Misguided Objectives that Destroy Value

G Whittle[1]

ABSTRACT

Although everyone is committed to the company's success, it is common for different parts of a mining/mineral processing organisation to work to local subobjectives, such as maximising the size of the resource, maximising life-of-mine/operation, minimising mining costs, and maximising processing recoveries. Whilst being well-meant, these can be demonstrated in many situations to be counter-productive to the overall corporate objective of maximising value. The fact is that most planning decisions are linked in terms of the consequences they have on the overall outcome, so many complex trade-offs must be considered. A comprehensive, holistic approach should be taken to planning decisions, and this must be supported by the appropriate analysis. Addressing this is both a challenge and an opportunity for business planning and optimisation specialists.

INTRODUCTION

The observations made in this paper are based on the author's experiences during optimisation studies involving over 15 mining and mineral processing companies during the last six years. The companies ranged from junior miners to divisions of the large, well-known mining houses. The behaviours referred to are certainly not universal, but have been observed on more than one occasion. The reason for challenging these behaviours is to promote, in the interest of furthering the objectives of the company, the understanding of the broad consequences of decision criteria that are too narrow. When undertaking optimisation studies for mining and mineral processing operations, it is not unusual to observe behaviours that reduce or limit the economic value of the business. These can occur due to the acceptance of certain simple subobjectives, which appear to be consistent with creating value or increasing viability, but which, with more insight, can be shown to be counterproductive. Misguided objectives have been observed at a range of levels, from departmental to corporate, and in several types and sizes of mining companies. The fact that this can happen is a reflection of the complexity of the mining and mineral processing industry, as well as the difficulty of running organisations involving wide ranges of specialists. This topic represents an opportunity for value enhancement that has not yet been comprehensively exhausted. The figures used here are based on a fictitious nickel operation. The geological model is a real lateritic deposit with some waste added on top, but is being treated as if it were a sulfide operation with a concentrator and smelter. This serves the purpose of numerical illustration.

MAXIMISING THE SIZE OF THE DEPOSIT

Original resource estimates are generally developed using fairly arbitrary mineral cut-off grades, based on industry standards or previous experience. This is inevitable, as resource estimates are usually made well in advance of detailed studies and the consideration of geo-technical, mining, and mineral processing, as well as market factors. The result is that terminology such as 'two million ounces of gold', or '100 Mt of ore above 0.8 per cent nickel' is used to indicate the size of the mineral deposit. Note that the JORC code prescribes strict guidelines for the basis of 'Resources' and 'Reserves' statements. This paper refers to the more general internal process of project scoping and scaling, not the onerous topic of substantiating public announcements. The

1. MAusIMM, Managing Director, Whittle Consulting Pty Ltd, Suite 13, 333 Canterbury Road, Canterbury Vic 3126.
   Email: gerald@whittleconsulting.com.au

next step is likely to run Gemcom-Whittle (or another Lerchs-Grossman approach) using estimated slopes, recoveries, mining and processing costs, and metal prices. Depending on the level of confidence in the resource model and the various estimates, the contents of the resulting revenue factor = 1 pit shell using the marginal cut-off grade, may be regarded as the quantification of how much of the deposit is economic. Having a large deposit implies validity, viability, economies of scale, and intrinsic value. It can be argued that a large deposit supports obtaining finance and market valuations, perhaps rightly because it presents a wider range of future options, or perhaps wrongly because size is used as a surrogate for value in the absence of the proper analysis. It is therefore tempting to select a development option that involves large tonnages. For a given deposit, however, there is usually a significant difference between the maximum tonnes that are economic (if that means above break-even), and the tonnes that maximise the economic value.

The issue becomes apparent when developing an optimal mining, processing and production plan. The following factors need to be considered:

- The curve of cash value versus tonnage tends to be flat at the top (Figure 1). For example, it is common for the last third of the life-of-mine to be quite marginal. Whilst it is worth maintaining the option to operate during this period and in this part of the deposit in case prices, costs, or technology improve, this part of the resource should not be regarded as a core part of and driver of the project.

- When the time value of money is taken into account, the outer shells of the revenue factor = 1 pit can be shown to reduce value, due to the fact that the cost of waste stripping precedes the margins derived from ore ultimately obtained. The effect of discounted cash flow means the discounted costs outweigh the more heavily discounted revenues. The optimal pit from a Net Present Value (NPV) viewpoint can be between revenue factor 0.65 and 0.95, depending on the deposit's structure and the mining constraints (minimum mining width, maximum vertical advancement per year, and limit on total movement) and processing capacity. This can be seen where the peak of the discounted cash flow of the specified case is at a lower overall tonnage than the peak of the undiscounted total cash curve (also Figure 1).

- When the cut-off grade is optimised and therefore raised in the early part of the schedule to maximise value (Lane, 1988), then the tonnage of material to be processed reduces further. Stockpiling may mitigate this (Figure 2).

- If new capital expenditure is taken into account, and it is generally not in the pit optimisation process described above, then the hurdle for margin is increased further, disqualifying even more tonnes of seemingly economic material.

All mine plans seek to exclude negative margin material (below the marginal cut-off grade, below break-even) as this obviously reduces value. The lower range of positive margin material should also be excluded as it will also dilute value, due to the above factors. Ken Lane published his work in 1988, but it still appears to take great courage for some managers to take this latter step, even when the analytical evidence is indisputable.

There are therefore a number of reasons why the 'optimal' size of the mined deposit (ie maximum value as measured by NPV) is significantly smaller than the apparent 'economic' resource (which usually includes all material above the marginal cut-off
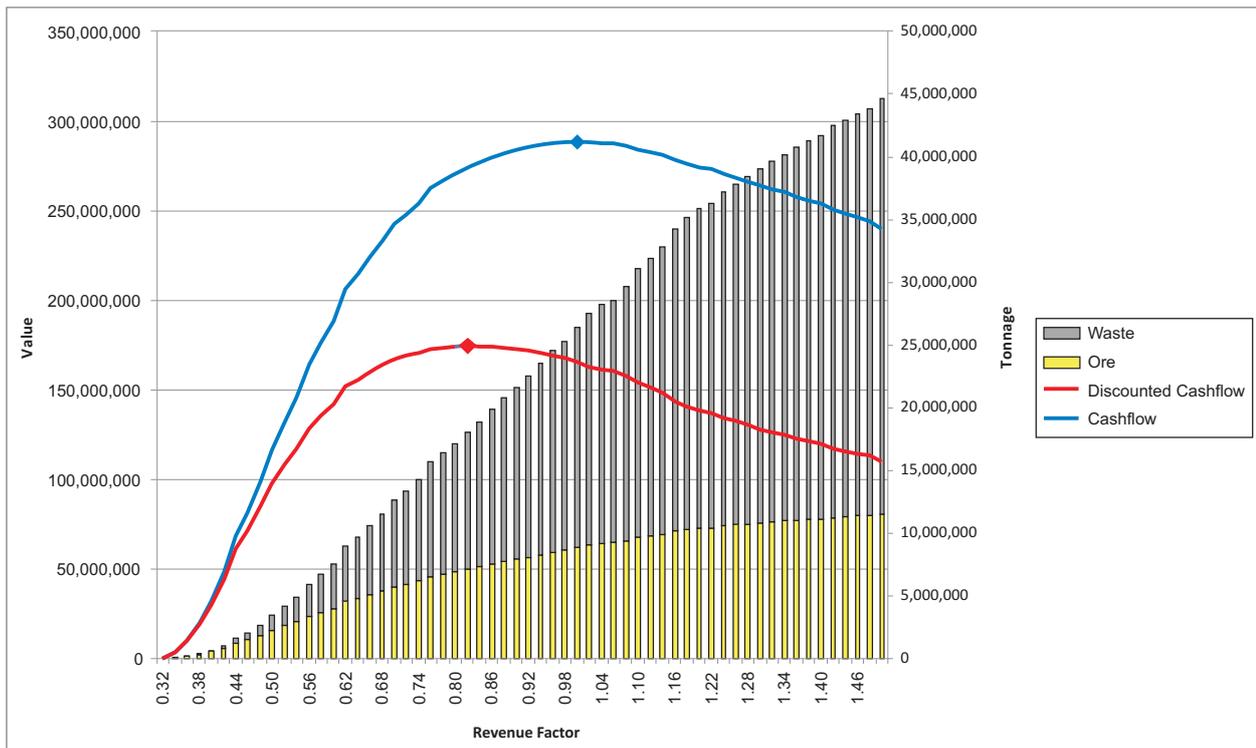
FIG 1 - The pit-by-pit graph from Gemcom-Whittle follows the progression through the nested shells generated by Lerchs-Grossmann as the revenue factor is steadily increased. The discounted cash flow peaks at much lower tonnage than the undiscounted cash flow, which by definition peaks at revenue factor = 1.
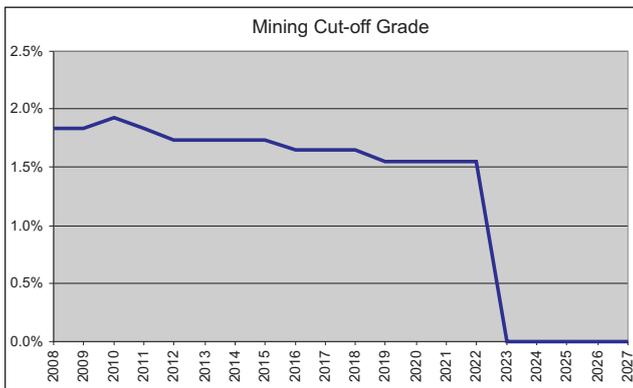

FIG 2 - When optimised, the cut-off grade applied when mining, between what is processed versus wasted, descends over the life of the operation to settle at the marginal cut-off grade as the deposit is depleted.

grade). Presenting an optimal plan that only mines and processes perhaps 60 to 80 per cent of what was previously regarded as the economic resource can lead to disappointment. The resource geologist should not be left to determine the useful size of the deposit alone. Plans for how much of the resource should be mined and processed require proper consideration of a range of factors, including mining methods and constraints, downstream recoveries, costs, throughputs, capital and ultimate metal price outlooks, and the understanding of how these affect the outcome.

MINIMISING MINING COSTS

It appears obvious to want to minimise cost per tonne or cubic metre of the mining activity; this objective is often pursued by simplifying and regularising the mining operation. It is easy to agree that any opportunity to reduce fuel consumption, tyre wear, haul distances, etc for the same effective work completed is beneficial, as it will reduce costs. It seems to make sense to minimise total mining activity whilst maintaining sufficient feed to the plant. It is more difficult, however, to determine the total consequence of these mining decisions. Examples of where well-meant efforts to reduce mining costs become counter productive to the overall outcome can include:

- using larger equipment with lower operating cost per tonne or BCM, but less mining selectivity and increased dilution;

- pit/phase shapes that favour mining simplicity or convenience rather than value of feed to the plant;

- schedules with constant waste strip ratios for ease of fleet size management;

- schedules based on constant mining rates, to make sure the fleet is fully utilised;

- schedules based on keeping the plant full (often a good idea, but not in itself a valid objective);

- schedules based on deferring waste stripping costs or minimising early haul distances as objectives in themselves;

- schedules based on the marginal cut-off grade, which minimises total movement whilst filling the plant;

- schedules based on fixed cut-off grades over time (even if it is higher than the marginal cut-off grade, a fixed cut-off is seldom optimal); and

- minimal number of stockpiles for ease of grade control and operational management.

The question is not 'what can be done to make mining efficient from a mining perspective?' but rather 'how much trouble and cost should we go to in mining to maximise the value of the business?'. In some operations, the mining cost is only 15 per

cent of the total cost of the value chain; it is clear that consideration of the consequence on downstream activities should be the priority of mining management. To calculate the trade-offs that are warranted by mining for the business, it is necessary to have:

- a realistic appreciation of the actual structure of the orebody (which is not necessarily what the block model contains);

- a good understanding of operational alternatives for mining and their consequence on the ability to control the blend delivered to the plant over the life-of-mine;

- a decent cost model for mining which reasonably accurately responds to changes in operating levels and practices, including the distinction between variable and fixed/period costs and the effect of tonnes or cubic metres, rock type, chosen grade control method, chosen level of material selectivity, horizontal and vertical haul distance, etc;

- a comprehensive model of the plant and downstream issues of cost, throughput and recovery and its flexibilities; and

- an appreciation of the market that the mining/processing system is feeding.

A well-developed mining function is likely to have the factors internal to mining well under control, but it is less common to see the external (downstream processing and market) factors harnessed with the analytical capability required to develop a mining plan that is optimal from the integrated view of the business. The mining manager should not be left to determine the optimal mining plan alone. Significant input and cooperation from other sources is required to determine the right mining plan for the business.

MAXIMISING LIFE-OF-MINE

It is often observed that decisions which maximise the life of a project are favoured. Extending an operation may prolong employment, royalties, and the other positive social aspects of the operation; it also increases the environmental and other negative aspects, but it is questionable as to whether it increases value in itself. It is sometimes argued that longer project life allows the capital to be amortised over more time or more tonnes. Whilst this may be true in an accrual accounting sense, the NPV calculation (rightly) only considers cash flows, so this consideration is already taken into account. If conditions change, and additional value can be generated from sunken capital and otherwise unusable assets and resources, then an opportunistic approach is entirely reasonable. If there is a desire to maintain operational continuity during poor economic times to maintain the option of being profitable if an upturn eventuates, that is a valid strategy also. However, it is questionable to design into a project plan a deliberate long life-of-operation as an objective in itself, and can be in direct conflict with maximising value.

If the material that is planned to be processed is economic, then NPV is favoured by mining and processing it quickly. This apparent financial benefit must be weighed against the capital, risk, and other consequences associated with setting the project up for higher rate operations. If negative or low value material were processed all together at the end of the life of the project, it would be an obvious problem, as the business would make negative or insufficient returns during that period. If poor material is spread throughout the life of the operation, it has an even higher negative impact on NPV, as it comes in earlier but is less obvious (Figure 3). An argument sometimes presented against the application of pit and phase optimisation, using an ultimate pit under revenue factor = 1 and raised cut-off grades, is that they 'reduce the life of the mine'. A good project developer will give impartial consideration to the size and life of an operation.
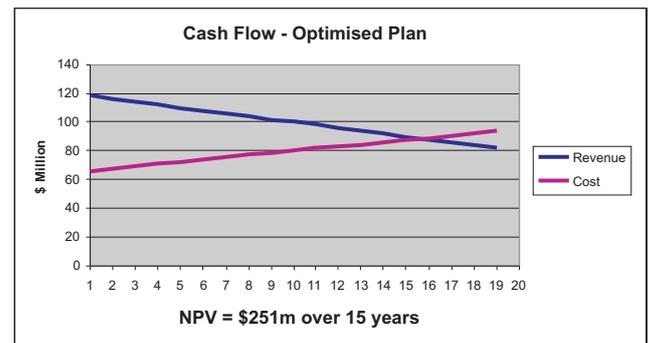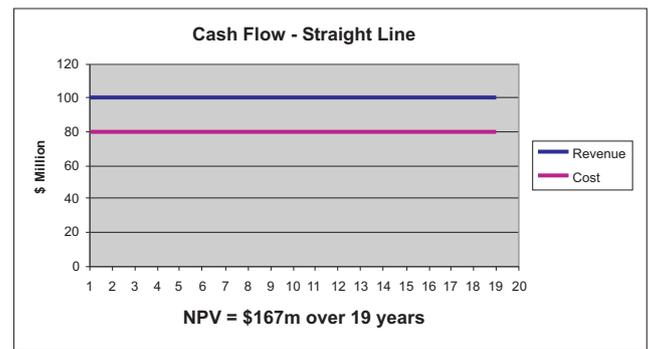

FIG 3 - As a minimum, the optimisation process will result in a retiming of revenues and costs. NPV can be significantly increased even if the result is a shorter life-of-operation.

MAXIMISING RECOVERY

It seems logical to aim to maximise metallurgical recovery in the plant. The company is in the business of making metal, so it should make as much as possible from the mineral resource it has. It is easy to agree that, with all other factors being equal, steps which increase recovery are beneficial. There is invariably a trade-off between capital spent and the recovery profile of the plant. Investing in more sophisticated technology (some examples are secondary recovery circuits, thickeners, and dryers) can lead to better effectiveness; this can be evaluated on a cost-benefit basis. However, for a given design of plant technology, there are other configuration and operating trade-offs that can be made between recovery, operating cost (increased concentration of acid, power, heat, etc), throughput (residence time), and the level of concentration/purity of the output to go to the next stage (Figure 4). Wooller (1999) observed that sacrificing some metal recovery in the interest of increased throughput can increase value, just as Lane (1988) observed that raising the cut-off grade applied during mining, and therefore sacrificing some metal recovery, would do the same.

Consider the example of an operation that involves a mine, a mill/concentrator and a smelter. The question is how to run the mill/concentrator. If the system is mining limited, then the mill/concentrator may as well run at high-recovery/low-throughput (from the mill's viewpoint). If the system is mill/concentrator limited, then it should tend towards low-recovery/high-throughput; it is worth sacrificing some metal recovery to maximise the overall metal throughput. If the system is smelter limited, then the mill/concentrator should maximise the concentration of its product, in order to maximise the metal flow through the smelter, which is the downstream bottleneck. A capable analyst could calculate the single period trade-offs for these parameters, if the alternatives were numerically defined. The complication is that the actual cost of sacrificing metal

Recovery/Throughput
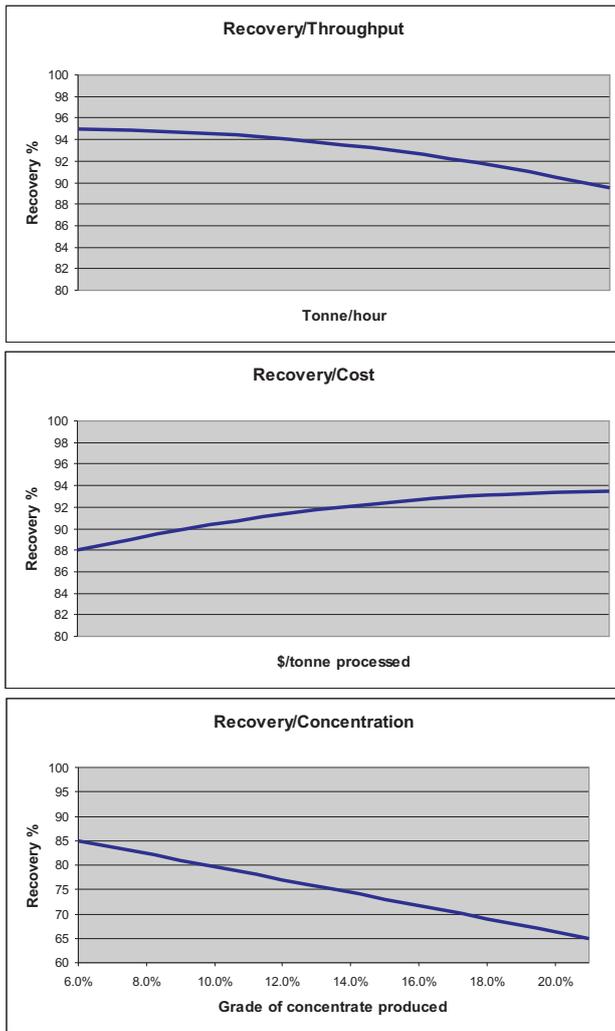
Recovery/Cost

Recovery/Concentration

FIG 4 - Illustrations of several typical recovery trade-offs that might exist within the range of plant configuration and operation.

recovery at any point in the system is a combination of: (a) the cost of mining and processing more material to compensate. This depends on the grade tonnage curve and the current position within the mining plan for the resource (renegotiable if necessary), and (b) the impact of shortening the life of the operation by depleting the resource faster.

Due to the discounted cash flow effect, the opportunity cost of the cash margin of metal sacrificed depends on when the end of the life-of-operation is. This depends on how much of the resource is left, and all the choices and variations that can occur between now and then. Just as with cut-off grades that are applied when mining, where the amount of metal warranted to sacrifice tends to start off high in the life-of-operation (high cut-off grade) before reducing to nil (ie the marginal cut-off grade) at the end, trade-offs in processing that involve recovery will result in initial high metal sacrifices (lower recovery), then tend towards lower metal sacrifice (maximum recovery) at the end. Expressed in another way, the opportunity cost of sacrificing metal recovery to pursue lower cost, higher throughput, and/or higher concentration benefits is dependent on how much resource is still ahead. As we approach the end of the resource, the loss from sacrificing metal for other benefits becomes imminent, and therefore relatively high, as the discounting effect is minimal compared to early in the life, when the consequence of sacrificing metal is remote.

To complicate matters, it is likely that during the life of a project the location of the bottleneck will move around, possibly in the order of being mining limited during initial waste stripping, then smelter limited when the early high-grade material hits the mill/concentrator, back to mill limited when the grade that the mine delivers drops as the best parts of the resource are depleted, then perhaps mining limited again when the high stripping ratio of the outer pit phases overwhelms everything else. Even when the bottleneck stays at the same point for several periods, it is inevitable that the pressure on that bottleneck will vary during that time. It is therefore logical that the optimal plant configuration may be different in every period, and is likely to swing from one extreme to the other during the life of the project. Why then are nine out of ten mine planning projects presented with fixed plant recovery/throughput/cost and resulting concentration? If plant configuration is to be varied to be optimal, the cut-off grade applied by mining should respond also, so these must be optimised simultaneously (Figure 5). Furthermore, if cut-off grade applied by mining is to vary over time, there is an opportunity to optimise the pit phase designs to support this. It follows that any project plan that uses a consistent plant configuration when any degree of flexibility actually exists cannot be optimal.

Processing Cut-off Grade
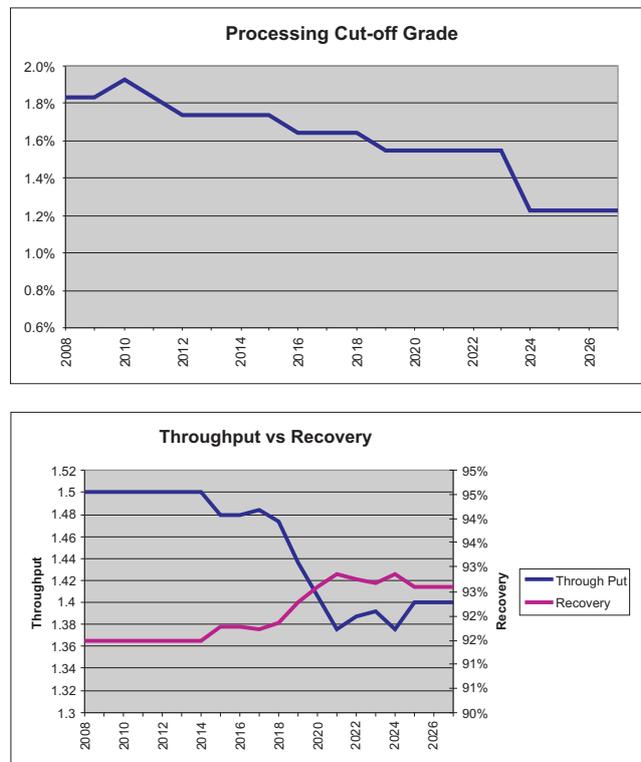
Throughput vs Recovery

FIG 5 - A life-of-operation plan, with (A) a variable cut-off grade and (B) a recovery versus throughput trade-off in action, shows how both these are used by the optimiser as levers for value.

Process engineers should not be left to make decisions on plant configuration alone. These must be made in the context of the resource, mining and downstream constraints, which are variables that can be designed into a project, considering the changing opportunity cost of the choices as the resource is developed and depleted.

THE CHALLENGE

The recognition of these issues creates a significant analytical challenge for optimisation specialists. It would take a superior

mathematician to formulate the overall solution. It may not even be possible in real life planning situations involving changing metal forecast protocols, input commodity price profiles over time, and possibilities to change mining, processing and production capacities, recoveries, operating costs, etc through expansion and operational/technology improvement projects. With the necessary tools and techniques, optimisation specialists who are aware of and can deal with these issues have a unique role; they must support general management in developing a framework which harnesses and integrates the range of knowledge and issues across geology, mining, processing and marketing.

Furthermore, great care must be taken that management reporting systems, performance incentive schemes, and overall corporate culture – heavily influenced by senior management's language and focus – do not inadvertently reinforce some of the dysfunctional behaviours identified.

CONCLUSIONS

It is not acceptable to try to optimise parts of the mining value chain in isolation. Optimal plans for every stage must be developed in the context of the resource that is or is likely to become available, the structure of the business that will exploit it, and the market it will supply. Any mining/processing plan that has constant stripping ratio, mining rate, cut-off grade, or plant configuration cannot be optimal, and is therefore subject to improvement. The reality of the mining/processing planning challenge is that decisions must be made based on integrated consideration of their consequences. Using simplified, seemingly well-meant, local objectives is not satisfactory, as these can be counterproductive to the overall outcome.

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