# Risk analysis in the mining industry

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## Synopsis

South Africa's Mining Industry operates in an uncertain world. The industry is buffeted by problems regarding retrenchments, unemployment, low productivity, rising costs, volatile exchange rates, commodity prices and government regulations.

With these uncertainties facing the decision makers, what does applied technology offer the industry's management?

Modelling languages with risk analysis have been available for decades, but in the past their use has been very expensive, requiring large mainframe computers and lots of computer time. Today, PCs and laptops have incredible power, which makes interactive risk analysis affordable and viable for all enterprises, whether small or large.

- What is risk analysis?
- What is Monte Carlo simulation?
- What kinds of computer models need to be created to use risk analysis and Monte Carlo simulation effectively?

This paper addresses these questions and illustrates, with a practical example in the mining industry, how risk analysis techniques can be used to support decisions in the climate of uncertainty.


## Introduction

No one knows better than people in the mining industry that mining is a very risky business indeed. And, not surprisingly, planners in this industry have used risk analysis extensively for decades. For example, at the 1969 International Symposium on Computer Applications and Operations Research in the Mineral Industry there were several papers on risk analysis.

Now here's the puzzle. The mining industry hasn't became less risky over the years. In fact, it has become more uncertain. So why are the techniques of risk analysis developed over the last few decades not used more widely? Indeed, the development of computer technologies make the use of risk analysis even easier than in the '70s when a risk analysis for the Goldfield's Black Mountain project took 24 hours for only 500 iterations. Today a similar simulation with 1 000 iterations would take less than 10 seconds. All this makes it more inexplicable.

## The problem

With the demise of mainframe computers in the early '80s and the proliferation of spreadsheets on desk stations within organizations, the complete corporate planning model gave way to 'silo' departmental models that tend to sub-optimize the operations by not treating the enterprise as a whole. At the same time, management began to lose the plot by outsourcing the key decisions to consultants.

So why is this a problem? Because domain models rarely interact with models in other domains and the top-down planning models are mostly superficial accounting commentaries they are unsuitable for risk analysis. If uncertainty estimates are applied at this level, the simulation results will generally reveal a much riskier profile because system interdependencies are buried in the operations.

In addition, if Monte Carlo simulation is contemplated, the model must be able to change itself in response to randomly generated data.

## What we have to do

There are a number of things we have to do to use computer-modelling simulations and risk analysis effectively.

- There has to be top man support and involvement. This means that the top management team must provide sufficient time and resources to the analysts and model builders
- All the factors that affect the outcome of the business have to be taken into account. This means that we will have to model the physical processes of the enterprise. The decision makers must also participate in defining the relationships between the variables affecting the evaluation variable

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- Best practices of coding must be adopted and the model documented at every stage so that none of the team is excluded. No cells should have hard coded data and all the input data should be in a separate input block where they can be easily accessed
- The model must be tested against reality with suitable data. Last year's data must reproduce last year's result.

Now the financial model is risk analysis enabled.

## Risk analysis

What is risk?

Risk is the amount of uncertainty in the outcome of a result.

There are traditional attitudes to risk.

- Express it verbally, which is tantamount to ignoring it. This could be at best misleading and at worst dangerous
- Analyse it formally, which is difficult to do. Few organizations have the mathematical knowledge and then the data used to derive the result are uncertain anyway
- Use Monte Carlo simulation to calculate a statistical forecast of the decision variable.

Monte Carlo simulation is a term describing computer simulation that uses random numbers generated by the program. The term Monte Carlo originated at Los Alamos during the Manhattan Project when scientists used a roulette wheel to generate random numbers. Now, most relevant software applications have random number generators embedded.

Why use risk analysis at all? Why not just ignore it? What useful information does it give the decision maker?

Risk analysis does give valuable additional value in contrast to a more usual one number evaluation answer. It provides the decision makers with an idea of the range of possible outcomes of a decision together with a probability estimate of the likelihood of results different from the average occurring.

Using risk analysis is best illustrated by an example. Professor G. Davis of the Colorado School of Mines together with visiting students developed the model used below.

## Mline evaluation example

### *Problem description*

A mining company is considering developing a small underground gold mine with an estimated reserve of a million ounces of gold. Although a geological survey was done, there is still some uncertainty about the size of the orebody. This translates directly into an uncertain project life.

In addition: capital, mining and milling costs, working capital, production rates, gold price, ore grades and recoveries are uncertain.

The objective is to value the mining project on a discount cash flow (DCF) basis, taking into account the impact of the geological and economic uncertainties.

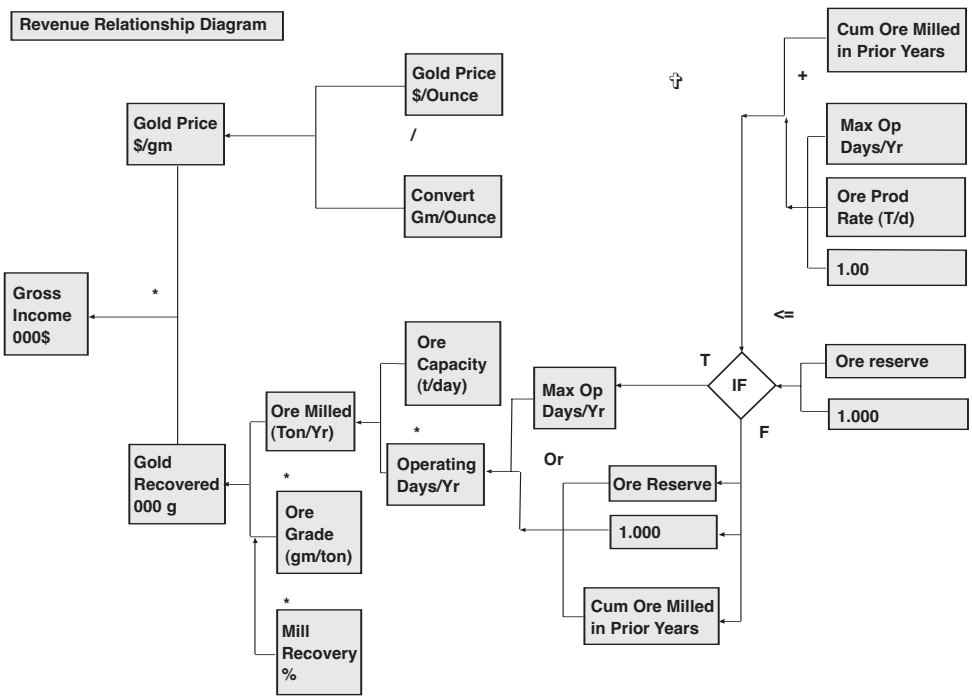
### *Building and testing the model*

Once the objectives of the model have been specified and the relationships between variables that can affect the outcome of the result have been defined, the model can be coded.

The diagram below traces the relationship between the ore reserve and the gross income of the mine.

The coding practices that should be adopted are:

- No hard coded data in the logic part of the model
- If possible, use variable names instead of cell references
- Use multiple worksheets
- Use charts.



The charts in the middle of this page show the net cash flow and the net present value profiles of the mine project evaluation.

***The best estimate deterministic value of the mine investment***

| | | |
|---|---|---|
| 89 | | |
| 90 | NPV @ 10% ($ 000) | 17,289 |
| 91 | IRR | 17.90% |
| 92 | | |

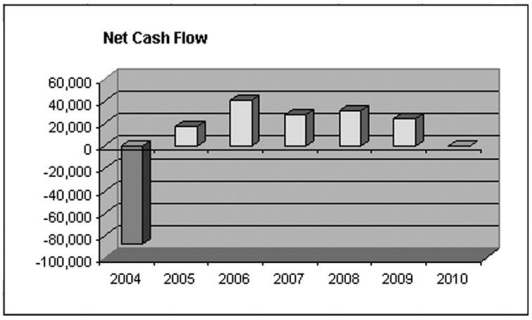
The results using most likely estimates show that the internal rate of return for the mine evaluation is 17.9% and a net present value at 10% of $17m.

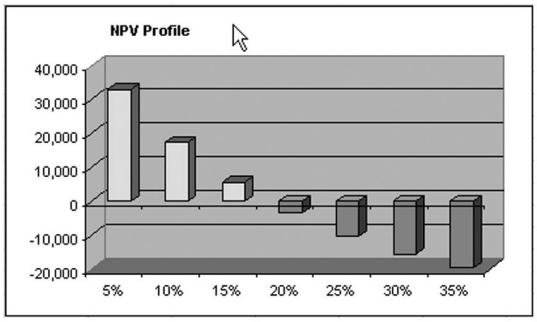
Once the model has been tested and calculates reasonable results, the uncertainty estimates can be entered into the model.

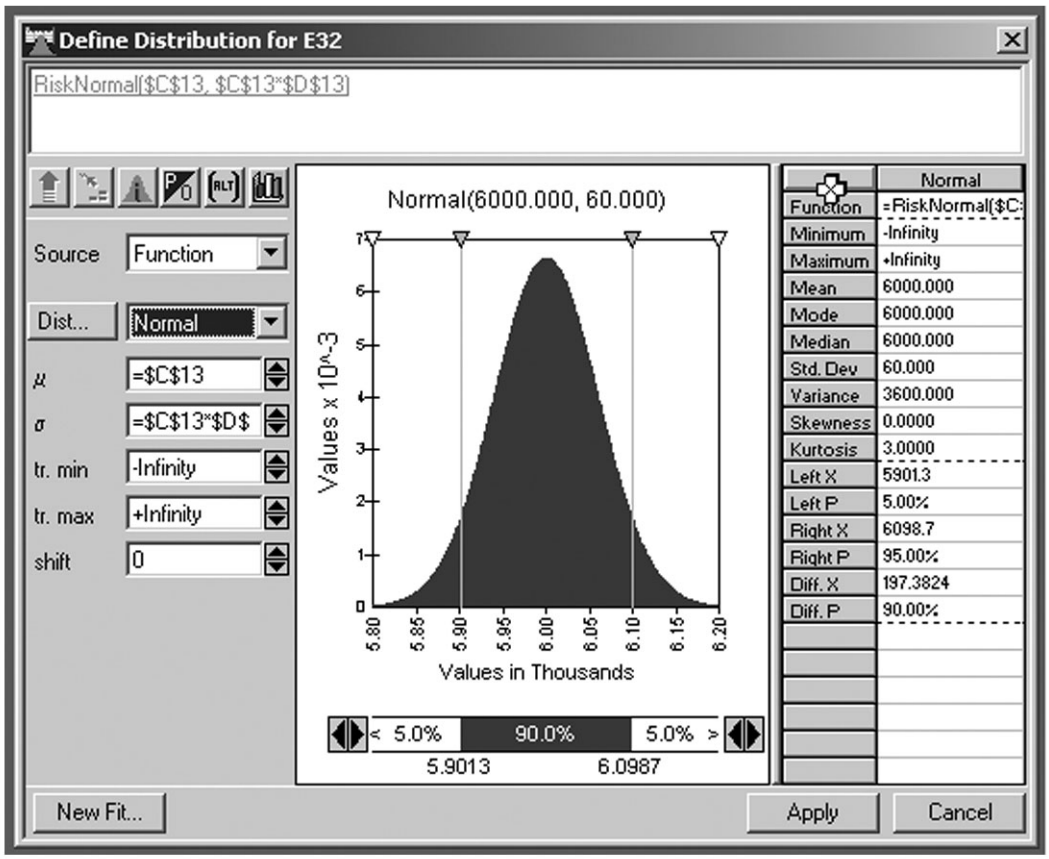
- Canvass estimates of uncertainties from experts in the company or from economists and experts in the industry
- Select suitable probability density functions from the library of functions in the software
- Apply the probabilities to the model
- Step test the model to see if anything looks really wrong, and correct if necessary.

The snapshot at the bottom of this page shows a normal function selected for the tons per day mined, which has an average of 6 000 tons with a standard deviation of 1% of the mean.

PROPOSED GOLD MINE PROJECT



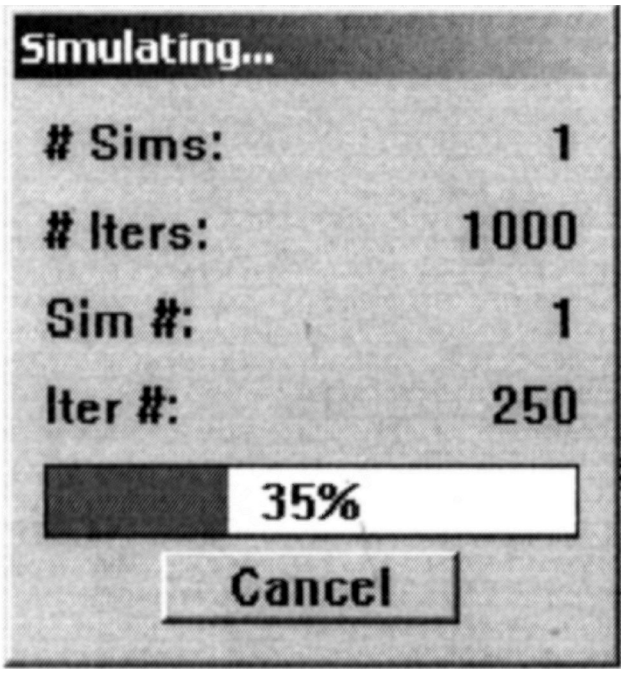



### *Running the Monte Carlo simulation*

To run a Monte Carlo simulation for this mine evaluation,

- Select the number of iterations
- Select the reports that you want to examine
- Run the simulation




### *Reviewing and analysing the results*

The risk analysis results will be displayed for analysis and reporting. Each of the charts and reports is obtained by highlighting the result variable and then mouse navigating to the chosen report.

The graph below shows that the average internal rate of return of the mine evaluation is 15.8% with a standard deviation of 11.2%. The graph also shows that we can be 90% certain that the IRR lies between 3.5% and 34%.

Notice that the risk analysis results show that the average internal rate of return is 2% less than the initial single point estimate based on most likely estimates.

Subsequent analysis of the data can show the conditions that gave rise to the adverse or very favourable results at the tails of the outcome histogram.

Alternatively, we can view the distribution of the IRR on a cumulative basis. This chart is shown on the following page.

In addition a sensitivity analysis using a Tornado Diagram. A chart is shown on the following page. This shows that the most import impact variable on the outcome of the internal rate of return of the mine evaluation is the ore grade, followed by the ore mined, and then the gold price.

### Conclusion—not just a 'so what'?

Now, I'm not saying that the analysis models described are not possible without specialist add-ins such as @RISK, but the modelling would be far more difficult and, much more importantly, would definitely fall outside the timescale of the decision.

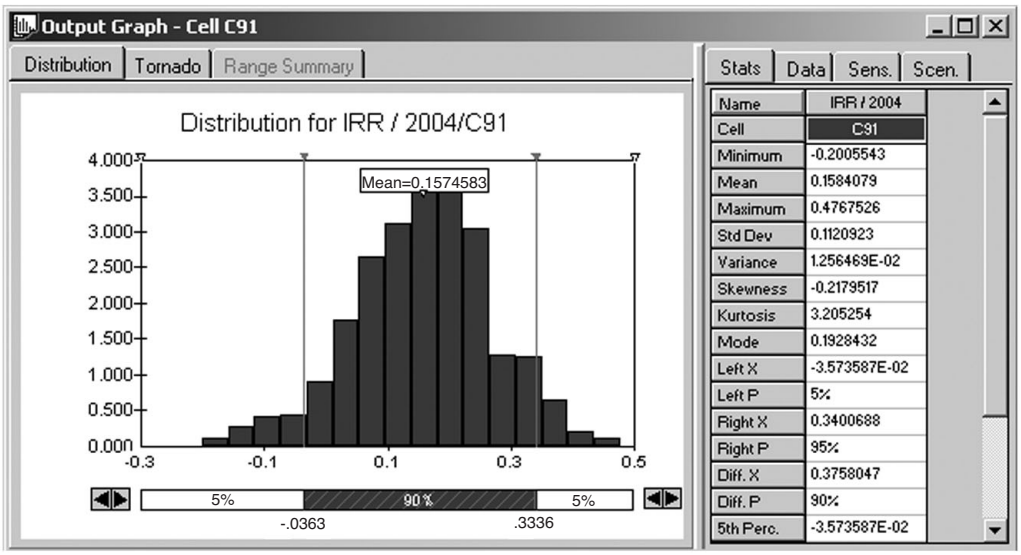
Modern software add-ins to Excel provide tremendous possibilities, enabling analysts to provide real benefits. With all the software available today, planners, designers, analysts and executives can use a combination of these tools to perform real option analysis (ROA).

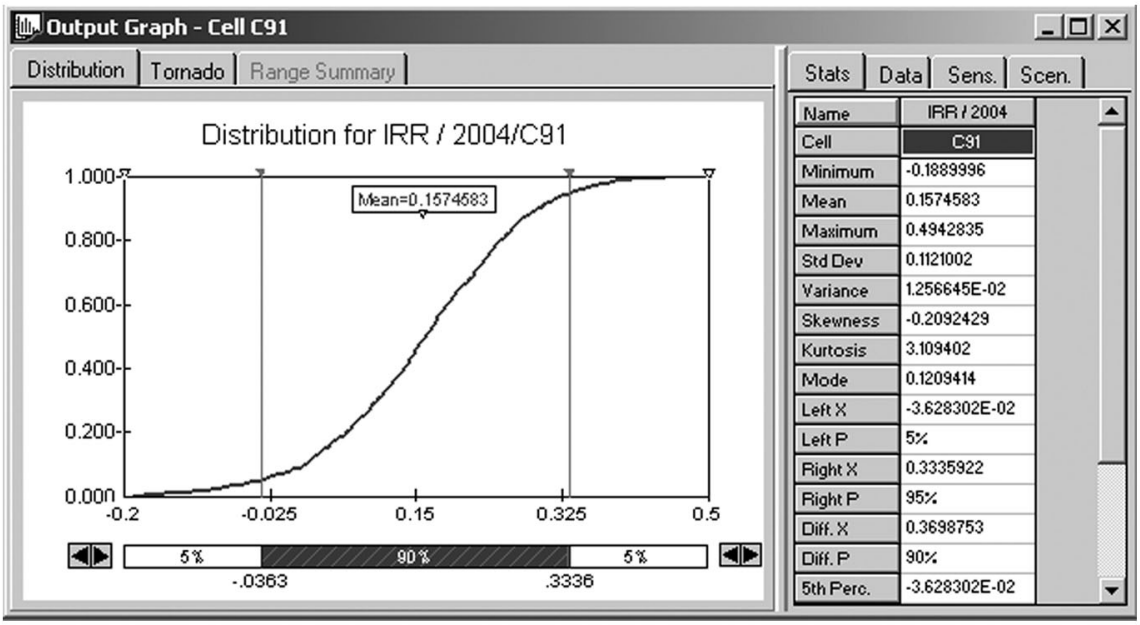
The software enables planners to get a better idea of how uncertainties may affect the project in the future, giving the planners the confidence to define the extent of the risk confronting the enterprise.

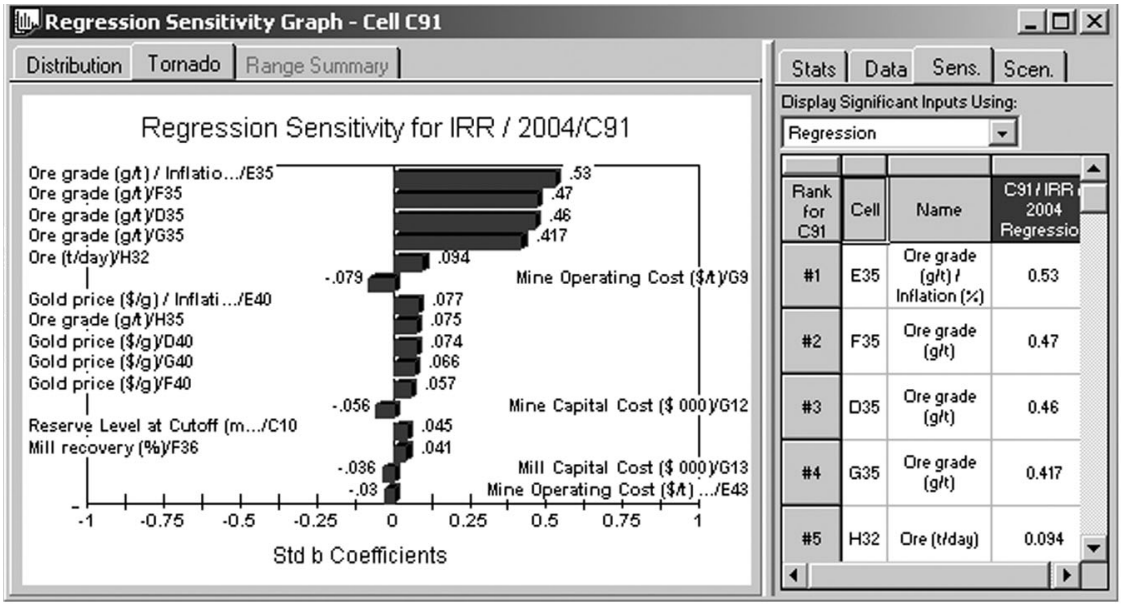
The simulation features of risk analysis allow planners and executives to practise strategies to avoid results that would be 'painful' to the company.

In addition, risk analysis simulation can provide management with the yardsticks to test and validate operational forecasts. Simulate – rather than speculate!

There is a caveat. Hindsight is 20–20 vision. Unfortunately, the perfect information of hindsight is never available at the crunch time of decision-making. All the risk analysis techniques can provide is the best information that is available at the time. But by using the techniques described above, you can be sure that you are making the best decision with all the information available to you. And that's not a bad bet!






Risk analysis potentially can lead to better decisions because the decision-making team is better informed about the threats and opportunities presented by the uncertainties likely to arise in the future.

There are, however, necessary conditions for risk analysis using Monte Carlo simulation to be useful. These necessary conditions are:

- The model must be an accurate representation of the enterprise that is being investigated
- The probability estimates must be realistic and based on experience gained in the relevant industry
- Be clear on what the objective is for the analysis.

After the initial analysis has been done and the decision taken, there is plenty of scope to perform further risk analysis to prevent taking operational decisions that might 'snatch defeat from the jaws of victory'.

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