Reserve Estimator™ Using the Proteus Environment™

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Abstract
The authors present the design of a new Whittle product - Reserve Estimator™.

As background, a review of reserve estimation theory, benchmark DCF analysis, and current Whittle optimization tools is given. The sometimes conflicting relationship between economic design objectives and reserve estimates is examined. There is a need for a simple tool that aids strategic ‘what-if’ style analysis of the potential economic value of mineral deposits. Two application areas are then identified:

1. **Investment Analysis**
   From the investment analyst’s perspective, a tool is required for ranking the potential of competing prospects. The traditional JORC reserve estimate alone is shown to be a very crude indicator of the likely economic performance of a project.

2. **Guiding an exploration drilling project**
   Over-drilling of an exploration target is wasteful and expensive. The decision as to the optimal placement and depth of the next drill hole can best be guided with regard to the possible economic benefit it could confer to the resource estimate.

Details are then presented for the design of Reserve Estimator™, a new package that will integrate very simple geological modelling, traditional Lerchs-Grossmann pit optimization and DCF analysis in a straightforward manner. A key part of the Reserve Estimator™ system is the Proteus Environment™, a Graphical User Interface based on current research and ideas in the field of Human-Computer Interaction.

Introduction
If you are contemplating doing a feasibility study or detailed mine design, especially one for which you wish to publicly quote the reserve, then you are well advised to use professional engineers, equipped with the most sophisticated tools available. These tools will of course include pit optimizers and life-of-mine schedulers and the input will be based on carefully calculated resource models, detailed geotechnical models and professionally forecast economic parameters. This will yield the most reliable forecasts of cash flows and Reserve estimate.
However there are applications for pit optimizers and life-of-mine schedulers, in other environments, where the data is sketchy or hypothetical, and where the users are not professional mine designers. The users include potential investors in mining projects, and field geologists. The tools would allow investors to experiment with data and to gain a better understanding of the economics and technical constraints of mining. In the case of field geologists, the tools could aid in decisions as to whether geological clues are worth investigating further. This is reserve estimation with a high level of abstraction, not for the purposes of mine design or quoting figures to the public, but to guide personal investment decisions and exploration programs.

Background

Whittle Three-D

The Three-D pit optimizer is the best known of the Whittle optimizing engines, based on Lerchs & Grossmann (1965). Three-D takes an input resource block model together with a description of the required average slopes and produces the three-dimensional pit outline that maximises the total value of the blocks within it. Thus it maximises the total cash flow for the pit. The values of the input model are the cash flows that are expected to result from mining and possibly processing each block. Blocks of sufficiently high grade have positive values and waste blocks have negative values.

Empirically, if the life of mine is three years or less, Three-D gives a firm basis for pit design. If the life of mine is longer, then the discounting of future cash flows starts to affect the final design.

DCF Analysis

DCF Analysis takes account of the fact that a dollar that we receive today is more valuable to us than a dollar that we might receive in a year’s time, and expected cash flows are discounted by an amount which increases with time. The rate is expressed as a discount rate, such as ten per cent per year.

The discount rate can be defined or determined in various ways, including:

- The risk-adjusted discount rate consists of two components. The ‘opportunity cost’ is the rate you could earn (risk free) with the capital elsewhere. The ‘risk adjustment’ is an additional amount to account for the geological, geotechnical, economic and political risks associated with the project.

- The cost of capital is the rate of return investors require to supply the funds for that project. Like the risk adjusted discount, it includes an allowance for risk associated with the project.

DCF Analysis can be used in two ways:

1. Determining whether a single investment be added to the investor’s portfolio. In this case, the choice of a discount rate has to properly reflect the risks associated with that opportunity, relative to the investments already in the portfolio. The investment will be added to the portfolio if it has an NPV greater than zero.

2. Determining which one of two or more mutually exclusive opportunities should be taken up. This includes the case where, for example, several different schedules are being considered for the same mine. The opportunities are mutually exclusive, because only one of them can be implemented. In this case, the risks associated with each alternative will be similar and the use of a single discount rate for all alternatives is not uncommon, and the choice of a discount rate is less critical. The investor would choose the alternative with the highest NPV.
The formula for calculating the Net Present Value (NPV) for a project is given in Equation 1.

**Equation 1: Net Present value**

\[
NPV = \sum_{i=1}^{n} \frac{R_i}{(1+k)^i} - C
\]

Where:

- \( R_i \) = cash flow for period \( t \)
- \( k \) = discount rate
- \( C \) = initial capital expenditure

There is a wide coverage of DCF analysis in the general literature. Torries (1998) gives a good treatment of the use of NPV as a merit measure in the minerals industry.

**Reserve Estimation & Decision Making**

Whittle, D (1997) showed there was a feasible economic domain for mine designs and strategies. In particular it is possible to categorise designs as 'risk averse', 'risk neutral' or 'high risk' based on where the final design resides in the NPV/Total Tonnes domain. Figure 1 shows the NPV/Tonnes domain.

![Figure 1: Range of feasible reserves and their corresponding NPV values](image)

Obviously, exactly where a particular Ore Reserve lies in the NPV/Tonnes domain is of critical interest to the analyst evaluating a project.

**User Requirements**

In designing the Reserve Estimator system, substantial market research was carried out with contacts across a number of industries. In addition to the traditional users of Pit Optimization software (mining companies, operators, consultants) interviews with practitioners from the finance industries were also conducted.

These potential users have a number of things in common:

1. The users have an interest in the economic potential of a resource.
2. The resource information that is available is based on limited empirical data. It may be in the form of a block model, but it may just be an idea, a verbal description, or a table of values.
3. The users' knowledge of detailed mine operation and processing economics may be very limited.
4. The users will have limited time or inclination to perform detailed mine design.

A number of target application areas were then identified for the product, which are described in the following sections.

**Existing Three-D Users**

Current users of Three-D are usually working at mines of limited life span and thus have minimal use for DCF analysis. These are traditional users of pit optimization and, although they would benefit greatly from improvements in the interface, do not represent a new market for Whittle products.
Interestingly, two new application scenarios were identified:

**Scenario I: Investment Analysis**

In spite of the JORC code, at present there is no universally accepted standard for calculating reserves reported by mining companies - The code states that "An 'Ore Reserve' is defined as that part of a Measured or Indicated Mineral Resource which could be mined, inclusive of dilution, and from which valuable or useful minerals can be recovered economically, under conditions realistically assumed at the time of reporting" JORC (1996). Whittle, D (1997) argues that depending on the planning objectives of the mining company, significant variations in compliant Reserve estimates are possible. In particular, a mine design that maximises NPV will probably be very different to one that maximises Total Tonnes (see Figure 1). Hence the traditional Reserve estimate is deficient in estimating the likely economic performance of a project from the viewpoint of the Investment Analyst.

From the perspective of the investment analyst, a tool is required for better ranking the potential of competing prospects. By combining a simple modelling tool, Lerch-Grossmann pit optimization and DCF analysis, the Reserve Estimator system will allow analysts to perform their own benchmark calculations for ranking competing projects.

**Scenario II: Guiding an Exploration Drilling Project**

Pattern in-fill drilling during the resource definition phase of a project can be unnecessarily wasteful, particularly when directing a limited exploration budget. Joukoff & Hanson (1997) showed how it was possible in the case of an open pit to use Whittle Four-X optimization as a cost effective way to select drill targets that will improve confidence in mineralisation. A strategy for drill targeting was developed for an elongated gold deposit. Drillholes are simulated for pessimistic and optimistic scenarios to give respective pit outlines. The mineralised areas between the two outlines then become the zone of priority for infill drilling.

Over-drilling of an exploration target is wasteful and expensive. The decision as to the optimal placement and depth of the next drillhole can best be guided with regard to the possible economic benefit it could confer to the resource estimate.

The anticipated solution for this problem is to use the interactive modelling tool in Reserve Estimator to take the current model (the 'pessimistic' case above) and extend it at depth to generate a new 'optimistic' model. If the optimistic model results in a deeper pit design with sufficiently greater NPV, it can be argued that drilling holes to prove the model extension is justifiable.

**System Components**

Evaluation of the economic value of a resource requires the creation of some sort of reserve estimation, which in turn requires the creation of some sort of mine design and schedule. The most efficient way to produce a mine design is by using a pit optimizer and the representative mining schedules can be produced by applying some long established heuristics. Existing pit optimization products do not suit the needs of the identified potential users of Reserve Estimator, hence the impetus for its creation. The product does not include any new or complex algorithms. Instead, it is a rearrangement of proven mathematical techniques into a package that is much more accessible.

The package offers the following:

a) The ability to perform benchmark DCF analysis.

b) The ability to create very simple resource block models from scratch as well as being able to import resource models from other packages.
c) Access to a large range of reserve ‘templates’. These templates contain typical costs, prices, processing and mining scenarios for different situations, which as a first pass, can be applied to create a Reserve estimate from a resource file.

**Data Nodes**

The Reserve Estimator data design consists of four separate modules. Each of these is represented as a ‘node’ on a navigation tree. Each node is shown as a distinctive icon graphic, and has an associated tab folder for parameters and output when that node is selected. These four types are listed below:

- **Project**
  This node comprises parameters that are global to the project being evaluated. This includes date of creation/update, a description for the project and some explanatory notes.

- **Resource**
  This contains parameters controlling the import and manipulation of block models in addition to specifications of the types of units used and rock regions within the model. A report tab displays summary information about the model in use.

- **Reserve**
  This contains parameters to control which subset of the Resource will be considered as the Ore Reserve. Controls are supplied for mining, processing and financial (DCF) analysis.

- **Estimation**
  The estimation node contains tabs for graphical display and reports for analysis of the Reserve.

See Figure 2 for a screen shot of Reserve Estimator showing these different types of nodes on the left, with a Resource node selected.

A key part of the design was to provide two different views of the parameters to be manipulated. These are described as ‘Novice’ mode and ‘Expert’ mode. The reasoning here is to facilitate ease of use for new users by limiting the number of settings that need to be made in order to get a reasonable result quickly.

In Novice mode, a minimal subset of parameters is presented to the user, with reasonable assumptions made for the more involved controls. In Expert mode, a more exhaustive set of parameters is available. Expert mode gives the user a level of control similar to that available in the current Three-D package.

**Interface Software Design Issues**

A key part of the Reserve Estimator system is the Proteus Environment, a Graphical User Interface based on current research and ideas in the field of Human-Computer Interaction.

**HCI – Human-Computer Interaction**

The quality of the Human-Machine interface for practically any application plays a significant part in how – and how well that application will be used.

An example – using the timer control on a VCR. Most people find it easy to use a VCR to play/forward/rewind and record. Often they do not find it easy to use the timer function to record a programme at some date and time in the future. For most VCR machines, it is not obvious from the interface how to specify the required information, nor is the feedback given by the system obvious. It is not surprising, then, that most people find out if the system worked by testing the tape – after the event.

Contrast this to the modern car which has dozens of controls (central locking, air-conditioner/ventilation, CD/radio, lights, accelerator, brakes, etc.). Most people can usually master most functions rapidly by a quick look at the manual or usually by trial and error when driving. The thing that makes the ‘car’ interface easier to use is that feedback is usually immediate and more obvious! The next thing is that people who have driven other cars know
what to expect. Models may vary, but the position for controls is usually similar, and similar symbols are used to indicate their function.

The goal of good interface design is to create a system with controls that have obvious effects and provide useful feedback. Computers are now used by a wide variety of different kinds of people, and not just technical boffins. It is important to design to support the needs knowledge and skills of the target users. The objectives are twofold - increased productivity and improved quality of results.

Norman (1992) identifies two guiding principles for good design of controls.

Visibility - controls must be clearly visible and map closely to their effects.

Affordance - controls should suggest their function.

Norman showed how getting these factors right has a significant effect on the quality of the final system.

GUI Metaphors

Metaphors are common in GUI design. We are all familiar with windowed interfaces, pop-up menus, pull-down menus, icons, and the like. Two particularly interesting metaphors are the tree and tabbed folders.

The Tree

Ben Shneiderman coined the phrase “direct manipulation” in the early 1980s. After analysing successful computer systems that captured the imagination of users, he found that the best had a few things in common. Firstly, each had a strong visual representation of the problem domain or ‘world of action’. The objects or actions of interest were clearly shown on the screen. Secondly, there was rapid feedback and minimal use of the keyboard wherever possible. He proposes that systems that use these guiding principles are effective because “they engage our strong skills of perceptual recognition”.

An important representation that is easily comprehended by people is the hierarchical tree. These structures are very common and provide a visualisation tool that helps to organise complex data by taking advantage of our strong perceptual skills. By adding the ability to use the mouse to select and interact with parts of the tree, a very powerful tool for data navigation and management is created.

Tab Folders

Tabbed folders are an extremely powerful visual metaphor for organising large numbers of parameters. Each set of related parameters is grouped on a separate pane or ‘tab’. Each tab has an associated title. Multiple tabs are grouped to form a ‘folder’. The user navigates between tabs by clicking on the desired title. The individual tabs are displayed prominently with a separate border thus giving a good level of visibility. The border is shaped similarly to that used in the very familiar personal organisers. Note the central ‘tabbed area’ in Figure 2. The use of the tab metaphor, with shading and overlapping to create a 3D effect, and colour to indicate selection, combine to suggest that clicking on a tab will display its contents - this is an example of good affordance.

Proteus Environment Workflow Paradigm

The Whittle Proteus Environment is a graphical user interface based on these two visual workflow paradigms - Tree based Navigation and Tab-Folder for Detail:

Navigation of the general workflow is accomplished by using a graphical tree representation that can be interrogated with the mouse/pointer. Using a tree structure assists the user with organising their work, particularly when analysing multiple hypotheses.

a) Each step or hypothesis in the analysis is represented by a ‘node’, displayed as an icon.
b) Related nodes are connected to a common parent; connections are shown as lines.

c) As the user tests new hypotheses, a hierarchy of nodes is built up.

d) Branches on the tree can be collapsed/expanded to reduce/increase the amount of detail displayed.

e) Browsing of earlier work is performed by clicking on the required node with the mouse.

f) Unwanted nodes can be deleted from the tree (pruning).

g) Existing nodes can be copied from one place on the tree to another (grafting).

**Detail** of any particular node is displayed on one or more panes in a Tab-Folder.

a) Logical grouping of related input parameter information on individual Tabs.

b) Used to contain output as well.

(See Figure 2 for a screen shot of Reserve Estimator showing these components.)

Early tests have indicated that adopting the Proteus Environment technology with the FXPE release of Four-X have achieved significant gains in usability and productivity.

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**Figure 2: Typical Reserve Estimator Screen.**

*(Note the navigation tree on the left, and the tabbed panel for parameters on the right. In this example the user is defining a set of optimistic parameters for reserve calculation).*
In one test case, a group of six engineering students at RMIT were able to learn the general principles of how to use and operate the FXPE software in a morning with fairly minimal instruction. For details of FXPE, refer to the paper by Darren McRostie entitled ‘Risk Analysis using the Four-X Proteus Environment’ in the proceedings for this conference.

**Stage II – Simple Modelling Tool**
The first release of Reserve Estimator will be limited to using existing grade models generated by third-party packages. Stage II of the system will incorporate a very simple model generation tool. This facility will enable the creation of very simple models for evaluation. The key idea is to provide a tool that will enable the practitioner to see the economic implications of various hypothesised grade model scenarios.

**Conclusion**
The importance of good software engineering, including client research and HCI design has been a guiding principle during the development of the Whittle Proteus Environment. This technology has been pivotal in the creation of the next generation of Whittle products. The design of Reserve Estimator has been undertaken with careful reference to the underlying theoretical structure of strategic optimization and analysis, and an appreciation of the needs of the anticipated users of the system. The product should stimulate interest in mine design issues among non-mining professionals, and may even help to improve communications between practitioners in differing fields.

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**References**


