can be adjusted and the impact understood.

Each of these models can be used for deterministic optimisation which involves the user testing different scenarios to identify the best, or depending on the type and
complexity of the problem, linear programming or genetic algorithm optimisation. This paper will not cover the optimisation techniques.

As with model design, so too different levels of optimisation apply in a business from portfolio optimisation of the group portfolio, asset optimisation of the operation configuration to individual activity and resource optimisation as depicted in figure 6.

**Figure 6 – Different Levels of Optimisation in the business**

### 4.4 Using the Economic Model to identify Root – Cause Effect.

A model is generally used for forward looking problems or scenarios where the impact of changes on the underlying variables is understood from a planning or strategic perspective. Figure 7 below is a simple model that indicates that for the model, in this example from left to right, changes to volume or efficiency will calculate profit.

Now if the model was used from right to left, in the example, and using actuals achieved, then this model now becomes a diagnostic tool that identifies why there is a variance in profit between budget and actuals for the month or YTD or what is causing the profit variance month on month.

So an appropriately structured model that is realistic in terms of the business logic and relationships could be integrated into the financial and mine planning systems to be utilised as an effective diagnostic tool to assist management to identify the root cause of operational trends or variance.
Figure 7 – A model can be used to understand ‘what’ is happening

So the integration of an Economic model into the business would allow the plan – monitor – replan loop to be closed as depicted in figure 8. With the economic model being used to generate the economics for the mine plan, then used to diagnose the ‘cause’ of variance to plan and the ability to understand this impact on the plan for the month or year and then the ability to rapidly replan if required.

The ultimate goal being to do rolling production scheduling and budgeting on a monthly basis.
5. Conclusion

Economic modelling is a crucial tool in all aspects of decision making as it allows a quantitative assessment of the impact of a decision as it links the reality of the operations to the strategic objectives of the business. It does not make decision making easier but makes the process more rigorous and many alternatives can now be tested and compared.

Economic modelling is not just confined to strategic decision making. It can be used to perform detailed operational and asset optimisation and understand operational trade-offs that exist.

An economic model integrated into the planning process can link the plan – monitor – replan cycle and make rolling planning a reality.

6. Acknowledgements

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7. References

Bondi E, “Applying Modelling and Simulation Technology to Add Value in the Mine Planning Environment” Cyest internal white paper.


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Started career in 1990 as an engineer at Anglo American in project management for new mines within the group. Completed an MBA in 2000 and left Anglo as one of the 3 founders of Cyest Corporation. Is a director of Cyest and manages the Cyest Analytics business area which specialises in enterprise modelling and optimisation consulting and software solutions.