'Short-term gain for long-term pain'—how focusing on tactical issues can destroy long-term value

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Transaction Paper

Synopsis

Maximizing shareholder value has become a common aim for mining companies. This paper discusses the results of a number of studies developing strategic mine plans, covering a wide range of commodities, styles of mineralization, mining methods, and processing facilities, for single and multiple deposits. It has become evident that traditional methods and conventional wisdom often do not in fact achieve these goals. Operating policies at many mines ensure that shareholder value is not maximized. Changing the overall strategy can provide significant value gains.

Typically, the new optimal plan involves a significant increase in the cutoff grade, at least in the earlier years. An increase in the underground development rate or open cut stripping rate is often associated with this, at least in the short term, to establish the new strategy. Cost minimization is found to be counter-productive. Counter-intuitive plans are often found to be optimal. For example, optimal cutoffs for different parts of an underground mine may be significantly different, even if mineralisation and cost structures are similar. Sub-optimal strategies are also frequently found to have a significantly greater financial risk than optimal plans, which have been found in many cases to be relatively insensitive to changes in major value drivers, such as metal prices.

This paper shows how identifying and then operating within the framework of an optimal strategic plan can have substantial benefits over being continually driven by short-term tactical issues.

Introduction

Operating policies at many mines ensure that shareholder value is not maximized. In a number of studies developing strategic mine plans, it has become evident that traditional methods and conventional wisdom often do not achieve stated corporate goals. Changing the overall strategy can provide significant value gains. Typically, the new optimal plan involves a significant increase in the cut-off grade, at least in the earlier years. An increase in the underground development rate or open cut stripping rate is often associated with this, at least in the short-term, to establish the new strategy. Cost minimization is found to be counterproductive. Counterintuitive plans are often found to be optimal. For example, optimal cut-offs for different parts of an underground mine may be significantly different, even if mineralization and cost structures are similar. Optimal plans have been found in many cases to be relatively insensitive to changes in major value drivers, such as metal prices, while suboptimal strategies are frequently found to have a significantly greater financial risk. Identifying and then operating within the framework of an optimal strategic plan can have substantial benefits over a plan being continually driven by short-term tactical issues.

Expediency in operational decision-making

The main thrust of this paper deals with planning and conscious decisions about long-term operating policies. This section, however, highlights briefly the impact of expediency on operational decision-making and on the achievement of the overall corporate goals. A few examples are given. These are typical of many instances observed over the years by the author and his colleagues, and have occurred at a number of operations. It is suggested that these types of decisions often arise because of the measures used to assess the performance of operating managers, which often place a high emphasis on regular achievement of production targets. This is of course a good thing, but if it leads to decisions which generate 'short-term gain for long-term pain', then perhaps the focus of senior management, or the understanding of the goals by the operating manager, needs to change. None of this should be taken to imply that management is not free to make such decisions if all factors, both short-term and long-term, have been identified and balanced against each other, and an informed decision made. Frequently, however, these decisions arise from a corporate, or even industry,

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culture that values only short-term performance, and that either fails to identify long-term effects, or deliberately ignores them, assuming that they will be fixable at a later date.

The examples are in the context of underground metalliferous mines, though similar situations no doubt exist in other sectors of the industry. The challenge for mine technical and managerial staff is to identify where these types of things are happening in their operations, and to address the culture and attitudes that allow them to continue to occur.

Chasing every high-grade tonne

It is often said that 'grade is king', and correctly so. Yet on many operations, small amounts of high-grade ore are targeted without consideration being given to how this affects on the overall achievement of production and financial targets. In some cases, there is no assessment of the desirability of getting those tonnes at all: if it is above cut-off, it is to be mined, and the higher the grade, the more desirable it is, regardless of the cost. Additional development, often through poorer ground than normal, with reduced advance rates and increased costs, may be required. It may also be necessary to deliberately incur dilution to produce practical mining shapes to recover this material: the high-grade material *in situ* can easily become an average or low-grade ore source.

Many operations at least do an analysis to identify whether such material actually generates a positive cash flow, taking account of the costs directly incurred to produce it and the additional revenue received from it. To the extent that this analysis fully accounts for dilution and increased costs due to slower advance rates and increased ground support, this is good. However, it is rare to find an analysis that accounts for the 'opportunity cost' of applying mining resources to this material.

All mines have limited resources, including such things as labour hours and machine hours per time period. One of the goals of the planners and the operators must be to make best use of these resources. As well as identifying the simple profitability or otherwise of a target block of ground, it may be worthwhile identifying the effort involved, and generating measures other than metal grade per tonne by which potential ore sources may be ranked. Measures such as 'net revenue per mill hour' (especially useful if different rock and mineral types have different milling rates and metallurgical recoveries), and 'net profit per man-shift' or 'per jumbo-hour' may give a totally different view of the value of a block of ground from just grade alone. All other things being equal, the goal of the operation should be to generate the most profit from the resources available, and grade alone will often not be the best guide to what should and should not be mined.

In this and other contexts, there will be the associated issue of 'if we don't mine it now, it will be sterilized forever'. This is addressed later in this paper.

Avoiding production delays to install infrastructure

For a variety of reasons—some acceptable as a normal part of the ongoing obtaining of knowledge in mines, others due to poor planning or earlier operational decisions—it will sometimes be necessary to disrupt production activities in order to install infrastructure for the future of the operation. Where the decision involves, for example, access to future production areas, the short-term disruption will usually be seen as a necessary evil, and the planned work will proceed. But if the planned work is for services, such as ventilation and drainage, then depending on the culture of the company, the relative power of operators and planners, and the time horizon of management, it may be that the decision is to forego the installation to avoid the short-term disruption. The long-term effect of this may be that the operation can never deliver the planned production rate, as the facilities to support it have not been provided.

As indicated above, if all of this has been evaluated, and the relative costs and benefits of the alternative plans have been assessed, then it is the prerogative of the management to make the decision as they see fit. Unfortunately, it is often the case that the downsides of these options are not fully evaluated: planners may have significantly less power than operators who perceive that the temporary reduction in output will reflect badly on them, and/or the shortage of technical staff currently experienced in the industry results in there being insufficient time to evaluate fully the relative effects of the two options. In the absence of information about the downsides, an uninformed and ultimately costly decision can be made.

Cut-offs and production rates

In many operations, the importance of cut-off for delivering long-term value from the operation is still not well understood. The optimum cut-off will generally vary over time, and at any point in time (Lane, 1988) depends on the prices for the product(s), the cost structure of the operation, the tonnage/grade relationships of the mineralization accessible in the period being assessed, and the capacities of the operation to:

- Mine or expose 'rock', which is then available for classification as 'ore' or 'waste'
- Produce and treat 'ore'
- Produce, handle and sell 'product'.

The term 'ore' in this context refers to mined material that is sold or sent for processing to generate a saleable product. It is not used in the strict sense of the definitions in the various international codes for the public reporting of resources and reserves.

In open pits, 'mining' in the simplest cases is the removal of all the 'rock' from within the designed pit limits, and this does not notionally become 'ore' or 'waste' until trucks diverge on the haul routes to ore and waste dumps on surface. In more complex cases, with different drilling patterns and/or loading and trucking fleets for ore and waste, there is a more complex relationship between ore and waste handling capacities, and hence between rock and ore handling capacities, within the pit. In underground mines, 'mining' in this context typically relates to development of declines and strike access development in waste. These openings give access to mineralized material, which can then be classed as 'ore' and stoped, or left *in situ* as 'waste'. In this three-fold classification of material as rock, ore, or product, most activities in open pit mines are typically dealing with rock, whereas most activities in underground mines are typically dealing with ore.

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For a full understanding of modern cut-off theory, it is important to appreciate these differences. All operations will have capacity limitations for all three material types, and at least one of these will normally be constraining the operation. Often, and particularly in mature operations, ongoing debottlenecking will result in a balance of both rock and ore capacities—in open pits, both the mining fleet and the treatment plant will be working at capacity, though the run-of-mine (ROM) cut-off may vary to maintain this situation. In underground operations, waste access development and ore throughput will be at their limits, though the ore limitation may be in either the mine or the treatment plant. In underground operations that continue below a previous open pit, it is not uncommon to find that the access development rate is the overall limitation—even if performing at its maximum capability, insufficient mineralization with grades adequate to cover marginal costs of production and treatment is exposed to ‘fill the mill’. Product constraints are not a concern for most operations. Treatment plants are usually designed to handle maximum ore quantities at grades above the expected average, and downstream product-handling facilities are also designed to cope with these, perhaps with some short-term stockpiling of product, so normal grade fluctuations do not constrain the ore throughput.

However, some operations have genuine constraints on the amount of product they can sell, and many operations experience periods of extra-high grade production, when the amount of product that can physically be generated or handled becomes the overall production constraint. However, strategic options that involve increasing the cut-off and therefore the head grade, or grade distributions that result in schedules generating higher than normal head grades for a period of time, may result in scenarios where the capacity of the product part of the mill circuit becomes the overall constraint.

Underground operations

Existing strategies have been found to be suboptimal in a number of strategy optimization studies conducted by the author and his colleagues in recent years. Figure 1 shows a typical ‘hill of value’ (HoV) for an underground metalliferous mine. The vertical axis is net present value (NPV), though HoVs can be generated for all parameters of interest to the company (Hall, 2003, Hall and de Vries, 2003), to allow selection of strategic policies that deliver close to the best for a number of corporate goals, rather than the best for one goal only.

Operations are found to be frequently operating with both cut-off and production rate lower than optimal, as shown in the figure. Some of the reasons for this are discussed below.

Typical causes of sub-optimal strategies

The suboptimal production rate is often found to result from failure to utilize the existing productive capacities, which in turn is often due to cost savings that result in insufficient development of ore sources to ensure that planned production can be maintained should something go wrong with one of them. ‘Just in time’ development in underground mines frequently turns out to be ‘just too late’. Cost savings can severely reduce overall value.

Cut-offs are frequently too low because they typically fail to account for ‘sustaining’ capital expenditure (the regular ongoing cost of maintaining the productive capacities of the plant and equipment and mine accesses), and the time-value-of-money ‘opportunity’ cost of deferring higher-grade sources in order to produce from lower-grade sources. Sustaining capex is simply another regular cash outgoing, the same as administration overheads. Its separate treatment in the financial accounts should not cause it to be ignored in cut-off determinations. In fact it can be shown (though it is beyond the scope of this paper to do so) that the after-tax net cost of capital expenditure is higher than that of an equivalent amount of operating expenditure, and it should therefore if anything bear a surcharge rather than be ignored in ‘breakeven’ calculations. It should be noted that the terms ‘breakeven’ and ‘cut-off’ are not synonymous, though breakeven calculations are frequently used to determine the value used as the cut-off, a common cause of the ‘typical’ cut-off in Figure 1 being too low.

Moving to an optimal strategy

The ‘production rate’ axis in Figure 1 is the ore production and treatment rate. Maximizing value at the same cut-off will typically involve an injection of working capital by way of a temporary increase in the development rate. This will increase the number of sources producing concurrently, in order to guarantee delivery of the actual ore handling and treatment capacity already available. Increasing the cut-off at the same production rate will require both a permanent increase in the development rate, since the ore tonnes per metre of development will typically reduce with increasing cut-off, and a further temporary increase, to reestablish the working stocks of ‘developed ore’. The HoV shown also accounts for product constraints that may become active at high production rates and/or cut-offs.

Many operations that increase their cut-offs, particularly as a rapid response to poor profitability and a perceived need to increase head grade, do so almost instantaneously, with little or no planning or immediate increase in development capacity. Developed ore stocks remaining at the higher cut-off are quickly consumed and within a few months, the mine has a production shortfall, as there are insufficient sources developed to sustain the planned production rate at the new

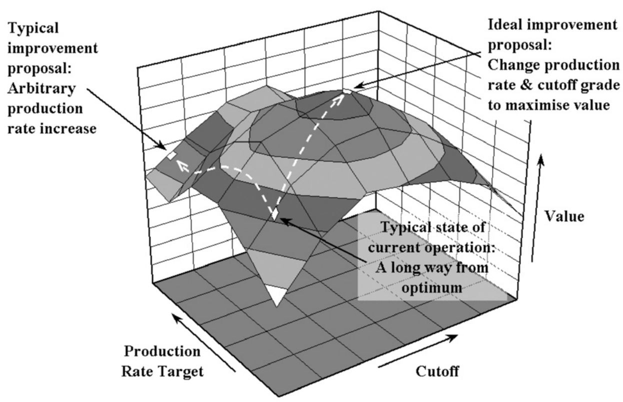

Figure 1—Variation of NPV with cut-off and production target – underground

cut-off. If lower grade sources that had been developed at the previous lower cut-off are still accessible, these may have to be mined as marginal material, but often with increased costs for access rehabilitation and/or extra development, and with a significant reduction in overall head grade. If these areas have been sterilized, there may be no alternative but to suffer the loss until the balance between development and production rates and developed ore stocks has been re-established.

This does not imply that cut-offs cannot be changed quickly. Rather it highlights that cut-off is an important strategic mine design parameter, and changing from an existing strategy to a new one is not a simple operational tactical issue, but one that requires careful planning and scheduling of the transition to predict and avoid problems such as those described. The results of numerous optimization studies conducted by the author suggest that some of the pain experienced by many operations during the global economic downturn in 2008 is due to mining plans with breakeven cut-offs derived during the preceding period of high prices. The rapid fall in prices of some commodities has not allowed time to change cut-offs and reestablished developed ore stocks at higher cut-offs. Use of a higher and more robust optimum cut-off taking account of the possibility of falling prices can significantly reduce the downside risk of price reductions (Hall, 2003, Hall and de Vries, 2003).

Varying multiple strategic policy items over time

It is assumed in Figure 1 that at each cut-off and production rate combination, the optimum mining schedule has been developed. There is no guarantee that a general development and stoping sequencing strategy that is optimal for one set of design parameters will be optimal for another. A full optimization methodology must be able to account for this.

Also, the three-dimensional nature of the chart allows plotting of only two independent design variables and one dependent variable. The cut-off specified on the cut-off axis is fixed for the life of the mine, which is how many if not most mining operations are planned. Even with this limitation, increases in NPV of 10% to 50% have been observed in a number of studies, for cut-off increases ranging from 30% to 50% of the value in use at the start of the study (Hall and Stewart, 2004). However, cut-off and the rock, ore, and product capacities can all vary, and it is well known that maximum value is obtained with a cut-off that can vary over time. The HoV shown could therefore be at least four-dimensional, with another independent variable axis for time, or perhaps six-dimensional, to allow for independent specification of alternative mine access development and product handling capacity changes. By varying the cut-off over time, additional value is potentially obtainable by mining higher-grade material first, then lower-grade material at a later date, to the extent that it has not been sterilized by the earlier higher-cut-off mining. But even if all lower grade material is sterilized at any cut-off, the HoV as shown indicates what the best cut-off is.

In caving mines, there may also be at least two different cut-offs, the one defining the ‘footprint’ or *in situ* volume of ground planned to be developed as ‘ore’, the other being the ‘shutoff’ defining the lowest grade of broken rock to be extracted from drawpoints.

Varying strategic policy items by location

Different cut-offs can also be applied to different areas within a mine to increase value (Hall and Stewart, 2004, Horsley, 2005). Figure 2 shows schematically how this arises. In the first part of the figure, two areas with similar mineralization, mining methods, and costs structures, and therefore notionally the same breakeven and cut-off, are mined. Different lives for the two areas result in an unprofitable low production rate tail that will be truncated by mine closure (if fixed costs cannot be sufficiently reduced to allow it to be mined profitably). During the life of the mine, production from the longer-life area will contain material that is above the common cut-off for both areas, but which is of lower grade than some of the material that remains unmined when the mine closes. The second plot shows how the cut-off in this area can be increased so that, at the time the mine does close, the best possible grades have been mined from both areas.

In this simple example, the cut-off policies to maximize value would be easily determined. In a real operation, predecessor/successor dependencies between various mining areas and other scheduling and sequencing constraints and options may make the selection of the optimal cut-off policy for all areas over time non-intuitive and nontrivial. Sophisticated optimization techniques may be required to select the best strategy.

Dangers of sub-optimizing for subsidiary parameters

Assume an underground operation that is both developing at the maximum rate in waste access headings, and, at the

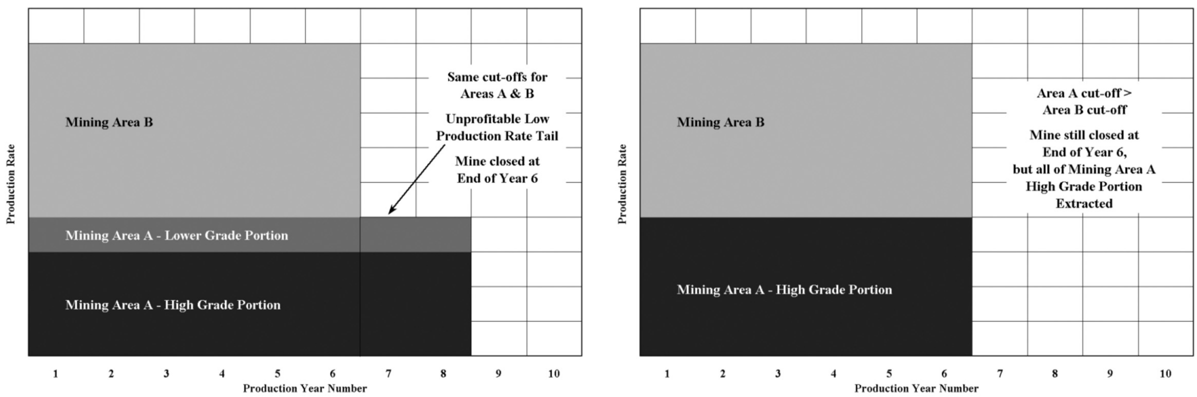

Figure 2—Value-adding by different cut-offs in similar areas

identified optimum cut-off, delivering the maximum quantity of ore that the mill can treat. There are also a number of activities in the mine that could potentially constrain the amount of ore produced. These include the in-ore development rate, the production drilling rate, the charging and blasting rate, the ore loading rate, and the ore trucking or shaft hoisting rate. Given the variations in these over time, and the different sizes of incremental capacity steps in each, it is unlikely that all of these will always be in balance.

Short-term tactical key performance indicators (KPIs) for operating managers typically include such things as maximizing equipment utilization. While this is notionally good, a better KPI is optimizing utilization. The difference is subtle but critical. Because of the imbalance in capacities of the various potential ore-constraining activities, the optimum mining strategy will involve some activities, and therefore the associated equipment, operating under capacity, rather than at maximum capacity. Attempting to operate all activities and equipment at maximum capacity will at best increase costs, and at worst, result in a de facto lowering of the effective cut-off, thereby reducing value.

Consider for example spare ore development capacity. In the example above the mill is being kept full at the optimum cut-off, but there is always the temptation to mine lower-grade material, whose grade nevertheless is sufficient to pay for its own marginal costs, because 'if it's not mined now, it will be sterilized forever'. There is therefore the temptation to utilize the spare ore development capacity to extend ore development into material below the identified optimum cut-off, but above the marginal breakeven, which improves the utilization statistics for the development equipment. Although the mill is being filled with above optimum cut-off material, developing into lower-grade areas will result in those areas also being produced, effectively lowering the cut-off, and thereby moving to a lower-value area on the hill of value, by deferring production of the higher-grade ore that should have been mined.

If the mill were not being filled with above optimum cut-off material, this would be a good tactical plan in the short-term. However, it must cause the mine staff to question why this situation has arisen. If simply a result of 'normal' variations in the mining cycle, short-term variations in effective cut-off are an appropriate response. But if the shortage of above optimum cut-off material is longer-term and resulting from a deviation from the strategic long-term plan, it will be necessary not only to devise a short-term tactical plan to get back to the optimum long-term plan, but also to identify what led to this situation and take appropriate steps to prevent its reoccurrence in the future.

The big danger, however, is for the short-term tactical response to become the long-term strategy by default. It is easier to fill the mill with a lower cut-off (it takes some of the pressure off the waste access development), the additional 'ore' is apparently 'economic', and the jumbo utilization statistics improve. The apparent tactical benefits will result in a move to a suboptimal strategic plan. If there were no other productive work for them, it would actually be preferable to pay the development crews to be idle until a planned development heading becomes available, rather than to incur the additional variable costs of extra development that then causes value-destroying material to be added to the ore stream.

A similar situation often exists in sublevel caving operations, where the shut-off used is often a relatively low marginal breakeven grade. Significant value can be destroyed by continuing to draw low-grade material when the next ring could have been blasted and higher-grade ore produced.

Open pit operations

Suboptimal strategies have also been found in use in open pits. Figure 3 shows a typical 'hill of value' for an open pit base metal mine, plotted as contours of NPV. The independent axes are the ROM cut-off (for ore sent directly to the mill) and the overall 'rock' (i.e. ore + waste) mining rate, expressed in this case as a percentage of the base case rates in the pre-existing plan, which may vary from period to period.

The figure indicates that, as the mining rate increases from low values, more material is available for treatment, and the cut-off can be increased to supply higher grades to the mill. Material below the ROM cut-off is stockpiled for later treatment if profitable. Up to a point, the higher grade, and hence increased revenue, more than pays for the increased mining costs, and value increases. Eventually, the mining rate will increase to the point where the tonnage/grade relationships of the deposit are such that any revenue gains are exceeded by the extra mining cost.

Varying multiple strategic policy items over time

Figure 3 has been generated simply by accelerating or decelerating the existing planned mining sequence. There is no guarantee that this sequence is the best, or is even practical, at all mining rates evaluated in the initial calculation. As with the underground situation in Figure 1, the three-dimensional nature of the chart allows plotting of only two independent design variables and one dependent variable. The cut-off and mining rate factors in Figure 3 are fixed for the life of the mine, but cut-off and rock, ore, and product capacities can all vary, and it is well known that maximum value is obtained with a cut-off that can vary over time. Other design parameters that can be varied include the sinking rate of the pit (e.g. in terms of metres or benches per year) and the ultimate size of the pit (expressed perhaps as a

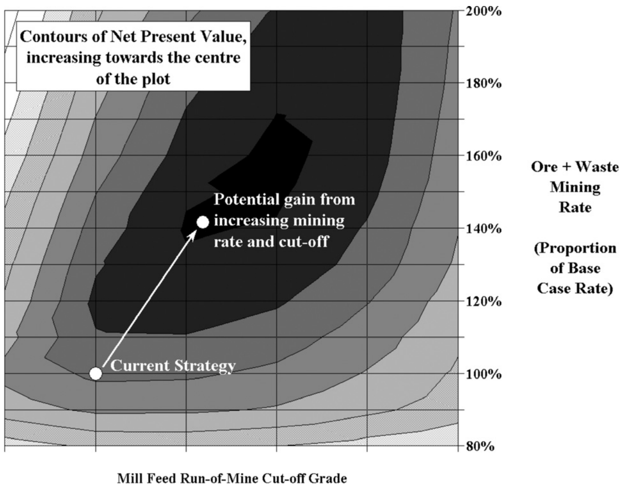

Figure 3—Variation of NPV with cut-off and mining rate—open pit

volume, tonnage, or Whittle ‘Pit Shell Number’). The HoV shown could again be multi-dimensional, to allow for independent specification of alternative mining and treatment capacity and rate changes.

Dangers of suboptimizing for subsidiary parameters

It was noted above that the simple picture presented by Figure 3 at higher mining rates might not be achievable, but a more detailed analysis would account for any implicit impracticalities. However, a reduced mining rate will always be a practical alternative. It is not uncommon to encounter a desire to reduce the mining rate, in effect by deferring waste stripping, which reduces the overall rock mining capacity earlier in the mine’s life. (This may or might not be countered by an increase later.) The effect of a lower mining rate is to reduce the amount of mineralized material available for classification as ore in the time period in question. To maintain mill throughput, it is necessary to reduce the ROM cut-off, moving to a new mining position below and to the left of the ‘current’ position in Figure 3. The value of the operation reduces, as the cost savings from reduced mining rates are more than offset by a drop in revenue from lower ore grades.

It can also be seen in Figure 3 that the value contours are significantly closer to the left of and below the peak in the figure than in the other areas of the chart. The overall implication of this pattern is that it is more costly in the long run to be mining too slowly than to be mining too fast by the same proportion.

Issues common to open pits and underground operations

The danger of evaluations at one cut-off or production rate

Many operations still use a simple breakeven grade as the cut-off. This takes account of prices and costs only, though the rock, ore and product production capacities provided will influence the costs used in the calculation. It is also not uncommon to find that these cut-offs are set early in the exploration process, using high-level cost estimates, when the size and shape of the ‘orebody’ is first becoming apparent. Scoping studies are conducted to obtain an initial estimate of the value of the potential project and to justify further exploration and/or more detailed studies. Subsequent studies often then result in the specification of mining fleets and facilities and treatment plants designed to handle waste and ore quantities (and qualities) defined by the initial approximate cut-off, with no guarantee that the best combination of capacities and cut-offs has been selected. Tactical decisions (i.e. to save time and costs) during the evaluation and feasibility study process can result in the specification of a significantly suboptimal strategy.

Figure 4 illustrates how this can happen. Using only a single cut-off in the evaluation, ‘Strategy A’ may appear significantly better than ‘Strategy B’. An analysis at a range of cut-offs can give a significantly different outcome. The same effect may be seen for other strategic decision parameters, such as rock mining and ore production rates, separately or in combination.

Testing the impact of apparent limitations

There will be practical upper limits on many physical capacity parameters, such as the rock, ore, and product rates, which will make some parts of the HoV impractical. If the value of the HoV surface is increasing at those limits, the ‘hill’ effectively ends at a ‘cliff’, and the indicated optimum strategy will be to work with that particular limiting parameter at its limiting value. In other cases, the value of the operation will be falling when it reaches the cliff, and the optimum strategy will then occur at the peak of the HoV.

As well as the more usual apparent constraints, such as limits on the various production rates, there may be practical upper limits on, for example, cut-off. The nature of the mineralization may be such that zones above a particular grade may not be able to be delineated for selective mining in practice, even though geologically they are known to exist. The cut-off cannot practically be specified above that grade. Similarly, the existing geological model may have been developed to identify material above a certain grade, and ‘orebodies’ at cut-offs significantly below that grade may be unreliable. However, it is often worthwhile continuing calculations and evaluations beyond these apparent limits. If the peak of the HoV is found to lie within acceptable ranges for the various parameters, there are no problems. But if the peak of the HoV lies beyond one of these limits, the difference between the peak value and the value at the limit gives an indication of what could be spent to remove the limitation, which in many cases will be more a function of current practices than an absolute and unchangeable constraint.

The effect of mining rate on optimum cut-off

It is not uncommon to find that an increase in mining rate is the solution proposed to get a marginal mine out of trouble. The assumption is that similar head grades, and hence cut-off grades, can be maintained. If the transition to a higher rate is properly planned and executed, with a corresponding increase in the waste development (underground) or waste stripping (open pit) rate, this may be so, and value gains can be realized – e.g. by moving higher up the HoV in Figure 1 at the same cut-off, but not going as far as the ‘typical improvement proposal’ shown there. (If waste mining rates are not increased, similar production shortfalls such as those described above for increasing the cut-off in an underground mine may occur.)

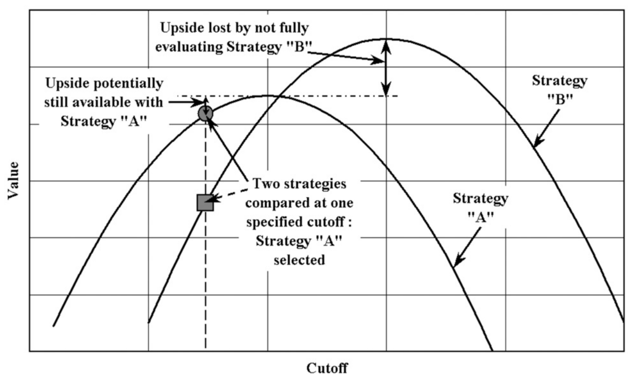

Figure 4—Potential losses from evaluations at one cut-off

It is often then postulated that, if the production rate is increased, the cut-off can be reduced to increase the reserve and the return. It is reasonable to expect that increasing the production rate will reduce the breakeven cost per tonne of ore. However, Figure 1 demonstrates clearly that reducing the cut-off, though it may increase the reserve, will reduce the NPV, not increase it. The cut-off will, however, have to be reduced if the waste mining rate does not increase in line with the ore production rate: this is the same situation as reducing the waste mining rate at the same ore treatment rate, as described for open pits and illustrated in Figure 3 above.

The implication of this is that the optimum combination of waste mining and ore treatment rates and cut-off will vary depending on whether one of the constraints is to be artificially constrained or not, e.g. by deliberately reducing the waste mining rate, or by deliberately or unconsciously not allowing it to increase in line with a planned ore production rate increase. The costs savings from imposing a limit may be more than eroded by loss of revenue from lower head grades.

The effect of metal prices and costs on optimum cut-off

Conventional wisdom suggests that if prices go up, cut-offs should go down in inverse proportion, and vice versa. And similarly, if costs reduce, cut-offs should go down in direct proportion, and vice versa. These are true of breakeven grades, and if the cut-off selected is a breakeven, then they will be true of those cut-offs also. However, Hall (2003) and Hall and deVries (2003) have demonstrated that this is not the case for optimum cut-offs that maximize NPV.

For optimum cut-offs, a number of case studies have demonstrated that the changes in optimal cut-offs are substantially less than suggested by a breakeven methodology. The methodology developed by Lane (1988) indicates theoretically why this is so. If a ‘balancing cut-off’ as defined by Lane (i.e. that which results from operating at the capacity limits of at least two of the rock, ore and product streams) is the current effective cut-off, it will be unaffected by price and cost variations, being solely the result of the physical plant capacities and the nature of the mineralization. The ‘opportunity cost’ terms in two of Lane’s ‘limiting’ cut-offs even make it possible for these cut-offs to move in the opposite direction to that suggested by the conventional wisdom, and this effect in the optimum cut-off has been seen by the author in some studies.

These effects make it impossible to predict the movement in optimum cut-offs for any specified price or cost changes without performing a full analysis of the strategic plan.

Hall (2003) and Hall and deVries (2003) have also demonstrated how working with a typical suboptimal cut-off will increase the volatility of returns as prices change, and can significantly increase the risk of achieving low or negative returns when prices fall. Operating with optimum cut-offs for lower prices will frequently capture most of the upside from price rises, and can significantly reduce the downside risk of price falls. The relatively small changes in optimum cut-offs observed, coupled with the relative flatness of the peaks of the hills of value, often mean that optimum mining strategies are relatively insensitive to changes in economic conditions, whereas suboptimal strategies on the slopes of the HoVs may require significant changes, perhaps with little notice, when conditions change. As noted above, it is possible that some of the problems experienced by many operations during the economic downturn in 2008 could have been avoided by use of optimum rather than breakeven cut-offs.

The timing of infrastructure capital spending

Saving or deferring of costs is always an important and valid way of improving the value of an operation. Frequently, however, the short-term tactical benefits cause long-term strategic problems. The issues often arise at the time of preparing the annual capital and operating cost budgets. Provisional budget items are often treated as ‘wish lists’, and the question will often be to the effect of: ‘Do we have to do or spend this now? Can it be deferred?’ The answer is often ‘Yes, but . . .’ ‘Yes’, the item can be deferred, in the sense that the mine is not going to come to a complete standstill overnight if it is not done. ‘But’ the operation may be less efficient, and the cost, either extra direct costs of doing it later, or lost revenue from lower production, may be significantly greater than the immediate savings apparently made.

As above, if all aspects of the alternatives have been evaluated, and the relative costs and benefits of the alternative plans—to spend or not to spend—have been assessed, then it is the prerogative of the management to make the decision as they see fit. But again, it is often the case that the effects are not fully evaluated—the downside costs or loss of revenue may be difficult to quantify, whereas the direct cost of the item in question is plain—and in the absence of information about the downsides, an uninformed decision to ‘save costs’ is made.

Service facilities

If the planned work is for service facilities, foregoing the installation to save costs in the short-term may result in a failure to provide the services needed to support the planned production in the future. ‘Required volume of clean air’ is a resource that rarely appears in mine scheduling systems, but it may be crucial to enable various planned activities to proceed in parallel. If it is not available, these activities may have to proceed sequentially, extending the overall duration of mining activities associated with a given tonnage of ore, and thereby reducing the overall mining rate. Similarly, inadequate drainage can not only result in increased wear and tear on equipment, but can also reduce the rate at which it can operate, restrict access to working places, and/or require labour and equipment that could otherwise be allocated to productive activities to be allocated to drainage system maintenance and clean-up of mine openings.

Mining information and production infrastructure

Cost savings by deferring capital development underground or waste stripping in open pits, and expenditure on exploration or infrastructure such as a shaft, can also have a significant negative impact on overall profitability. Deferral of waste stripping in open pits has been discussed above. Slowing decline advance rates in underground operations can have a similar effect.

While improving truck haulage efficiencies are continuing to extend the economic depth of trucking—in many instances to below 1 000 m below the tipping point—this does not necessarily imply that a shaft should not be sunk until that depth is reached. Deferring the sinking of a shaft can both reduce the value of the operation and significantly shorten its life. However, the increasing economic depth of trucking appears to provide some comfort to managers deciding to defer shaft sinking capital expenditure. Also, many operations limit in-mine exploration expenditure to merely continue to provide perhaps two or three years’ worth of reserves. Together these types of cost-saving policies can have a major negative impact on value. The limited reserves may never be sufficient to justify the capital outlays for more efficient infrastructure, by reducing operating costs over a long enough period of time. If sufficient mineralization is eventually proven, it may be too late to have an effect.

The example below relates to trucking all ore to surface, versus installation of a shaft, with reduced trucking up to the bottom of the shaft. The rationale, however, applies to any situation where major capital expenditure to install efficient systems can significantly reduce future operating costs.

Value lost by deferring spending on infrastructure

Hall (2005) describes a hypothetical steeply dipping orebody, with a single production front moving downwards through it. Production is by truck haulage, currently to surface, and a shaft to 1 000 m depth has been proposed. In the scenario presented, proved and probable reserves currently extend to 900m depth, and inferred resources extend some distance beyond that. The deposit is still open at depth. The analysis has projected the known orebody characteristics to 2 000 m depth to assess what the company’s options might be. Figure 5 shows the effect of deferring the shaft sinking decision.

The ‘trucking only’ curve shows a maximum value at a little over 1 000 m depth, which is therefore the economic limit of trucking. A dashed line at this value to greater depths indicates the value that a shaft option must have to be better than trucking only. A dotted and dashed line $5M dollars above this indicates the value that a shaft option must have to be that much better than trucking only—perhaps a ‘safety margin’ to account for some of the risk associated with the large up-front capital cost of the shaft option. With a 1 000 m deep shaft, the economic depth of the mine—with trucks hauling up to a tipping point above the skip loading station—is about 1 550 m–1 575 m.

The time of the start of shaft hoisting is expressed as the elevation of the production front, which in the scenario illustrated is moving down at 40 vertical metres per year (‘vm/y’). The lines plotted for shaft hoisting starting at 100 vm intervals therefore represent deferral time increments of 2.5 years. It can be clearly seen that deferring the shaft option (the value of which includes its capital costs) results in decreasing value, as the later the start, the less ore is hoisted at the lower shaft operating costs.

If the mineralization extends to at least the economic depth of say 1 550 m, then the shaft option will no longer deliver the required $5M margin over trucking only if the start of shaft hoisting is deferred beyond when the production front is at about 1 030 m. The value of the shaft option falls below the maximum value with trucking only if the start of shaft hoisting is deferred beyond when the production front is at about 1 140 m. If the mineralization is closed off at a shallower depth, earlier shaft starting times are needed to make the shaft option viable.

If analyses were done at one final depth of the mine only (typically the known bottom of mineralization at the time of the evaluation, and often with a downgrading factor applied to inferred resources), a value destroying decision could be made. This is similar to the situation in Figure 4, for analyses done at one cut-off. Although the value of the shaft option is greater than the value of trucking only for most specified final depths below the shaft starting depth, shaft hoisting is nevertheless not always the best option. As is evident in Figure 5, the value of the shaft option at a range of final depths of the mine can be significantly less than the value at the economic limit of trucking-only if the shaft is deferred too long.

It can also be seen that deferral of the shaft effectively results in a range of uneconomic final depths of mining. For shaft hoisting starting when the production front is at 1 000 m depth, mineralization extending below the economic limit of trucking (at approximately 1 030 m depth) is uneconomic unless it extends below 1 150 m, at which point the shaft curve exceeds the maximum trucking-only value. If the shaft is deferred to start when the production front is at 1 100 m, the uneconomic final depth extends to approximately 1 230 m. If mineralization extends only to these depths, its value will be lost if the shaft is deferred too long—the mine should cease with trucking only at the economic

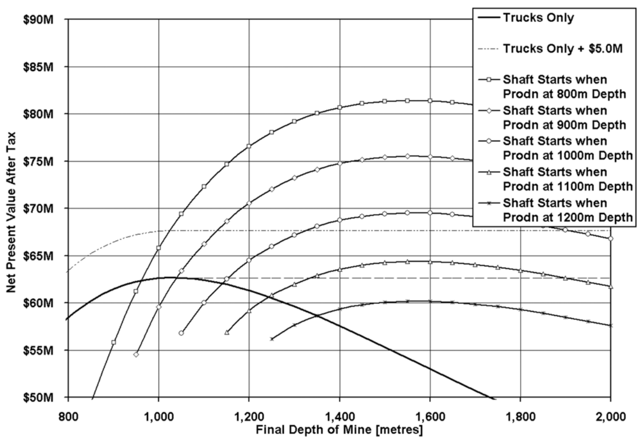

Figure 5—NPV with trucking only, and a shaft starting at different times

limit of 1 030 m depth. But if the shaft is built early enough, the mine will be economic for any depth of mineralization, down to the economic depth with shaft hoisting of 1 550 m, and the value will be significantly greater than with trucking only.

Identifying the exploration target required to justify the infrastructure

Hall (2005) also describes how hypothetical calculations for a range of potential depths of mineralization can identify the reserves required to justify the proposed infrastructure. It can be seen that, if shaft hoisting starts when production is at 900 m depth, the mineralization must extend to 1 030 m for the shaft option to break even with trucking only, and to 1 130 m to generate an extra $5M, which are 130 m and 230 m respectively below the hoisting starting point. However, if shaft hoisting starts when production is at 1 000 m depth, the required minimum depths of mineralization become 1 150 m and 1 330 m, 150 m and 330 m respectively below the hoisting starting point. Working backwards from the starting point of shaft hoisting, to allow for construction, preceded by analysis and decision-making, the time when the exploration data must be available can be estimated. In the example used, this is a total of 2.5 years, or 100 vertical metres of production advance. Depending on the existing knowledge, the timing of the start of the exploration programme and the overall depth that it has to cover can be determined. Applying this process to a range of shaft starting depths, curves such as in Figure 6 can be derived.

The dotted lines show the minimum depth, in absolute terms, of mineralization required, which is shown on the left-hand vertical axis. The solid lines show this as the extra depth or exploration lead at the time of starting the analysis and evaluation, after the exploration results are available, with values shown on the right-hand vertical axis.

It can be seen, as is also evident in Figure 5, that as shaft sinking is deferred, the required depth of mineralization to justify it increases, and at an increasing rate. The required exploration lead, however, has a minimum at somewhat less than the trucking-only economic limit. Although Figure 5 indicates that, if it is justified, the earlier a shaft can be installed the better, Figure 6 suggests that there may be practical constraints on this. If for example drilling cannot be done to depths beyond 300 m, it will never be possible to prove a shaft with a $5M margin over trucking only. If, however, it is only necessary for the shaft to break even with trucking only, this will be feasible for shaft hoisting starting when the production front is anywhere between 700 m and 1 080 m. The absolute minimum exploration lead for breaking even is approximately 240 m, with hoisting starting when production is at approximately 920 m. This is equivalent to 6 years' production at 40 vm/y.

If it is decided to limit exploration costs by maintaining say 2 or 3 years' reserves only ahead of the production front, it is clear that a shaft will never be justifiable, even though it may have been a better option. As well as limiting exploration expenditure, the mine can also now avoid the costs of an expensive study of shaft hoisting, since this will never generate a better scenario with the limited reserves data available. The mine must close at the economic limit of trucking only, regardless of how much deeper the mineralization may ultimately be found to extend, and the fact that, with hindsight, the shaft could have been installed with significant benefits.

Conclusions

Numerous strategic plan optimization case studies are showing that conventional wisdom is often far from wise. Typical industry practices for determining cut-offs result in mine plans that are often far from optimal. Significant extra value can be obtained from many operations, often by increasing the cut-off and thereby reducing the reserve and the mine life. These strategies can also reduce the volatility of returns when prices change, and in particular can reduce the risk of negative returns when prices fall.

The natural desire to reduce costs is often counter-productive. Reducing the waste-stripping rate in open pits, and the rate of decline advance underground, reduces the amount of mineralized material available to work with, and will typically result in reduced cut-offs to keep the mill full, and reduced revenues that more than outweigh the mining costs saved. Delaying or failing to provide apparently expensive services infrastructure can later result in the services being unable to support the planned production rates, with the loss of revenue again outweighing the apparent saving.

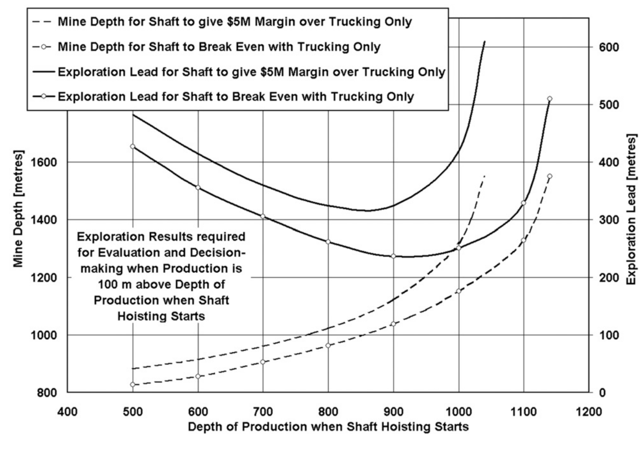

Figure 6—Exploration requirements to justify infrastructure capital

'Short-term gain for long-term pain'

Savings obtained by deferring exploration expenditure may make it impossible to ever justify capital expenditure for efficient and low operating cost production facilities, which could have extended the economic depth of mining, the mine life, and increased the overall value extracted from the deposit. Even if the expenditure is justified, continual deferral of capital expenditure can result in there ultimately being insufficient resource left to pay for it, again resulting in a reduction in both mine life and value obtained for the company's owners.

Ideally, the short-term tactical mine plan and the mine operations should be working within the framework of an optimized long-term plan that best delivers the company's goals. Occasional deviations from the strategic plan are a reality in mining, but the tactical plans should be seeking to return to the optimum strategic plan, which may in some circumstances have to change as a result of events in the operations. The danger comes when the tactical deviations are allowed to become the long-term strategy by default, without an assessment of how this may drive the operations away from achieving the corporate goals. Tactical expediency can very easily become 'short-term gain for long-term pain'. Planning and analysis tools and processes are available to deliver more and better information to decision makers than they have had in the past. The industry must look beyond unwise conventional wisdom, and the costs of studies to identify optimum strategies, to see the long-term benefits that are available but unfortunately are often not realized in mining operations today.

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