

UNDERGROUND OR OPENCUT COAL MINING?

WHEN, WHY AND WHAT TOOLS TO UTILISE.

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ABSTRACT:- The question of whether to utilise underground or open cut mining methods generally arises at two different times in the assessment within the life of a resource. The first time it arises is at the feasibility stage for a greenfields site. The second time arises during the more mature stage, when the operation has been established for some time and a change is perceived to be required. At this point the decision is either to take an existing opencut and develop some underground mining capability from the opencut highwall, or to look at open cut mining of a subcrop and the part of an existing underground.

This mature-age decision making has arisen a number of times and will continue to arise in the future. The question is when do these decisions arise, what is driving the decision, and what tools are used to assist in the process. This paper looks at some of the issues driving the decision-making, and the tools used in the process.

This paper is a treatise of the methods and logic for the strategic decision of whether to mine via underground or open cut methods. The accompanying presentation will detail the case studies and review historical examples.

INTRODUCTION

In the past MineConsult has run strategic planning studies for a number of projects and operations. Many of these strategic reviews have included the choice between underground and open cut mining methods. In this paper we describe the current strategic planning process within the company and where it may be heading. MineConsult believe the scope of a strategic review may either enhance or limit the potential of a project or prospect. From our experience many companies perform only parts of the strategic review planning process outlined in this paper.

WHEN

Much has been written about the transition from open cut to underground mining (Hayes, 1997) and on the decision to mine using open cut or underground methods (Blackham, 1993). In fact, the selection between underground and opencut mining occurs in three distinct circumstances:

1. For a greenfields site when determining the best mining method to exploit the geological resource.
2. As opencut mining costs rise a decision may be made to commence underground, punch or highwall mining.
3. Towards the end of underground mining, market and economic conditions may allow a decision to commence open cut mining to recover coal from subcrops, pillars, or to provide greater resource recovery.

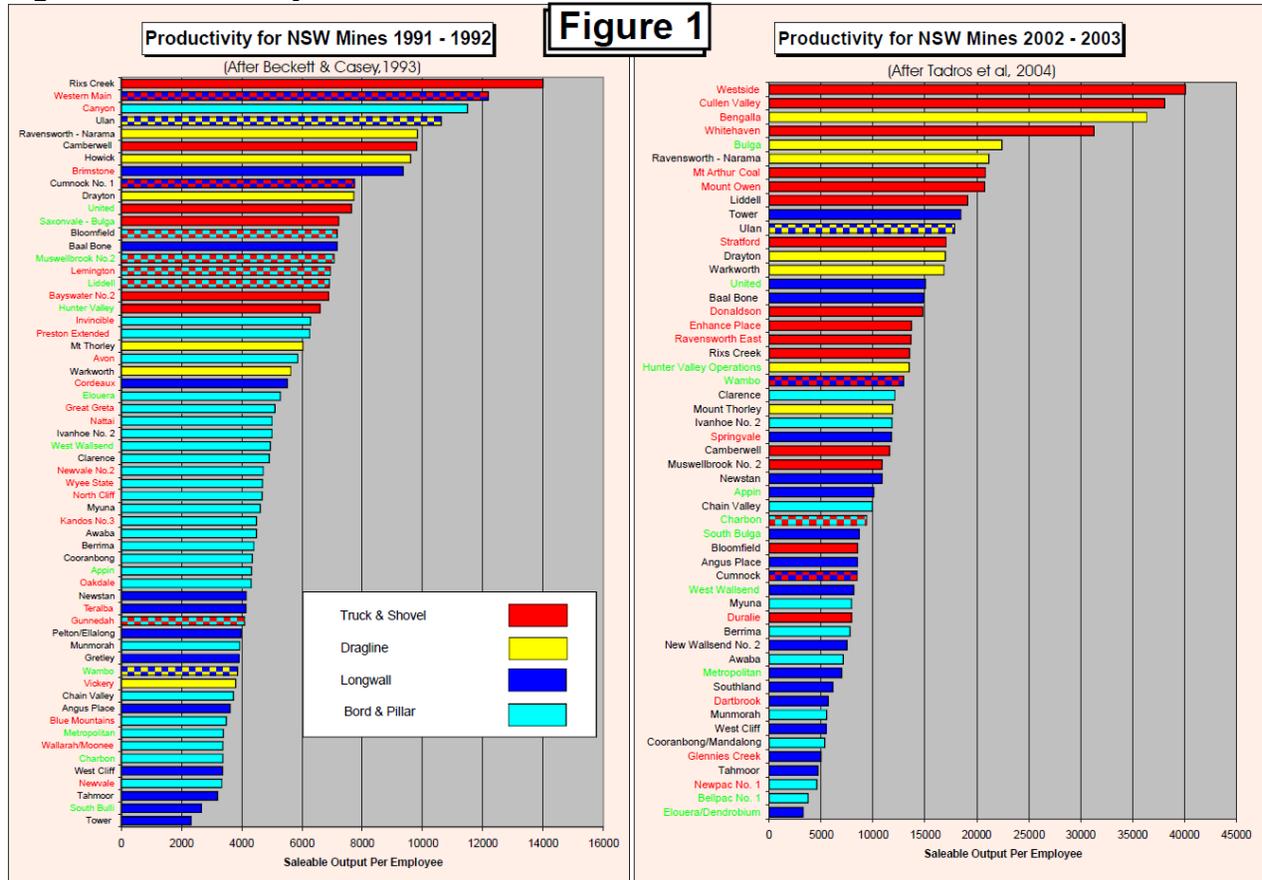
The timing of the decision to change between opencut and underground methods is influenced by a number of factors. As economic reserves reduce, continued production may only be possible by changing mining method. This may be necessary to meet market requirements in terms of output, or to match specific coal qualities. The South Bulga and Beltana underground mines were developed to assist the Bulga project to meet market requirements. Similarly, it has led to the development of a number of opencut mines such as at Pelton, to recover the shallow subcrop coal not readily accessible by underground methods.

Timing of the decision may also be influenced by change in the underlying fundamentals. This change may be technological, political, market, community standards, mining conditions or ownership. The advent of large-scale low-cost opencut mining equipment in the 1970's resulted in the development of numerous opencut coal mines throughout Australia. This was assisted in New South Wales (NSW) by the policy of the Joint Coal Board (JCB) for maximum resource recovery (Blackham, 1993), reversing the earlier union attitudes that favoured underground mining. Liddell opencut mine in the Hunter Valley is re-working areas previously mined by three underground operations. This was brought about by changes in technology, ownership, government and union attitudes, market requirements and the exhaustion of economically recoverable and accessible underground reserves. Today the growing emphasis on environmental impacts and continued improvements in underground mining costs and productivities are beginning to shift the pendulum back towards underground mining.

WHY

Previous authors (Hayes, 1997) (Luxford, 1997) have suggested that opencut operations continue till they become economically challenged. This has been the perception of some companies. In our experience this is not normally the case as is demonstrated in **Figure 1 – Productivity for NSW Mines**, where the majority of continuing operations have changed mining method over the last 15 years.

Figure 1 – Productivity for NSW Mines

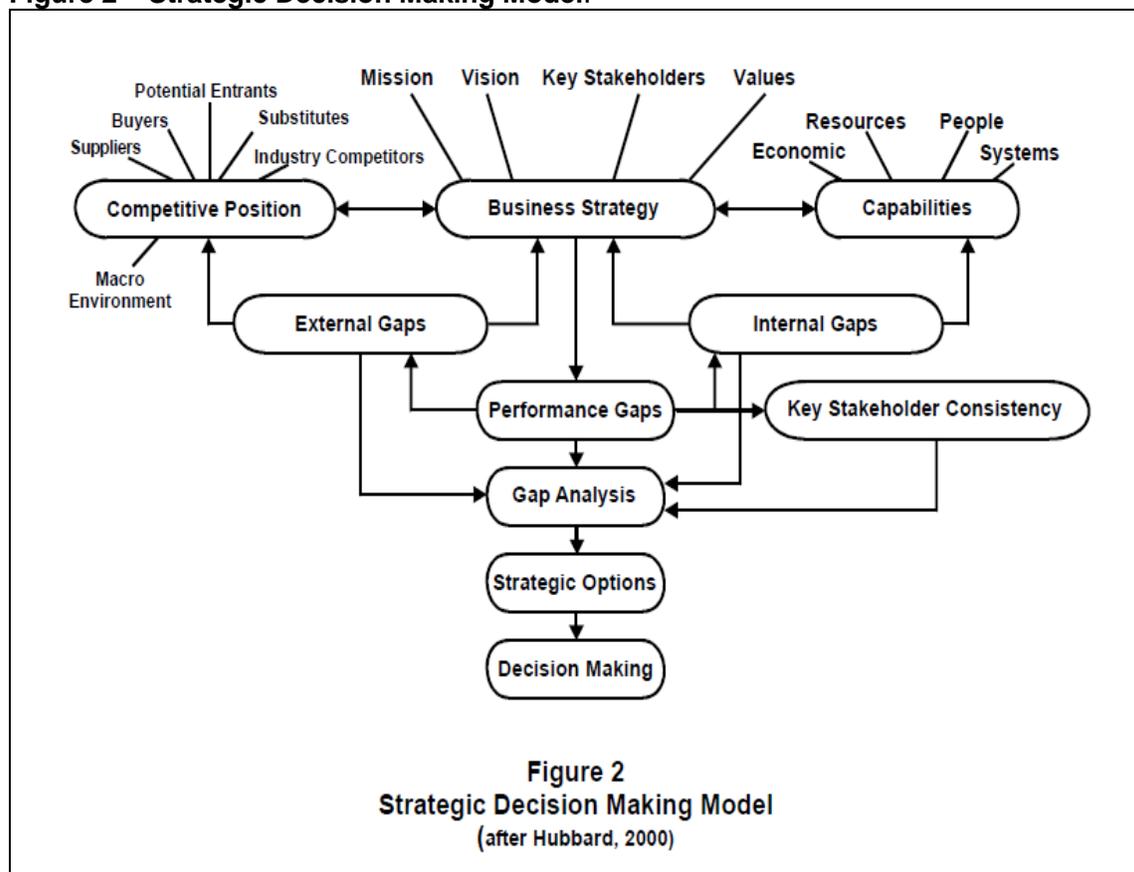


There has been a major improvement in productivity, with many doubling or tripling their productivity. There has been a reduction in the number of bord and pillar mines and an increase in long wall and truck shovel operations. This is not just because of costs, but also to maintain a competitive advantage in a changing industry.

The mines in red on the 1991-1992 graph are those that have ceased operation in the period. Those mines in black on both charts have continued operations with the mining method unchanged for the period. Those in red on the 2002-2003 denotes new mines that have started in the period. Those mines in green have changed their mining method.

The reasons for selecting an underground or opencut mining method are not that simple. They involve a complex interplay of factors that must be carefully weighed to determine the best mining strategy. In fact, the selection of opencut or underground mining is part of a strategic management decision. This decision can be represented by the model proposed by Hubbard (2000, p17ff) and shown in **Figure 2 – Strategic Decision Making Model**.

Figure 2 – Strategic Decision Making Model.



Strategic decisions on whether to go underground or open cut should first be done commensurate with the detail used to determine the key value drives for a project or prospect. These strategic decisions are not detailed business planning, but are at a higher level. If the cases under consideration require a lot of detail to differentiate between them, then the economics alone will not be the main determinant. The decision will be defined by risk capabilities, competitive positioning or other key performance indicators.

Competitive Position

The competitive position of the business unit is a major determinant of the mining method. By carefully targeting the coal to be produced a mine may be able to improve its advantage within a particular market segment. This is an analysis of factors external to the company and consists of an analysis of social issues as well as segmentation and industry analysis.

Macroenvironment

Social issues such as community and political attitudes can have a profound effect on the choice of mining method. While there is still a Mines Department preference for resource maximisation, community and legislative trends are towards minimising environmental impacts. In areas of high community or environmental impact there is a preference for underground mining to minimise these impacts.

Industry Analysis

Industry analysis is predominantly a market analysis. The selection of opencut or underground mining can have a profound impact on the coal to be marketed. Porter (1980) outlined five forces that determine strategic advantage within an industry:

- Entry barriers that restrict potential entrants. These barriers are generally large in mining.
- Supplier power can be a major determinant of mining method. The lack of adequate labour and equipment suppliers is a major disincentive for underground mining in Indonesia (Walle, 1998).
- Buyer power is generally greater in coal markets, resulting in mining companies being price takers.
- Substitutes can reduce the size of the available market and provide downwards pressure on prices.
- Industry competitiveness must be assessed to identify the likely position on the supply cost curve for the proposed product.

Business Strategy

A company's business strategy takes into account the mission, vision and values of its key stakeholders. The selection of mining method needs to take into account risk profile and perceived core competence of the organisation. This, of course, must recognise that business strategy is not static and that 'strategic capabilities' can become 'core rigidities' (Leonard, 1998).

Capabilities

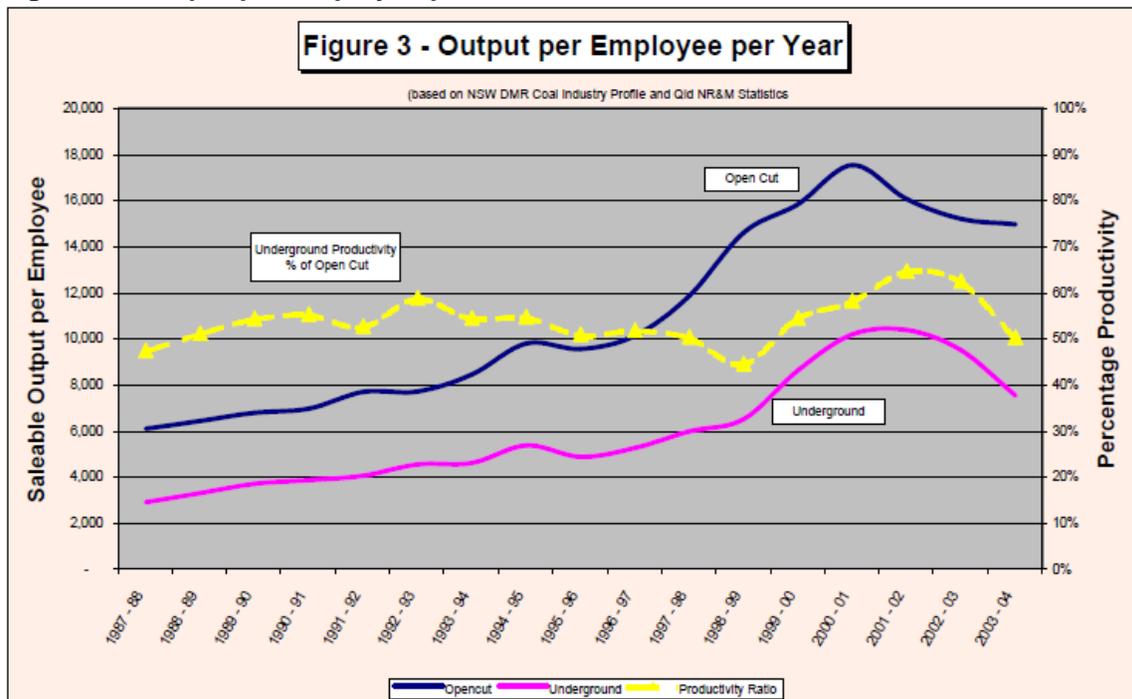
The capabilities of the company and the resource being investigated are the most important factors in determining whether to choose underground or opencut mining. These need to be investigated to determine where the strategic capabilities of the company lie and how these can be turned into a strategic advantage.

The factors that differentiate opencut and underground mining have been investigated by Blackham (1993) and include:

- Cost stability – opencut mines generally have lower operating costs.
- Start-up time – opencut mines usually take less time to reach full production.
- Capital requirements – underground mines generally require less capital than opencuts.
- Human resources – undergrounds typically have greater labour requirements with a more specialised workforce.
- Flexibility – the ability to increase production rapidly to take advantage of market opportunities is a function of mining method, with opencuts arguably being more flexible.

These differences are becoming far less pronounced as underground productivities increase towards those achieved in opencut mines. **Figure 3 – Output per Employee per Year** shows the change in opencut and underground productivities in New South Wales over the last 15 years.

Figure 3 – Output per Employee per Year

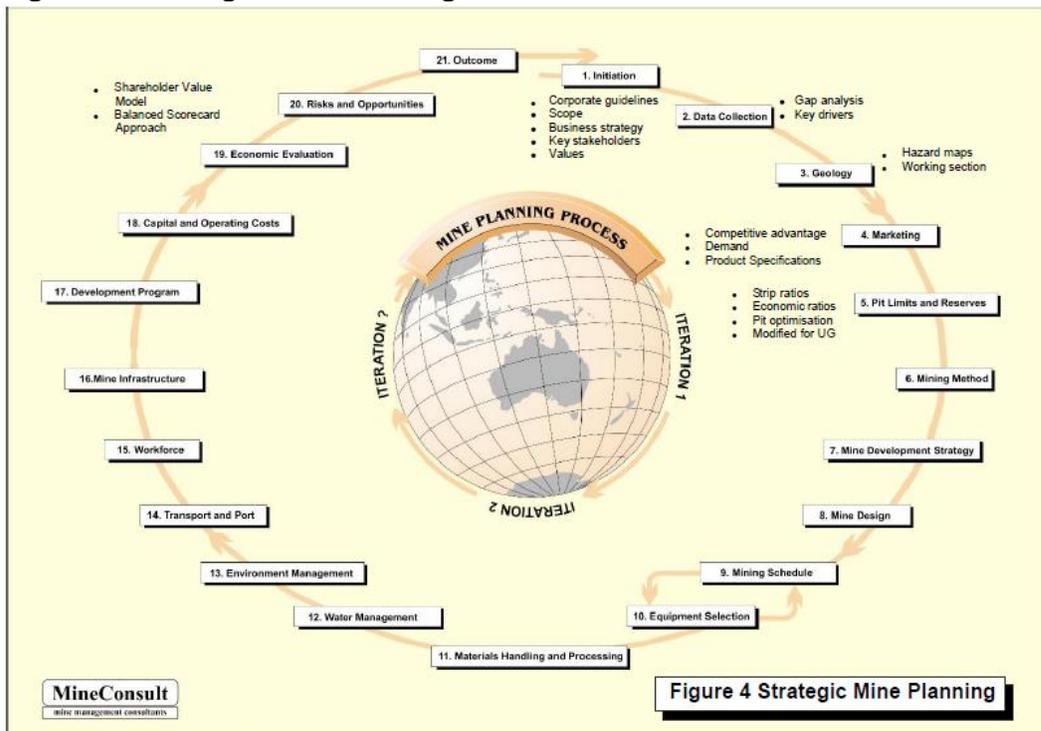


Productivity improvements in opencut and underground mines over the last 15 years have been similar, maintaining the relativity between open cut and underground mines. However, **Figure 1** shows that new generation underground mines are more productive than most mature open cut mines.

HOW

The tools and processes used to determine where to mine by underground or opencut methods are the same as those used for normal strategic mine planning. The strategic mine planning process is outlined in **Figure 4 – Strategic Mine Planning**. Planning proceeds by identifying mining targets and defining the mining areas.

Figure 4 – Strategic Mine Planning



Target Identification

The easiest method for identifying potential mining targets is to construct a series of hazard maps. These maps need to identify the spatial disposition of factors that will preclude or impact upon the selection of the mining methods under consideration. These factors were discussed by Hayes (1997) and have been combined with factors used by MineConsult:

- Geographical
 - Social Infrastructure
 - Water Management
 - Physical Features
 - Land Ownership and Tenement Issues

- Structural Geology
 - Faulting and Folding
 - Subcrops
 - Intrusions
 - Stone Rolls, Washouts and Palaeochannels

- Coal Seam Geology
 - Working Section thickness
 - Interburden Thickness
 - Seam Dip
 - Strip Ratio
 - Depth of Cover

- Coal Seam Quality Parameters
 - Washing Ash and Yield
 - Sulphur and Ash
 - Volatile Matter
 - Specific Energy
 - Coking Properties, etc.

- Geotechnical Impacts

<ul style="list-style-type: none"> Open Cut <ul style="list-style-type: none"> ○ Wall and Floor Stability ○ Rock Breakage 	<ul style="list-style-type: none"> Underground <ul style="list-style-type: none"> ○ Roof and Floor stress ○ Support Density ○ Coal Recovery ○ Ability to Cave ○ Mining Direction
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- Previous Workings

<ul style="list-style-type: none"> Open Cut <ul style="list-style-type: none"> ○ Mining hazards ○ Water ○ Gas 	<ul style="list-style-type: none"> Underground <ul style="list-style-type: none"> ○ Coal recovery ○ Difficult coal preparation ○ Hazards water / gas / fire and increased stress
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Mining Area Definition

To define mining areas the normal approach is to use some form of cost or economic indicator in conjunction with the hazard maps described above. This allows the design of mining pits for opencut mining and mining panels for underground mining to extract the economic resources from the defined mining areas.

The commonly used cost or economic indicators for opencut mining include: strip ratios; economic ratios; and, open pit optimisation. Each of these has its drawback. Strip ratios do not take into account differing product values or variations in technique.

Economic ratios may be calculated on the basis of cash costs, owning and operating costs, cash margins, or equivalent annual costs. The drawback with economic ratios is that they do not take into account pit batters, and the interpretation of the impact of these is left up to the design engineer. Block ranking is a further economic ratio tool that attempts to incorporate the impact of batters by calculating economic ratios for a mine design. The selection of a mine design prior to pit limit determination may prove a deficiency with this tool.

Lerchs Grossman pit optimisation tools have been applied to defining the optimum pit limits in open cut coal mines. The standard algorithm utilises a

constant vertical block size with orthogonal blocks. The inclusion of underburden makes the results highly inaccurate at times. A modification to the standard algorithm to either ignore underburden or to allow blocks that follow seam horizons is required to make this technique reliable.

All three economic indicators outlined above can be modified to incorporate underground mining. Luxford (1997) discusses the use of a surface to underground breakeven ratio. This ratio will need to take into account resource recovery and is only applicable in simple cases.

For economic ratios and pit optimisation the incorporation of underground mining is similar. For all resources amenable to underground mining the in-situ value of coal is calculated. This is a lost opportunity if these resources are mined by opencut methods. The in-situ value of underground coal should therefore be incorporated as an “opportunity cost” against opencut mining. If opencut mining is more desirable, then its value will exceed the “opportunity cost” of underground mining. Using this approach a logical, value-based cut off may be determined between open cut and underground mining.

Analysis of Current Performance

It is essential that current performance is adequately analysed since this clearly defines the basis from which further improvements are to be made. This analysis should include current operations as well as industry comparisons.

There are a number of models for analysing current performance. Two of these have been outlined by Hubbard (2000, pp95ff) as:

- The Shareholder Value approach based on cash flow measures of shareholder value. With this model the various factors influencing value, such as revenues, sales, costs, productivity, capital and leverage are analysed.
- The Balanced Scorecard approach that analysed various performance indicators related to four key areas: financial; customer; internal business indicators; and, learning and growth.

Regardless of the performance model used, comparisons need to be made with internal targets, industry averages and best practice.

Gap Analysis

A gap analysis examines any gaps between strategy, performance, capabilities and the industry environment (**Figure 2**). These gaps may be summarised as:

- competitive position – business strategy

- business strategy – performance
- capability – business strategy
- stakeholder expectations – performance.

In our experience gap analysis is one area that is normally performed poorly. Many strategic plans are produced on the assumption that it is “business as usual” rather than incorporating improvements. Gap analysis is not just an analysis of gaps existing at present. It should also indicate where the business unit needs to be to maintain a competitive advantage within the industry. Both **Figures 1 and 3** indicate a continuous improvement throughout the Australian coal mining industry. The strategic plan must highlight where the gaps exist and how they will be overcome to give the required continuous improvement and remain competitive.

Alternate Mining Scenarios

Based on the gap analysis and the possible mining areas, alternate mining scenarios can be developed. These scenarios need to examine how the gaps will be filled. They may contain combinations of open cut or underground mining, but should always encompass a coherent strategy that describes how the planned approach will be achieved. This includes the fit with existing capabilities as well as the stretch to achieve new goals.

When evaluating alternative mining scenarios an appropriate level of detail must be used. To do this the key drivers must be ascertained. For most evaluations, factors impacting on revenues will have greater importance than costs, although other key performance indicators such as risk, safety or market position may be the key determinant. We have observed a tendency in mining studies to excessive detail, when less detailed analysis would suffice. Once a strategic option has been selected and an implementation strategy is agreed, detailed planning and budgeting will be performed on the selected strategic plan.

Decision Making

The final decision between open cut and underground mining is therefore a business unit level strategic decision. There is no correct answer for all occasions, and it is certainly not as simple as a cost-driven exercise. Either the Shareholder Value Model or the Balanced Scorecard Model may be used for the final evaluation. The result is a mining strategy utilising mining techniques that best fit the requirements of the business unit and the opportunities that present.

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