# Dollar Driven Mine Planning: The Corporate Perspective to Operational Mine Planning

**By T P Horsley [1]**


## Abstract

*The competitive nature of the mining industry and the increasing cost and time required to bring new mine projects to fruition can leave a small margin between success and failure.*

*Orebodies with sufficient grade to make them 'management-proof' are exceptionally rare. A good orebody and a well engineered mine are not good enough any more to guarantee success.*

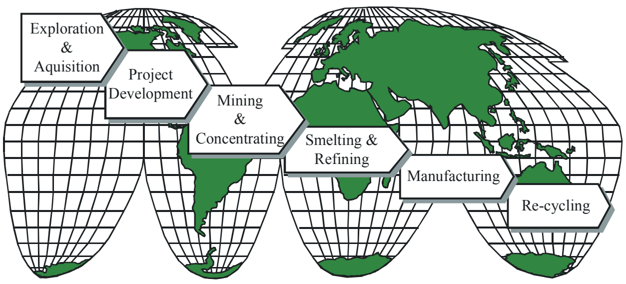
*Success has to be planned for with a integrated process from global strategy through to operational mine planning.*


## An Overview of the Planning Process

Nobody will argue that mining is a global industry. Some companies operate over all or a large part of the value chain. Others focus specifically in key segments or provide highly specialised services. Some companies may prefer not to be active in certain segments but may strategically invest to ensure a market for a product or feed for a process plant.

This paper will focus on the first 3 segments of the value chain.

**Figure 1 – *Mining industry value chain***




### Where is the value is created?

In any industry it is important to focus on where the value is created. In the mining industry the answer to this is not as simple as it may seem, however, it is an important issue as it will affect not only where a company chooses to focus within the value chain but how it operates the business.

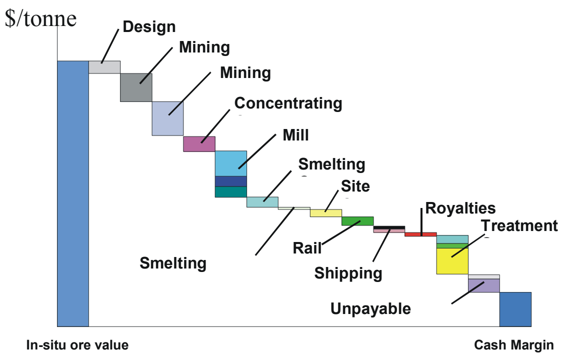
The difficulty lies in the fact that the value of products is only clearly defined towards the end of the chain. Concentrates are normally tradeable commodities but value depends on many factors, not least quality, treatment charges, metal prices, location etc.

The value of a mineral deposit or an operating mine can only be recovered by sale and the perceived values of the vendor and buyer may be considerably different.

Some would argue that value is progressively increased as the product is progressively refined. I prefer to assume that the maximum value is the ore in the ground with subsequent costs and losses occurring during the refining process.

This is illustrated in the following diagram.

**Figure 2 – *Every step in the process loses value….***




Taking this approach makes it easier to focus on creating maximum value by eliminating wastage and targeting theoretical best practice.

Even small changes in any of the components can make a huge impact on the bottom line. Poor planning, design or operating practices can easily wipe 10's of millions of dollars off the value of a project.

One of the dilemma's of the industry is the fact that prices are very volatile and the value of the mineral in the ground can vary considerably over a very short time span. Some of the 'loss' components (eg. recoveries or royalties) will also vary

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with price and will serve to dampen the volatility of the cash margin, however there will still be a significant leverage affect.

This cash margin has to repay the capital invested in a mine and to fund ongoing capital requirements.

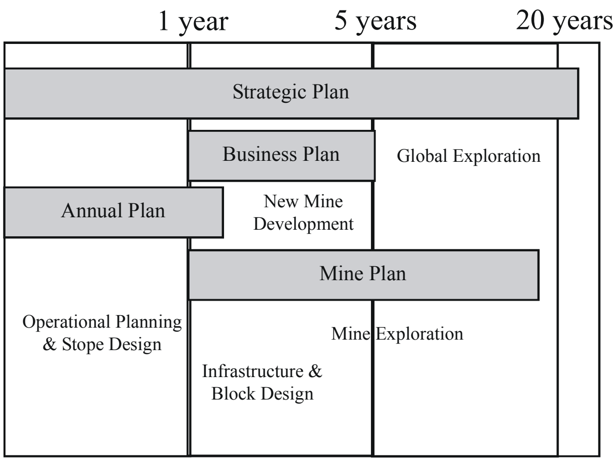
If this example shows a mine at the bottom of the price cycle it may well be a very profitable operation, however if it represents average prices then periodic shutdowns would have to planned for during periods of low prices.
At every stage of a mineral resource project, from before the first hole is drilled, there is both a value and the associated risk of realising this value. If a company does not have an indication of value then it is unlikely to maximise the return from a deposit.

Some projects may have a greater value to a third party and pursuing an exploration programme may not necessarily add further value (it is possible to reduce value by over drilling a deposit).

## The Planning Process

Planning is an essential part of the process to maximise the return on a project. This paper will discuss 4 components of planning.

**Figure 3 – *Four components of mine planning***




## Strategic Planning

There are many different views and definitions of *strategic planning*. The definition I use is:

*"positioning to take advantage of possible future outcomes "*

These outcomes may be discrete events, such as a change in government, or gradual change over time, such as a change in the demand of a particular commodity.

Any event or change which either directly or indirectly affects the future of a company should be identified and evaluated. There will be some outcomes which are significant and can be influenced. Others maybe outside the scope of a mining company to change and plans need to be drawn up according to the possible outcomes (scenario analysis).

Strategic planning is not a one off event that is undertaken once or twice a year: the world does not stop changing. A company cannot wait for events to happen and then decide what to do. It has to analyse various scenarios, steer for the most likely outcome but be prepared to change course quickly and decisively.

## Example

A good example would be the lead metal industry. In the order of 70% of refined lead is used for the production of lead-acid batteries, the bulk of which are used as SLI (starting-lighting-ignition) batteries for motor vehicles.

A considerable research effort is currently being directed towards the development of electric vehicles with billions of dollars spent over recent years. Much of this research has been targeted at battery technology.

A primary producer of lead metal would obviously need to monitor technological developments very closely in this area. If a technological breakthrough occurs and a commercial alternative to the lead-acid battery is developed it would have a devastating affect on the lead industry.

Replacement would not be left to market forces as environmental legislation would undoubtedly ensure a rapid demise of the use of lead-acid battery.

A company may choose to make a strategic investment into research to improve the efficiency of the lead-acid battery in order to make it more attractive to the embryonic electric vehicle industry. Closer evaluation would prove this to be a double edged sword: improved efficiency means less lead required and if electric vehicles account for only a few percent of new vehicles this investment will only serve to reduce lead demand.

Things become even more complicated as one of the contenders for the lead-acid battery is the zinc-air battery. As many of you will know both lead and zinc occur naturally together and are rarely mined separately. Most lead-zinc mines require the revenue from both metals to be economic. The economic extraction of zinc alone would require a significant increase in the price of zinc.

One of the main uses for zinc is die casting and even a moderate increase in price would trigger substitution by aluminium.

This has only scratched the surface of strategic planning and I have used this example to illustrate how complex it can become and how essential it is to ensure the long term survival and growth of a mining company.

Strategic planning is about understanding, and monitoring anything that is likely to affect the performance of a company, anticipating and planning for change, should it occur, and determining the key triggers points that would require changes in the business or annual plan to be implemented.

Any change that can be identified and planned for has the potential to add value.

At a corporate level planning should extend to 20 years and beyond. Indeed, the success of many companies today may well be owed to the planning 10-20 years ago. Failure however, is much easier to achieve over a shorter timeframe.

### Predicting the future

It is not possible to predict what new projects will be available over a 20 year time period but clear strategies have to be developed.

In order to make a decision on what minerals/metals to target it is necessary to have some view on the future.

What will the world look like in 20 years? Extrapolating supply and demand balances into the future may give some indication but the past is not a good indicator for the future.

Embryonic technologies have to be monitored and evaluated. Any potential changes that may affect the supply-demand need to be analysed.

### Forecasting metal prices

If a mining company could reliably predict prices it shouldn't be in the mining industry - there are much easier ways of cashing in on this knowledge.

Statistical analysis is essential to test the reliability of long-term data and the weighting a company places on this information. How reliable are price forecasts beyond 6 months let alone 5 and 10 years.

Attempting to forecast prices years into the future is a futile exercise. (I was once told that over a certain period of time the best correlation of the gold price was the spawning of salmon in North America.)

The only certainty is that forecasts will be wrong - the question is: how wrong? What is more important is to identify the longer term swings of the price cycles.

The main outputs of strategic planning are the establishment of the operating boundaries within which the company operates: what countries?, what minerals? what parts of value chain etc..

### Countries & Commodities

Strategic planning will have it's greatest impact in the first segment, *exploration & acquisition*, which is primarily concerned with sustaining and growing the business.

A mining company needs to target a defined range of commodities. It would be typical to rank a series of minerals/metals with upper exposure limits over time.

Whilst many aspects of a company's strategic plan will be regarded as confidential it is important to communicate as much as possible to the lower levels within the organisation. The feet need to know where the head wants to go!

## Business Planning

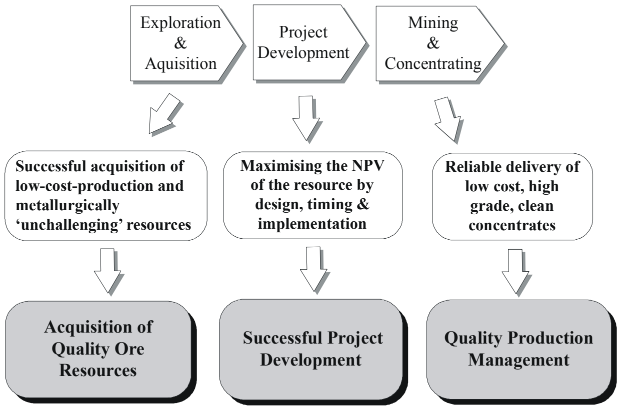
The business planning function coordinates the planning of all company divisions/departments within the framework provided by the strategic plan. It establishes corporate direction, goals and action plans.

The focus is generally medium term of 5 years or less. Often the plan is integrated with annual plan (or budget), however, there is a danger of placing far to much focus on short term operational concerns at the expense of planning for the future.

If the planning function reports directly through operational management there can be a strong tendency to re-direct resources into short term firefighting. Short term problems are the product of poor planning and using planning resources to fix these problems is often the thin end of the wedge. Unfortunately the lack of planning may not be apparent for one or two years by which time it will be too late.

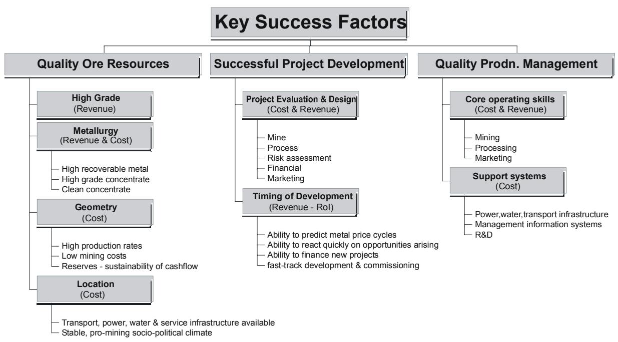
Business plans tend to be revised annually but, like all planning, should be an ongoing process with dedicated resources. In terms of the success of a company this part of the planning process is the most critical in that it plans the major capital projects essential for sustaining the business.

**Figure 4 -** ***Three key areas that the business planning process has to address***




These key success factors can be broken down to a further level of detail.

**Figure 5 –** ***Further breakdown of the business planning process***




This diagram reflects key success factors at the corporate level but is equally valid at different levels within the organisation.

It takes more than just a good orebody and failure in any of these key areas can lead to overall business failure.

### Quality ore resources

No mining company will be successful without quality ore resources. These are not easy to come by. Even with today's technology exploration success cannot be guaranteed and it can take many years of extensive effort and expenditure to locate a commercial deposit. Even then there are many obstacles to overcome before any return can be realised.

Grade is only part of the equation of success. Metallurgy, geometry and location will all have significant impact on both capital and operating costs.

### Successful project development

Project evaluation & design will be covered in greater detail later. Poor mine design can create a legacy that severely handicaps future production performance. Working to unrealistic timeframes and budgets can also compromise projects, particularly in the data gathering phase, and significantly increase the risk of failure.

The first 3-4 years of any project are critical. If the timing is such that the project is commissioned on a price down cycle then this can have a devastating affect on the overall return.

### Quality production management

The requisite skills need to recognised, developed and nutured within a balanced organisational structure. Traditionally organisational structures tend to be matched to control operating expenditure rather than the ability to add or lose value.

Conflict of interest between operating the business and sustaining the business can easily occur with the wrong organisational structure.

Support systems include management information systems (cost control, financial reporting, asset management, stores, maintenance etc.). Also included under this heading are primary infrastructure services (power, water supply etc.)

Information systems need to focus on providing timely, quality data for decision making and continuous improvement. Even the best systems rely on people - garbage in - garbage out. Too much information will obscure important data which may be overlooked.

## Annual Plan

I have included this for completeness. It is essentially the annual budget, supporting activity schedules and short term action plans.

Activities and expenditure have largely been locked in by previous planning.

## Mine Planning

The global requirements of acquisition of ore resources, project development, and production management are mirrored at the local minesite level. This is illustrated in figure 6.

In an established mine the planning can be represented as a production line.

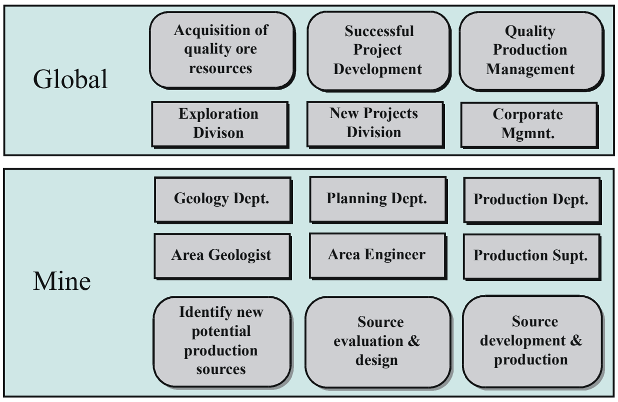
### Exploration target definition

Many resources will not been completely delineated during the feasibility study phase and will have ongoing exploration programmes to close off known orebodies and to explore for others.

As with global exploration, potential targets will require to have some broad hurdle criteria to satisfy prior to committing to a drilling programme. Potential targets need to be identified early in the mine life as they will affect the location of infrastructure, waste dumps, tailing ponds etc.

Sterilisation drilling may have to undertaken to finalise the placement of mine infrastructure.

**Figure 6 – *Three key areas, which can be identified at all levels within a mining company***




### Exploration drilling

Most of the initial drilling effort is normally established to improve the geological confidence of a resource. Although this is essential it should not be exclusive as mine design requires geotechnical and hydrological data well outside of the ore boundaries. Potential ore handling horizons and other mining constraints have to be identified to focus the programme.

### Resource definition

An operating mine will have a global cut-off defined, however, different areas of the mine will have different cut-offs depending on local operating costs, variations in mining method, grade ore type etc.

Cut-offs may well change with changing economic conditions.

Historically changing the definition of ore in an underground mine was a time consuming process. Computer software currently available makes it very easy to change cut-off and, while a global cut-off is required for the reporting and management of ore reserves, every stope source can effectively have its own cut-off to maximise return.

### Life-of-mine plan

The mineral resource sets an upper limit to the value of a mine. There is effectively no lower limit.

The life-of-mine plan forms the basis of the business plan on a local scale. Without an effective life-of-mine plan the value from a resource will be diminished considerably.

Some of the requirements of a life-of-mine plan are to :

- Sequence the production to maximise NPV.
- Analyse and manage regional stress and subsidence.
- Determine future infrastructure and capital requirements to sustain the operation.
- Focus and schedule the exploration effort.
- Flag major projects and critical start/completion dates.

- Identify areas for potential improvement.
- Plan for mine closure and rehabilitation.

### Conceptual design

Within the framework of the life-of-mine plan conceptual design is required as a pre-cursor to more detailed design. It will identify long lead time items and provide data for economic evaluation prior to committing further work. Conceptual design is completed on production areas rather than discrete sources.

### Economic evaluation

Successful evaluation is required before re-classification of ore from resource to reserve staus. This process will allow the selection of the most appropriate extraction plan and filter uneconomic ore before it is committed to any production schedule.

This evaluation may take the form of a formal feasibility study requiring management approval.

### Reserve definition

Preliminary design (PD) is required to reliably schedule future work and is normally undertaken on a source by source basis.

### Production & project scheduling

Scheduling is an integral part of the planning process and, although shown as a discrete activity in the diagram above, will extend from detailed short term production and resource schedules to long term life-of-mine production scenarios.

Ideally all production and resource schedules should be integrated with each other and linked to economic models and other optimisation tools if available.

### Final design

Quality design is a product of sound planning and attention to detail. In an underground mine safety is of paramount importance and all designs have to satisfy safety checklists before they can be approved.

All the value added from previous planning, perhaps over many years, can be lost by inferior or rushed final design.

The visible output from mine planning departments is predominantly blasthole design and development layouts, which is probably why many people associate mine planning only with mine design.

Mine planning and mine design are separate activities. While mine design can proceed without mine planning (and often does!) it is the planning which adds most of the value.

### Operational planning

The term operational planning is used to differentiate between the short term operational support and longer term planning requirements. The short and long term planning has been split to highlight that there needs to be a balance between the two.

This activity may be undertaken by the planning engineer in a small mine but is best carried out by a production engineer in a larger mine. This should avoid compromising the longer term planning requirements by short term fire-fighting.

Where strategic planning sets the boundaries for business planning mine planning establishes the operational constraints.

World's best operational practices in a poorly planned mine can easily give an inferior result to poor operating practices in a well planned mine.

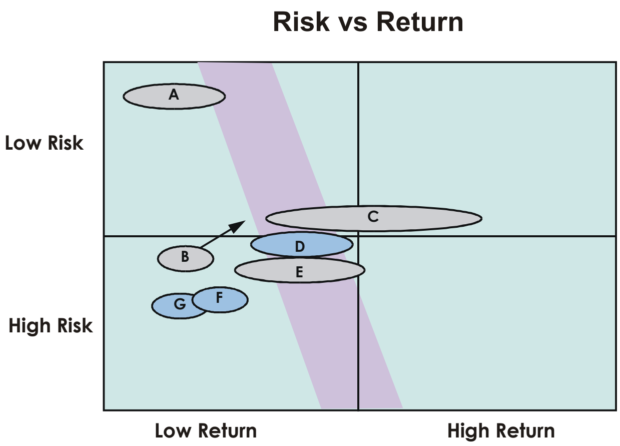
## Projects and Feasibility Studies – The Probability of Success

Planning a new mine is an iterative process. The simplicity of an open pit makes it relatively easy to optimise the design using computer software. Underground mining relies heavily on the experience and knowledge of the planning team and the margin for error is much higher.

It is important, when undertaking any evaluation, to clearly identify at an early stage, the maximum potential of any project. Some projects will never achieve the required hurdle criteria - no matter what effort is put into them - and should be aborted before too much is spent. Unsubstantiated optimism can waste a good deal of time and money, and divert resources from other projects.

Risk-Return diagrams are a good way of showing the potential and relative attractiveness of projects. They can be used right through from initial exploration target definition though to final feasibility study.

**Figure 7**

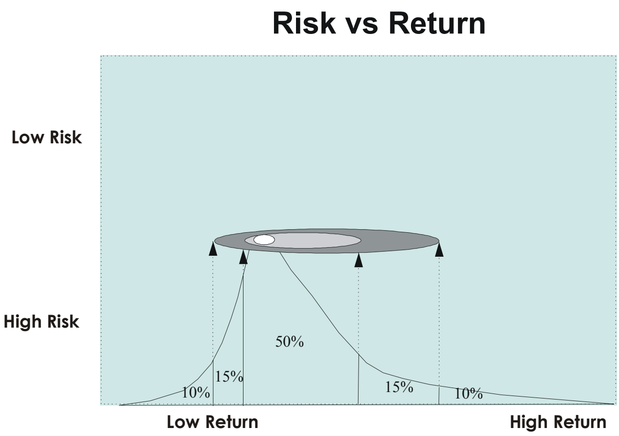



The horizontal axis can be NPV or IRR (payback or other criteria could also be used). The band represents project hurdle criteria. Higher risk projects will generally require higher returns.

The more marginal a project the more work, time and expenditure is required to make a decision. High return projects should not be handicapped by unnecessary detail during the feasibility phase which will not influence a decision to proceed. The detail can be transferred to the engineering phase of the project.

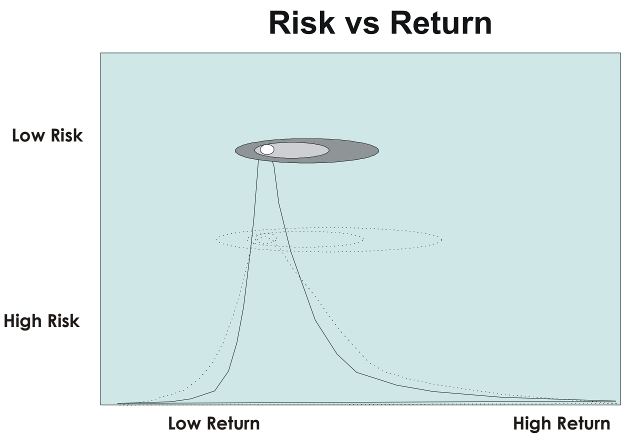
The placement in the vertical plane can be subjective or the result of a rigorous risk assessment. For example a curve showing the probability of achieving a certain NPV can be created using a monte-carlo simulation. Nested ellipses can be used to show sensitivity and skew.

**Figure 8**




If the areas under the curves are standardised for different projects then the height will show relative risk.

**Figure 9**




Historically, studies are heavily biased towards estimating costs and revenues down to certain limits of accuracy rather than the contribution to the project as a whole.

For example : the estimate of mine development costs to within 20% could have the same affect of estimating head grades to within 1% accuracy.

### Estimating tonnes & grade of the resource

Improving the estimate of grade is an expensive and time consuming process. Many studies are often conducted under tight constraints of time and money and reducing the risk associated with the resource estimation is often the first to be compromised. This can't be compensated for with detail in other areas.

If a resource has not been adequately defined then the project will be taking unnecessary risk.

### Estimating production rates

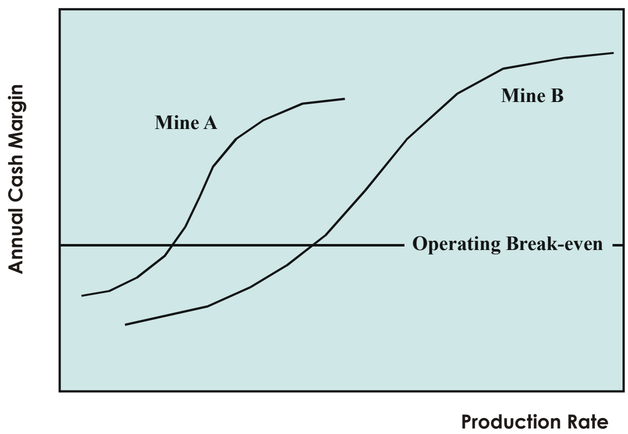
Many studies seek to maximize the production rate to improve the economics. This may well upset some of the metallurgists who would much prefer the highest grade possible at the expense of tonnes but it is rare that the economics aren't improved by increasing throughput.

Increasing size means increasing risk. Production rates for an open pit are largely a function of the equipment selected and can be estimated with a high degree of confidence.

Production capacities for underground mines are extremely difficult to estimate with any degree of certainty.

There is however a critical mine size below which it will be virtually impossible to achieve an acceptable return. The probability of achieving a minimum sustainable production rate is an important consideration. For a given set of economic criteria the critical mine capacity is largely a function of grade, mining method and orebody geometries.

**Figure 10 – *Minimum production rates***




In the example above mine A has a higher grade resource than mine B and requires a lower production rate to achieve profitability.

### Technical risk and commercial risk

It is necessary to differentiate between technical risk & commercial risk.

Every component of any project has some degree of uncertainty. These can be grouped into 2 main areas :

### Technical Risk:

- Resource grade & variability
- Production Rates
- Operating & Capital costs
- Metallurgical performance
- Product quality

### Commercial Risk:

- Commodity prices
- Exchange rates
- Marketing
- External costs
  - Government charges
  - Freight charges
  - Treatment charges
- Political risk
  - Government stability
  - Security of title

- Exchange controls
- Access to commercial markets

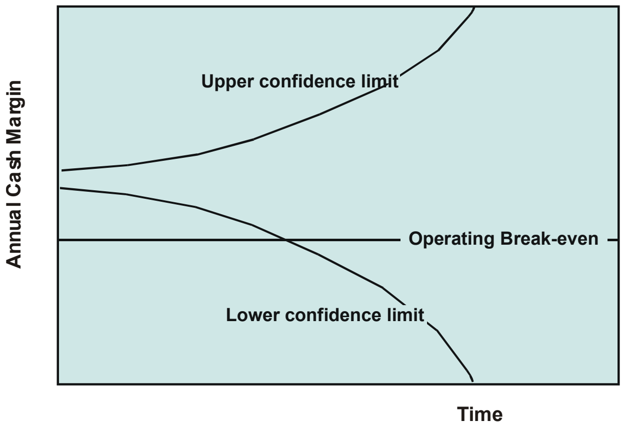
Some of these are obviously very difficult to quantify. Political risk (or country risk) is best allowed for by varying the hurdle rates of return required on projects.

Some countries would be excluded from a company's sphere of operations, others would have significant restrictions on investment imposed.

### Risk vs. time

The probability of achieving a certain profit or cash margin diminishes over time. The larger the project the greater the overall risk. Larger projects are often staged, to bring the risk down to an acceptable level, albeit at the expense of the estimated total project return.

**Figure 11**




The use of discounted cashflows will compensate for this by decreasing the weighting on sucessive years cashflows.

Projects with extended payback periods are high risk.

### Reducing risk

There are several ways of reducing risk:

- Acquire more data.
- More detailed estimates/research.
- Contract out - particularly for open pit.
- Sell product forward.
- Sell part of the project to a JV partner.
- Staged development.

Reducing risk will generally reduce return, although partial sell-off, at the right time can decrease risk and increase the overall return from the project.

## The Changing Role of the Mine Planning Engineer

Over the past 15 years there has been tremendous change in the way mine planning & design is undertaken. When I graduated there were no PC's and computing was done by room size mainframe computers with punched card data input.

Larger companies introduced mainframes to support their accounting and payrole systems in the late 70's

At this stage 'user friendliness' had yet to be defined
and there was a communication gap between the computer and mining disciplines - computerspeak.

Geologists were the first to bridge this gap with the development of drillhole databases, geostatistical programmes etc. and now computer literacy is an essential requirement for virtually any graduate. Literacy amongst senior management however, still has a way to go.

Today planning professionals have a bewildering arsenal of computer based tools to choose from, although software development still has a long way to go, particularly for underground mines. These tools are only as good as the craftsman that uses them.

The rapid change in the way mine data is acquired, managed and used has come at a price however, with the main casualty being the effective management of this data.

Unfortunately mine planning software cannot force the adoption of good file management standards and it is very much reliant on the users. This is of particular importance with respect to safety. In an underground mine there is no room for compromise on safety.

For example, a computer can be programmed to ensure all electrical cable-holes are plotted on survey memos. If a user has put a cable-hole into the database, but accidently registered it as a drain-hole, it wouldn't necessarily be shown. Drilling through an unmarked electrical cable hole could easily lead to a fatality.

The old drafting skills are no longer relevant but the overall function of 'plan maintenance' is still required.

The ability to process increasing volumes of data has promoted the gathering of increased ammounts of data. Stope surveys are a good example. Survey instruments available today are so effective that surveys can be conducted frequently during the life of a stope. This allows virtually 'continuous' monitoring of overbreak/underbreak etc.

As more and more data becomes available and increasingly powerful tools are developed the level of confidence and quality of planning and engineering increases. This is taking more and more of the uncertainty out of mining, reducing risk and reducing wastage/adding value.

The evolution of new tools has made some of the old skills redundant and has required the development of new skills. The overall affect is the broadening of the skills base of the planning engineer and, to some extent, the merging of what used to be distinct disciplines.

## The Future Role of Mine Planning

Although the PC has had a considerable impact on the technical side, mines have not fundamentally changed. Rock is still broken predominantly by drill and blast and transported by rubber tyred, track mounted vehicles or conveyors. Equipment has increased in size over the years and partial automation is starting to become commonly used on selected items of equipment.

Automation and robotics are still in their infancy and new mines will increasingly look towards these technologies as substantial cost savings can be achieved.

The mining industry has still a way to go before the people-free mine becomes a reality.

The step change to a people-free mine will allow a radical change in mine planning & design.

Some people may criticise engineers for sitting in front of a computer all day but the time will come when it will be difficult to obtain permission for an underground visit! Mines will not have been developed with people in mind:

- Ventilation will be minimal
- Blanket ground support unheard of
- Most development will be bored will minimal clearance for equipment.
- Mobile equipment will be modular and 'disposable'

Site inspections wherever possible will be by tapping into videos mounted on mobile equipment.

We have a few years to wait yet.

The rapid advances in information technology will have a much earlier impact on how, and where, mine planning and design are undertaken.

### The remote mine dilemma

Fly-in fly-out operations, particularly in third world countries, are having increasing difficulty in attracting, training & retaining specialised technical staff.

The training burden, coupled with staff turnover, is of major concern at some remote sites and there is an increasing reliance on external support from consultants.

Video links and communications technology can allow a large part of the planning & design function to be undertaken off-site. This will keep on site staffing to a minimum with significant operating cost savings and on-line access to a greater technical resource that could not otherwise be justified.

### Further into the future...

With the continued development of the tele-operation of LHD's it would not be inconceivable to even have operators off-site.

Computer software will continue to be developed as will the processing power of computers.

Mine simulators with enhanced virtual reality will be used increasingly to refine and optimise mines before any development is committed.

A greater investment in mine equipment will require much greater emphasis on planning and data acquisition.

The planning engineer will become less dependent on hands-on data gathering and site investigations and more focussed on data analysis. The technical function will become more remote with the production and technical roles becoming increasingly divergent.

## Conclusion

Planning is like freedom - you only know what freedom is when you've lost it!

A company's perceived core skills will also influence how it operates the business.

People create & lose value.

The exploration geologist will need to determine the likelihood of meeting these criteria to prioritise target selection.

Primary infrastructure is normally locked in during the study process and early acquisition of data is essential.

While many of the activities can be undertaken simultaneously there should be a clear logistical sequence to any evaluation. For example the ventilation system has to one of the last components to be finalised. Plant capital costs vs. cut-off definition.

It is essential, when undertaking project evaluation, to focus on the required decisions which are required to be made on submission on the completed study.

The optimum cut-off is not always easy to define particularly for poly-metallic deposits.. Open pit software and block models make it relatively easy to establish a cut-off. Underground mining is far more complex and many studies simply gloss over cut-off (1% will do) and procede directly to mine design.

Cut-off policy.

Natural cut-offs. High-grading.

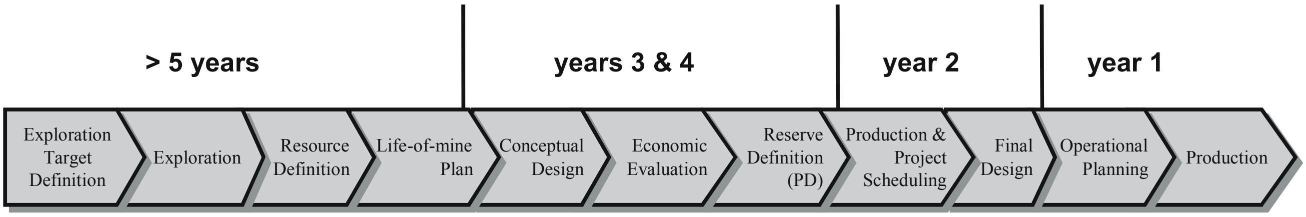
The placement of critical mine infrastructure will have a significant impact on the overall economics of a mine. Detailed definition of ore can proceed in parallel with mine development if the project has been given a green light.
A new underground mine feasibility study will have partitioned the mine into regional blocks and sequenced the development of these. Detailed evaluation will have been concentrated on the early production requirements, leaving subsequent blocks to be planned and developed as part of the normal mine planning process.

Most operating mines will have projects in various stages of development and they should be treated to the same discipline of a full feasibility study.
Much time and effort is often wasted by attempting to design out of sequence or before adequate data is available. There is no point refining successive stages until required confidence is achieved.

Move from mine engineering to financial engineering.
Move away from global ore cut-off to financial engineering of individual sources.

Complex ore evaluation models taking account of detailed mineralogy and variable metallurgical performance.
The end product is essentially the same, equipment has not fundamentally changed, significantly higher engineering input.

**Figure 12**




Rotation of skills every 5-6 years. Highly specific (software) requirements. Recruitment and training lead times for new planning engineers burden on new mining projects. Fly-in fly-out can double staffing requirements.

Ore was defined as a line on paper.

The risk of starting up new mining projects is considerable. Technical risk is managable however commercial risk tends to rise exponentially with the size of the project. This will favour smaller projects with larger ones being staged in a series of discrete expansions to minimise risk. 'Continuous' mine planning by progressively proving up resources to reserve status ahead of production is likely to become a thing of the past. New production areas will require separate feasibility studies before approval. More and studies will be done off-site either contracted out or undertaken by Head Office.