Enterprise Optimisation

G Whittle[1]

ABSTRACT

Enterprise Optimisation is a methodology for increasing the value of mining and mineral processing operations through better long-term planning decisions. It involves a combination of ten mechanisms which deal with decisions at different stages of the value chain. A decision made at any point in the chain potentially affects the decision for all other points in the chain. The key, therefore, is to optimise them simultaneously. The Enterprise Optimisation approach can be shown to produce increases of five per cent to 35 per cent or more in net present value (NPV), even when several optimisation methods have already been applied. This paper steps through an example case study, illustrating the effect of each mechanism and how they can work together to develop greatly improved results. This example results in a series of counter-intuitive outcomes, which challenges conventional management practices and typical organisational objectives based on organisational silos.

INTRODUCTION

Enterprise Optimisation is a methodology for increasing the economic value of mining and mineral processing operations through better long-term planning decisions. It involves a combination of ten mechanisms, which deal with decisions at different stages of the value chain. A decision made at any point in the system potentially affects the optimal decision for all other points in the chain. The key, therefore, is to optimise them simultaneously.

Enterprise Optimisation involves simultaneously optimising:

- All steps in the value chain (see Figure 1). It is clear that a decision on one step in the value chain can affect all the others, eg the plant constraint will affect the optimum cut-off grade, a change in cut-off grade will affect the mining schedule, and a change in schedule affects which pit shells should be selected as mine phases. A change in the metal price affects everything, right back to the pit design.

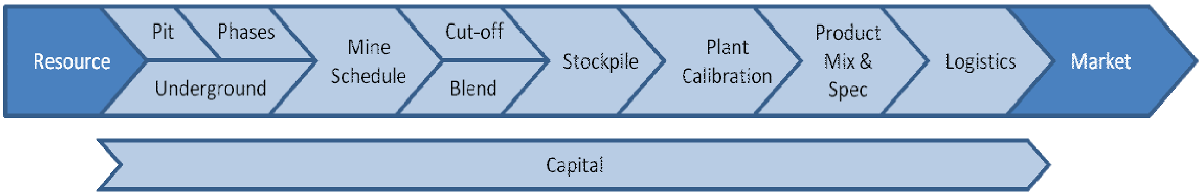

FIG 1 - The steps in the value chain.

- All assets in the enterprise portfolio. A decision affecting one component of an asset portfolio (many mines, plants, products) can affect the optimal operation of the others.
- All periods together. We are mining a depleting resource, so a decision for one period affects our options for the other periods. What is mined determines the surface for the next period, what will be available from stockpiles, etc. You cannot just optimise one period and then consider the next.

Apart from the analytical and computational challenges this raises, organisation barriers exist in the form of departmental and divisional silos which compound the problem. Organisation-wide participation in an Enterprise Optimisation study is essential to ensure that the analysis is correct, and that the outcomes are accepted and understood by the individuals who must implement them.

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To simplify the planning process many decisions are fixed, when they should be dynamic (plant configuration, head grade, product specification, production rate, etc) and many decisions are made too early, before the options are analysed (size of the resource, product specification, capital, plant size/type, mine life, etc). These simplifications prevent the full value of a project being realised.

Enterprise Optimisation overcomes the analytical challenge in dealing with these issues, but we must all cooperate to overcome the organisational challenges for simultaneous optimisation to be achieved effectively.

Money has a time value. Net present value has therefore been used as the basic measure of economic value.

CASE MODEL

This is a fictitious but realistic case, developed so that we can clearly demonstrate the mechanisms involved without client confidentiality issues. The settings have been made very simple to make the case easier to follow. Do not interpret this as a limitation on the methodology which can account for full details of real-life complications in a real case.

- single copper/gold pit with four phases;
- 60 Mt/a mining, maximum eight benches pa vertical advancement (ie 160 m);
- plant is 20 Mt/a crush/grind/float;
- 88 per cent copper recovery, 60 per cent gold recovery, fixed;
- producing 28 per cent copper concentrate, with gold contained;
- concentrate is transported 70 km by a 600 Kt/a pipeline to the port;
- the concentrate is then shipped offshore to a smelter/refinery;
- gold price US$900/oz;
- copper price US$2.50/lb declining to US$1.50/lb in the first five years; and
- ten per cent discount rate for NPV calculation.

CASE 0 – MANUAL CASE

The starting point is a manual pit and phase design, scheduled with five bench fixed-lead between phases. All economic material is processed, and there is no stockpiling. It took three frustrating days to develop the manual pit and phase shapes, and the designer had a guide as he had already seen the optimised pit. Considering the waste stripping required to gain access and the contribution of other economic material accessed on the way, it was a question of judgement of whether to include pockets of high-grade material.

The manual plan produced an NPV of US$1598 M. That is the sum of the discounted cash flows after US$592 M in capital expenditure. This is a good result, but it can be improved.

Although Enterprise Optimisation is about simultaneous optimisation, in this example we will turn on one mechanism at a time so that the effect of each can be discussed.

STEP 1 – PIT

Pit designs can be optimised using Lerchs-Grossmann (1965). Lerchs-Grossmann is effective at determining the economic three-dimensional shape of the pit considering block grades, pit slopes, costs, recoveries, and metal prices. In this step, pit shells 4, 8, 10 and 16 with roughly equal tonnes were arbitrarily selected as intermediate phases from the 16 nested pits produced by varying the revenue factor. The optimised pit does not look significantly different from the manual pit but it does vary in detail in certain parts. You cannot beat the computer. NPV is increased by 7.2 per cent.

The Lerchs-Grossmann optimisation is based on the valuation of each block in the model. The cost modelling applied and the degree to which material can be characterised for its processing throughput, cost and recovery can have a significant impact on the resulting pits and phases.

STEP 2 – PHASES

Phases can be selected using Whittle auto-pushback chooser and skin analysis (choice of ultimate shell). Selecting 4 phases from 16 nested shells generated by varying the revenue factor in Lerchs-Grossmann, involves testing 1820 combinations. With simple scheduling assumptions this can be computed quite quickly. This leads to a smaller ultimate pit with 18 per cent less rock but only nine per cent less ore. Shells selected for phases are 2, 3, 8, and 12 giving better early access to ore, but reduced overall mined resource. Only a small proportion of the NPV increase is due to reducing the size of the ultimate pit, but this change causes much discussion and controversy. In most pits, although the outer shells may be cash positive (which is why Lerchs-Grossmann included them), NPV may be negative due to the time delay between the waste mining near the surface and the eventual revenues derived from the deeper ore – the extra discounting of the later periods in the NPV calculation causing this effect. The bulk of the value, however, is produced by designing the best first phase with early access to high grade material with a low stripping ratio. NPV is increased by 6.4 per cent.

STEP 3 – SCHEDULING

So far simple five bench fixed-lead scheduling has been applied. Applying the Whittle 'Milawa' algorithm produces a different bench lead for each phase for each period. The optimiser is able to delay waste and bring forward high grade material within the phases presented. Mine scheduling is mathematically challenging as the orebody is not linear. Conventional mathematics would indicate the use of mixed integer programming for this purpose. Milawa applies a search algorithm (not mixed integer) to solve the mine scheduling challenge. NPV is increased by 4.4 per cent.

STEP 4 – CUT-OFF GRADE

Inspired by Ken Lane (1988), the Whittle cut-off grade optimiser raises early cut-off to increase early metal production, even if positive margin material is discarded and the mine life shortened. This is not 'high-grading' but 'right-grading'. The magnitude of the effect may be a surprise to many but not to those familiar with this mechanism, which is sadly not universally practised. Extra mining capacity is required to raise the cut-off grade – if mining rate variations have already been flattened by applying a limit before this step, then little or no gain will be observed which would be an opportunity missed. Cut-off grade optimisation produces the best results in deposits with lots of grade variation, ie a wide grade-tonnage curve. It is common for geologists and mining engineers to be uncomfortable with the proposition of discarding economic material – this is an arguably irrational reaction. NPV is increased by 15.1 per cent in this case.

STEP 5 – STOCKPILES

Stockpiles were limited to 60 Mt in this case. Rather than discard low value material, it may as well be stockpiled and processed later in the life of the operation. Reclaiming low grade material later recoups extra value and allows the early cut-off grade to be raised even further. Rehandling costs and possibly different recoveries for the additional weathering of the material must be taken into account. The mine life and overall resource recovery is almost returned which is comforting to many. NPV is increased by 4.6 per cent.

Note: This is how far you can go with the widely used Gemcom Whittle software – the shades on individual steps 1 to 5 on the graph in Figure 2 are different as the mechanisms are sequential and isolated, but nevertheless sum to a total increase in value of 37.7 per cent. In late 2010, Whittle version 4.4 will integrate steps 3 to 5 (schedule, cut-off/blending, stockpile), which gives most of the benefit of step 6.

STEP 6 – SIMULTANEOUS OPTIMISATION

We now switch to Whittle Consulting's proprietary 'Prober' software described by Whittle (2009). This more recent development is capable of performing the previous steps 1 to 5 simultaneously from a set of nested shells produced by Lerchs-Grossmann. Same settings, same problem, simply a better optimisation by having the mechanisms work together. NPV is increased by a further 14.1 per cent (Note: approximately two per cent of this was due to reselecting the phases to shells 3, 5, 9, and 13).

Components 1 to 6 cover what can be referred to as Mining Optimisation – everything the mining department is responsible for (see Figure 2). From step 6 onwards the graph covers all previous steps as these are reassessed simultaneously. Now we must consider the rest of the value chain.

STEP 7 – PROCESSING CALIBRATION

All the steps so far presumed that the plant will be run at its nameplate 20 Mt/a with fixed recoveries of copper 88 per cent and gold 60 per cent.

The fact is that the plant could be run at a range of throughput rates, with consequences on the recovery. Less grind time and residence can increase plant throughput but recoveries suffer significantly, and conversely slightly higher recoveries can be achieved if the plant is slowed down.

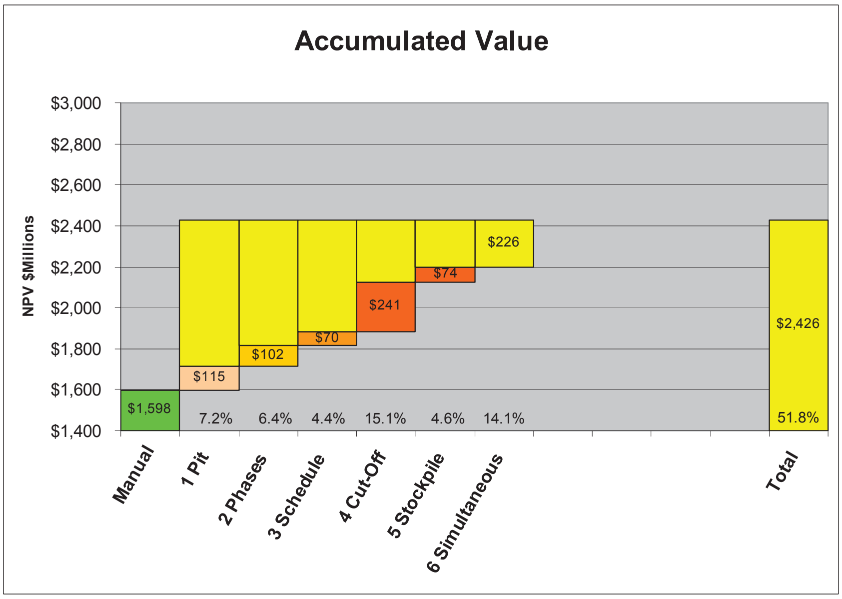

FIG 2 - The steps in mining optimisation.

Please note that we are not expanding the plant with capital in this step, just changing the residence time and therefore altering the throughput and recovery.

Looking at Figure 3 in isolation is unlikely to result in a metallurgist or process manager selecting the high throughput solution. If the plant is only to be run at one speed then 20 Mt is possibly the right choice. However, if the optimiser is in control it uses the whole range during the life of the operation – a dynamic mechanism.

Given throughput flexibility, the optimiser often sacrifices recovery to increase throughput. It is a complex trade-off between extra immediate cash flows, extra mining and processing cost, and the value of the metal lost and the impact that it has on the longevity of the operation and future cash flows. At the end of the mine life it enjoys the benefit of higher recovery, with less throughput (see Figures 4 and 5).

Allowing the optimiser to use this approach adds a further 4.4 per cent to the NPV. This figure would have been closer to eight per cent if not for the fact that we are now regularly hitting the concentrate pipeline limit of 600 Ktpa – a downstream bottleneck.

This mechanism has some similarities with cut-off optimisation in that it is trading off overall resource recovery against more rapid delivery of metal to market early in the life of the operation to increase early cash flows.

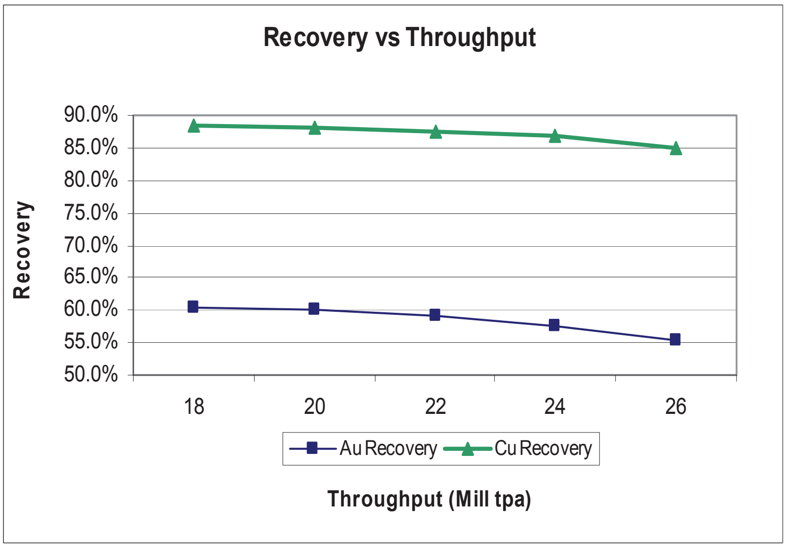

FIG 3 - Recovery versus throughput.

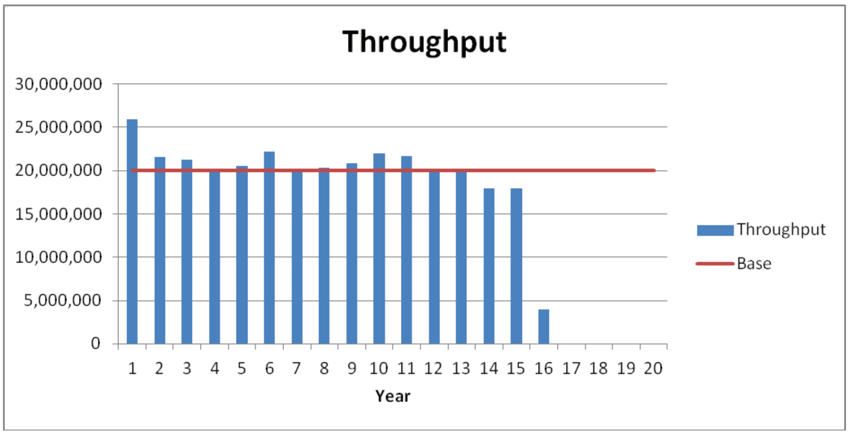

FIG 4 - Throughput optimised.

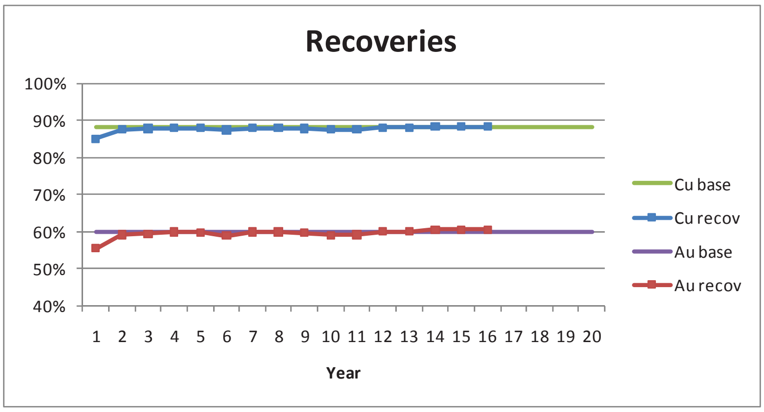

FIG 5 - Recovery optimised.

STEP 8 – PRODUCT SPECIFICATION

The base case presumes that a 28 per cent copper concentrate is produced, with recovered gold contained.

Figure 6 shows how a range of concentrates could be produced with significant impact on recovery, with an effect on the transportation of a more or less bulky concentrate product and different percentage of metal paid by the smelter to the mine for its concentrate.

With a spreadsheet to calculate net smelter return (NSR) it is easy to show that:

- when the copper price is $2.50/lb, the best solution is a 24 per cent concentrate as the benefit of extra recovery outweighs the extra transport cost of the bulky product; and

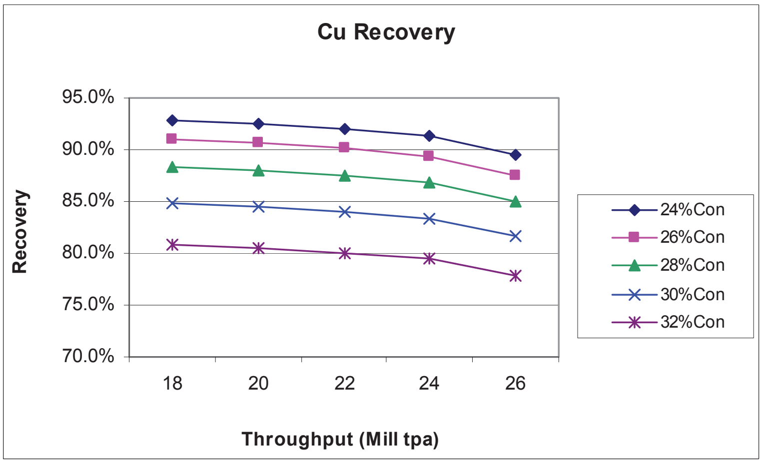

FIG 6 - The effect of concentrate percentage on recovery.

- when the copper price is $1.50/lb (as per long-term in this case), the best solution is the 28 per cent concentrate as used in the base case.

This approach is pursuing 'margin'.

It is more difficult, however, to calculate the benefit of throughput. The optimiser has used this flexibility, at great expense in terms of metal recovery at certain times, to get more metal to market through the restrictive pipeline, which at this point is the major constraint in the system.

A metallurgist would be unlikely to recommend producing a 32 per cent concentrate involving an eight per cent lower recovery by looking at Figure 6 in isolation, yet the optimiser has shown this to be the best decision for the business under many circumstances. In Figures 7, 8 and 9 it can be seen that when the pipeline is active as a bottleneck, the optimiser moves to a higher grade concentrate to get more metal to market, even at a significant cost in terms of lower recovery.

Allowing the optimiser to use this approach adds a further 5.5 per cent to the NPV.

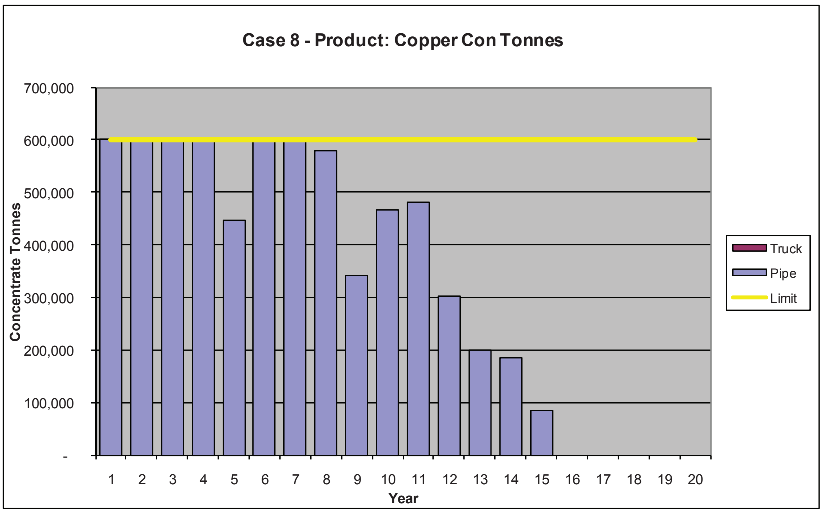

FIG 7 - The concentrate production reaches the pipeline limit.

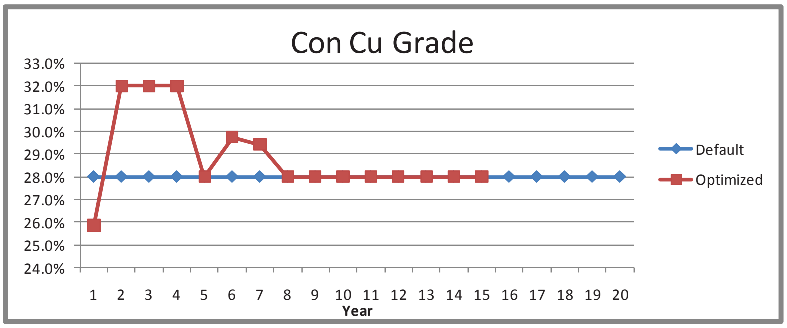

FIG 8 - Concentrate copper grade raised to increase metal production.

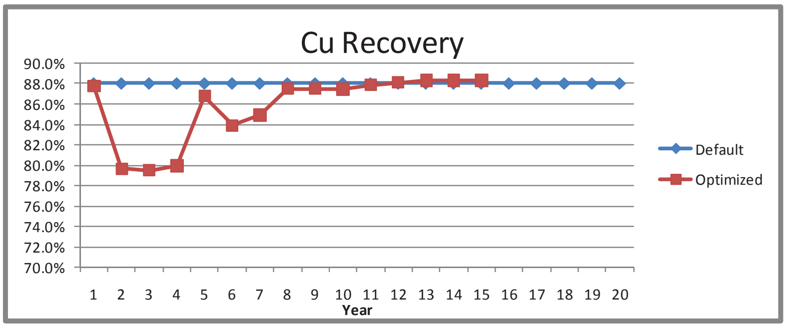

FIG 9 - Copper recovery losses – a consequence.

STEP 9 – LOGISTICS

Additional trucking of concentrate is possible at a cost of $30/tonne. This cost is high because it is a short-term strategy – we will not make a long-term contract, nor invest in handling facilities to make this process less costly, and because the road needs significant maintenance not having been designed for this level of heavy traffic. The additional capacity allows the previous mechanism (processing and product specification, supported by all the mining mechanisms) to pursue margin again, not throughput. More costly logistics but better value overall.

Allowing the optimiser to use this flexibility adds a further 7.1 per cent to the NPV. See Figure 10.

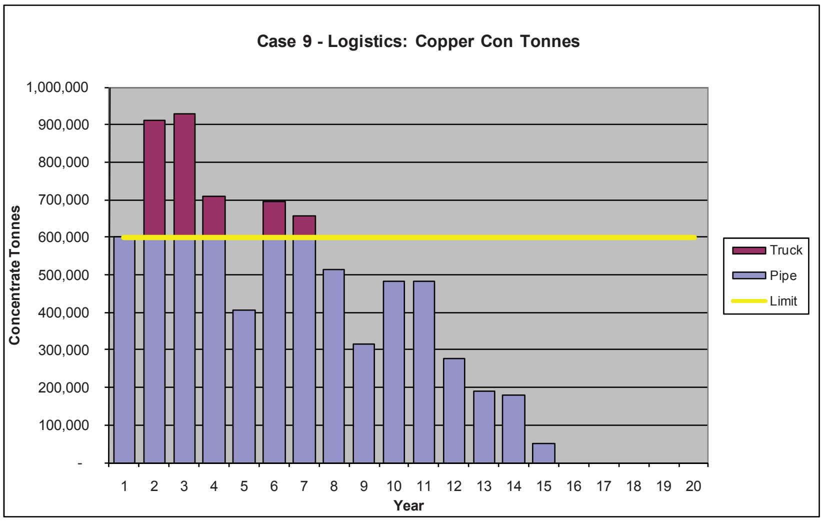

FIG 10 - Movement of the concentrate with additional trucking.

STEP 10 – CAPITAL

Rather than taking such drastic measures to manage the bottlenecks in the system, why not size the components of the system correctly in the first place. As long as this analysis is done during the feasibility study and not after construction of the plant and infrastructure, then rescaling is feasible.

In the manual base case, there was ample mining fleet capacity and pipeline capacity; in fact the finance manager may have taken steps to save some capital in these areas. However, now that we have simultaneously optimised the pits, phases, schedule, cut-off, stockpiles, then raised the plant throughput, we have both the mining fleet and the pipeline fully utilised. This raises the question of whether they should be expanded. (Increasing the plant size should also be considered, but that has been left out of the scope of this example). We can add extra mining capacity at $1.25 per tonne per year and extra pipeline capacity at $20 per tonne per year – these increases are only allowed in period 0 for simplicity of this example.

Making a single capital decision can be done by design trial and error iterations – say five, increasing the capacity progressively and seeing if the NPV increases more than the capital cost of the expansion. With two capital decisions that affect each other, that would be 5 × 5 = 25 iterations of a complete life-of-mine plan with nine active mechanisms.

If we did not increase the pipeline capacity then we would not need so much mining capacity, and if we did not increase the mining capacity then we would not need such a large pipeline. These decisions must be made simultaneously, yet it is typical to delegate these decisions to the mining manager and the logistics manager respectively, without any dialogue or cooperation between the two. This would lead to a suboptimal outcome.

In practice, there are dozens of capital decisions that would require thousands of life-of-mine plan iterations. This is not possible, so it does not get done.

The optimiser can determine how much capital is worth spending on each constraint – simultaneously, and rebalance the pit and phase selection, mine schedule, cut-off, stockpile, processing, product, logistics at the same time (steps 1 to 9).

Mining capacity goes up to 83 Mt/a, the pipeline to 1 Mt/a. Trucking no longer required. The shells used for phases are now 4, 7, 9, and 14. An extra $37 M of capital spend but NPV after the extra capital increases by a further 4.9 per cent.

SUMMARY

Figure 11 summarises the impact of all ten components described above. The recent ones have been focused on dealing with downstream bottlenecks and although each one introduced a new mechanism, it was critical to assess the impact it had on the previous mechanisms to calibrate it properly. The benefits of downstream modifications must be assessed with consideration of what the mine can deliver – due to its internal limits the head grade is likely to reduce as mining tonnage increases. Simultaneous optimisation is essential to get the balance of these effects right.

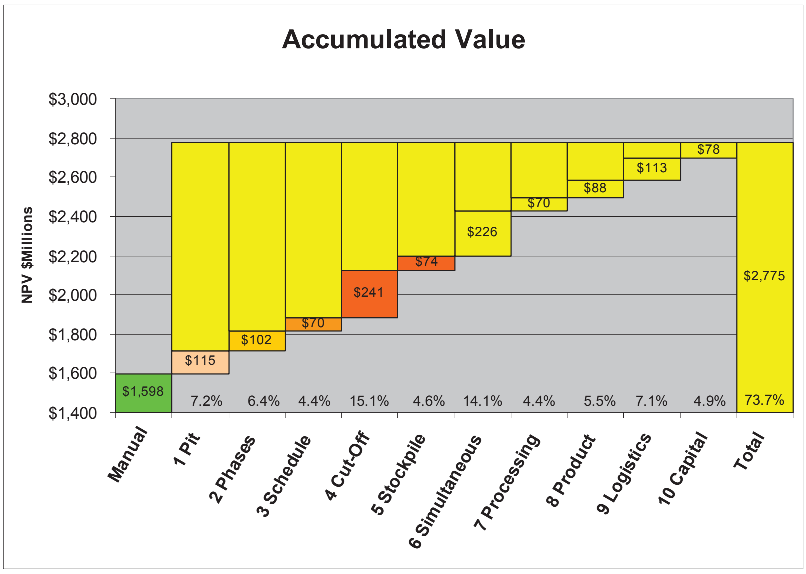

FIG 11 - The ten components of Enterprise Optimisation combine to increase net present value by 73.7 per cent in this case.

OVERALL RESULT

NPV has been increased from US$1598 M in the base case, to US$2775 M in case 10 with all mechanisms working together – an increase in value of 73.7 per cent.

The optimised plan is undoubtedly more complicated than the manual plan as can be seen from Figures 12 and 13, but the higher NPV justifies this. Mining has increased, significant amounts are stockpiled, plant throughput is up for many of the early years, and most importantly the early feed grades to the plant are approximately doubled. The combination of these significantly increases metal production in early years when the time value of money is highest and the copper metal price is high.

Please consider what has been done in the various cases:

- ultimate pit has been reduced, along with reserves;
- mining, processing and logistics costs have been increased significantly;
- plant recovery has been significantly decreased, due to higher throughput and higher concentrate grade in some cases;
- mining equipment has been made idle, two thirds of the fleet for several years;
- capital expenditure has increased; and
- life of the operation has reduced by several years.

All these outcomes are counter-intuitive and in a typical organisation would have been resisted by the individual managers concerned, and by the Chief Executive Officer. However, together they have transformed the economic performance of the business. If any of these changes were made in isolation it would be disastrous, so a coordinated approach to the analysis and implementation is essential. The value comes from looking at how the different steps in the value chain can affect each other and can work together, rather than looking at them in isolation. Much of this new value is hidden 'between' the steps managed by the organisational silos, and so a different mindset is required to identify it.

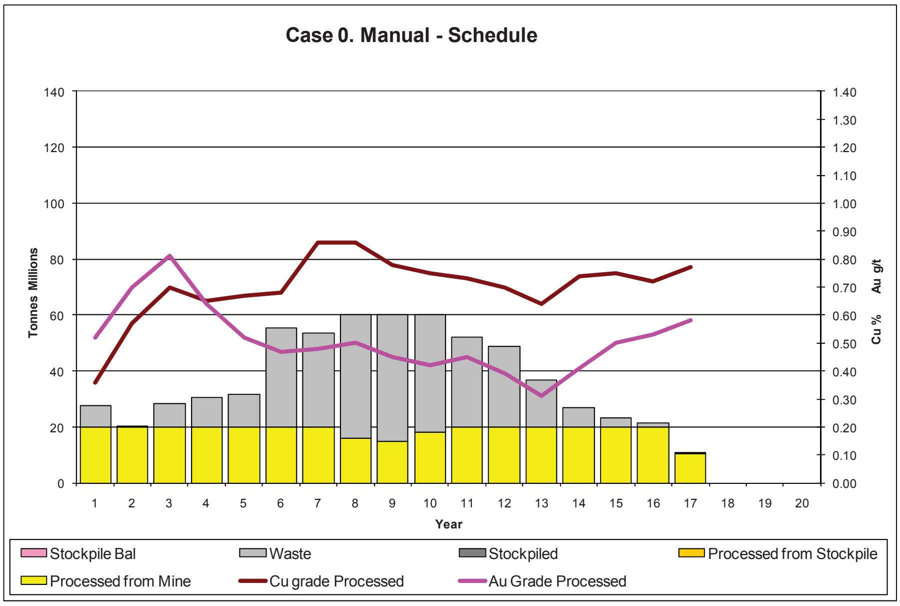

FIG 12 - Schedule for the manual design.

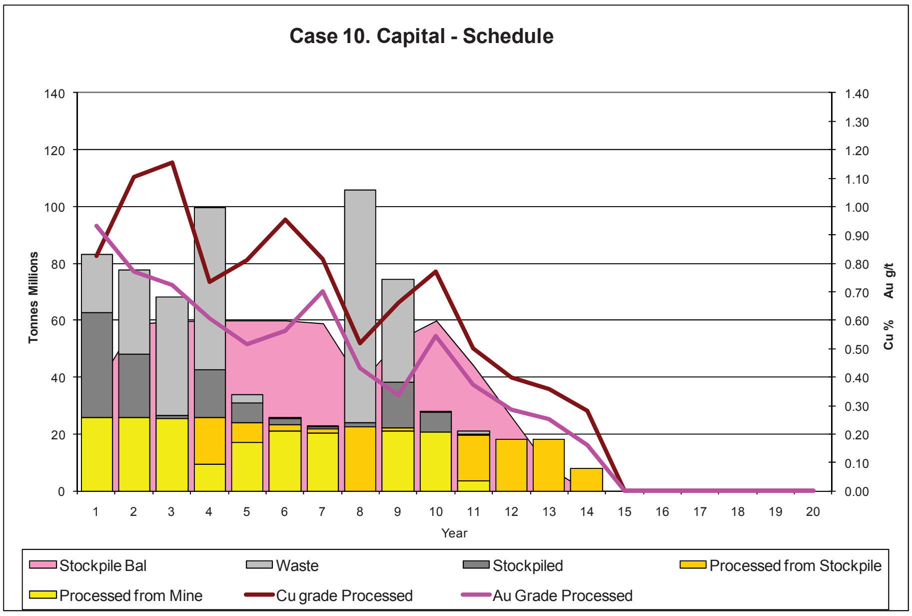

FIG 13 - Schedule for full Enterprise Optimisation plan.

Figure 14 sums up the overall change in the cash flow profile due to the ten mechanisms applied. Basically US$1.5 billion of cash flow has been moved from the last few years of the life of the operation to the first three years. This provides business options and security for the project, and greatly increases the likelihood that it will achieve financial support and approval. The possible negatives of reducing reserves and reducing employment longevity can be compensated for by reinvesting some of the early proceeds into exploration or other worthwhile projects.

See Tables 1 and 2 for details of the manual case and the fully optimised life of mine schedules.

Please note that some of the benefit in this case is derived from increasing copper production in the early years when the copper price is high. Repeating the entire case study with flat copper price at $1.50/lb still generates and overall increase in NPV of 53.9 per cent (rather than 73.7 per cent).

The amount of the improvement possible depends entirely on the configuration of the base case, and the orebody itself. Applying the mechanisms in a different order would also affect the quantification of the effect of each step.

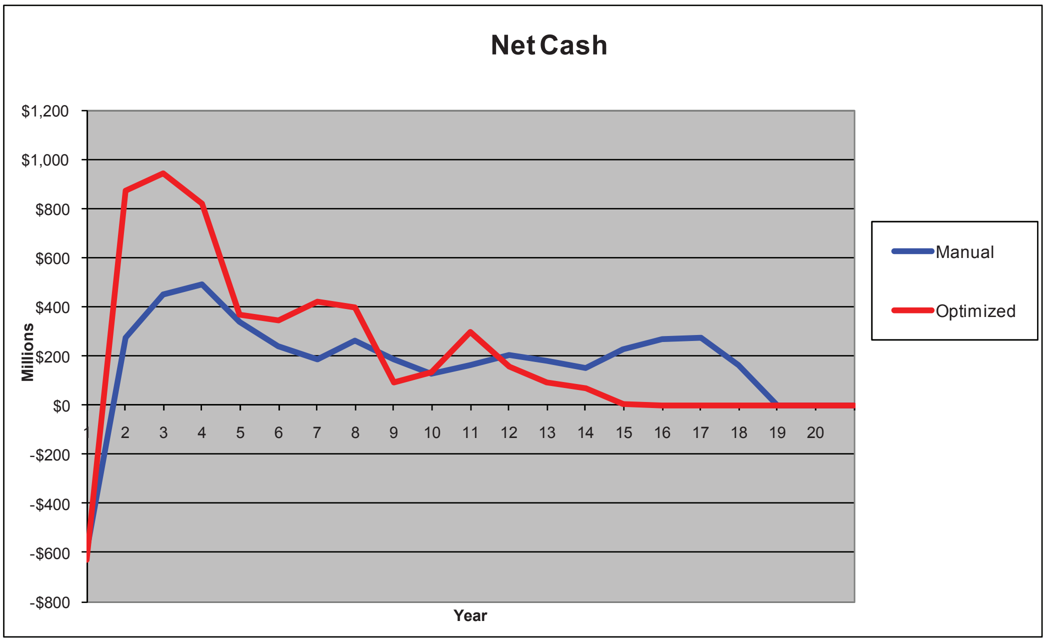

FIG 14 - Net cash flow before and after Enterprise Optimisation.

ACTUAL PROJECTS

The example above involves just one pit. The Enterprise Optimisation method has been applied to situations involving a significant number of pits, underground stopes, elements, processing plants, products, etc and all their attendant interactions.

Portfolio Enterprise Optimisation studies performed to date include:

- 86 mines, smelter and leach;
- 38 pit and underground mines, five concentrators, smelter, leach and refinery, blending requirements, 15 product options;
- 18 deposits with 130 pits, pressure and heap leach and refinery;
- 40 underground mines, three pits, two product streams with shared infrastructure;
- 80 deposits country-wide, several wash plants, logistics options to central smelter; and
- three pits with direct feed and flotation option, negotiable oxygen ratios with throughput and recovery implications.

Actual Enterprise Optimisation studies completed this year have identified opportunities for NPV increase of between 25 per cent and 85 per cent. In each of these cases conventional optimisation approaches (including the use of Whittle software) had already been applied.

CONCLUSION

Management performance measurement involving key performance indicators like minimising cost, maximising recoveries, maximising reserves and life of mine, may be leading us away from significant value enhancing opportunities.

Any business plan which has the same setting for any decision (mining rate, stripping ratio, cut-off grade, plant head grade, throughput, production, product specification) year after year cannot be optimal. The orebody is not the same each year and even if it was, the time value of money would lead us to different trade-off decisions in each period. It is therefore relatively easy to spot where opportunity for improvement by this technique may exist.

Enterprise Optimisation unleashes value by dynamically harmonising the flexibility in all parts of the operation. It relies on a combination of philosophy, methodology and sophisticated software to achieve the result. We have shown that there are very considerable gains to be made by optimising a number of mechanisms that are not usually considered by many organisations, and by optimising them simultaneously. Complexity and variation are opportunity – embracing this with a structured approach can realise significant economic benefits.

TABLE 1

Case 0: Manual base case.

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Year	**Total mined Ktonne**	**Waste Ktonne**	**To Stkpl Ktonne**	**To plant Ktonne**	**From Stkpl Ktonne**	**Ore proc Ktonne**	**Cu %**	**Au g/t**	**Conc Ktonne**	**Con Cu %**	**Con Au g/t**	**Revenue $M**	**Min cost $M**	**Reclaim $M**	**Proc cost $M**	**Sell cost $M**	**Net cash $M**	**DCF 10% $M**
1	27 609	7609	0	20 000	0	20 000	0.36	0.52	226	28.0	27.5	531	$40	$-	$136	$83	$273	$248
2	20 146	146	0	20 000	0	20 000	0.57	0.70	358	28.0	23.3	742	$29	$-	$136	$131	$446	$369
3	28 468	8 468	0	20 000	0	20 000	0.70	0.81	440	28.0	22.1	827	$41	$-	$136	$160	$490	$368
4	30 723	10 723	0	20 000	0	20 000	0.65	0.64	409	28.0	18.9	665	$45	$-	$136	$148	$336	$230
5	31 677	11 677	0	20 000	0	20 000	0.67	0.52	421	28.0	14.8	570	$46	$-	$136	$152	$236	$146
6	55 488	35 488	0	20 000	0	20 000	0.68	0.47	427	28.0	13.2	556	$80	$-	$136	$153	$187	$105
7	53 747	33 747	0	20 000	0	20 000	0.86	0.48	541	28.0	10.7	668	$78	$-	$136	$194	$259	$133
8	60 000	43 899	0	16 101	0	16 101	0.86	0.50	435	28.0	11.0	542	$87	$-	$115	$157	$184	$86
9	60 000	45 080	0	14 920	0	14 920	0.78	0.45	366	28.0	10.9	454	$87	$-	$108	$131	$127	$54
10	60 000	41 869	0	18 131	0	18 131	0.75	0.42	427	28.0	10.8	527	$87	$-	$126	$153	$161	$62
11	52 297	32 297	0	20 000	0	20 000	0.73	0.45	459	28.0	11.7	583	$76	$-	$136	$166	$205	$72
12	48 999	28 999	0	20 000	0	20 000	0.70	0.39	440	28.0	10.6	544	$71	$-	$136	$159	$178	$57
13	36 904	16 904	0	20 000	0	20 000	0.64	0.31	402	28.0	9.4	483	$54	$-	$136	$146	$148	$43
14	27 011	7 011	0	20 000	0	20 000	0.74	0.41	465	28.0	10.5	572	$39	$-	$136	$167	$229	$60
15	23 308	3 308	0	20 000	0	20 000	0.75	0.50	471	28.0	12.6	611	$34	$-	$136	$171	$270	$65
16	21 585	1 585	0	20 000	0	20 000	0.72	0.53	453	28.0	14.2	604	$31	$-	$136	$163	$274	$60
17	10 654	327	0	10 327	0	10 327	0.77	0.58	250	28.0	14.3	335	$15	$-	$70	$90	$159	$32
18	0	0	0	0	0	0	0.00	0.00	0			-	$-	$-	$-	$-	$-	$-
19	0	0	0	0	0	0	0.00	0.00	0			-	$-	$-	$-	$-	$-	$-
20	0	0	0	0	0	0	0.00	0.00	0			-	$-	$-	$-	$-	$-	$-
Total	648 616	329 138	0	319 479	0	319 479	0.70	0.51	6 991	28.0	14.0	9814	$940	$-	$2187	$2525	$4162	$2190
																	Less capital	$592
																	NPV	**$1598**

TABLE 2

Case 10: Fully optimised.

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Year	**Total mined Ktonne**	**Waste Ktonne**	**To Stkpl Ktonne**	**To plant Ktonne**	**From Stkpl Ktonne**	**Ore proc Ktonne**	**Cu %**	**Au g/t**	**Conc Ktonne**	**Con Cu %**	**Con Au g/t**	**Revenue $M**	**Min cost $M**	**Reclaim $M**	**Proc cost $M**	**Sell cost $M**	**Net cash $M**	**DCF 10% $M**
1	83 259	20 628	36 630	26 001	0	26 001	0.83	0.93	799	24.0	16.8	1447	$121	$-	$177	$277	$873	$793
2	77 809	29 624	22 183	26 001	0	26 001	1.11	0.77	968	26.0	11.5	1570	$113	$-	$177	$341	$939	$776
3	68 257	41 853	820	25 584	0	25 584	1.15	0.73	999	26.0	10.4	1446	$99	$-	$174	$352	$821	$617
4	83 259	57 142	16 863	9254	16 496	25 750	0.73	0.61	638	26.0	13.7	892	$121	$5	$175	$225	$366	$250
5	26 974	3042	6955	16 976	6955	23 931	0.81	0.51	601	28.0	11.8	762	$39	$2	$163	$217	$341	$212
6	23 470	244	2167	21 060	2167	23 227	0.95	0.57	689	28.0	11.1	859	$34	$1	$158	$248	$418	$236
7	21 120	146	740	20 234	1740	21 974	0.81	0.70	559	28.0	16.3	780	$31	$1	$149	$202	$398	$204
8	83 259	81 689	1570	0	22 425	22 425	0.52	0.43	362	28.0	15.6	500	$121	$7	$152	$131	$89	$41
9	73 363	36 163	16 191	21 009	1175	22 184	0.66	0.34	460	28.0	9.6	553	$106	$0	$151	$165	$130	$55
10	28 154	608	6839	20 707	0	20 707	0.77	0.55	501	28.0	13.5	659	$41	$-	$141	$181	$297	$114
11	4865	1189	302	3375	16 384	19 759	0.50	0.37	312	28.0	14.2	417	$7	$5	$134	$113	$158	$55
12	0	0	0	0	18 000	18 000	0.40	0.28	226	28.0	13.7	299	$-	$5	$122	$82	$90	$29
13	0	0	0	0	18 000	18 000	0.36	0.25	203	28.0	13.5	267	$-	$5	$122	$73	$66	$19
14	0	0	0	0	7 918	7918	0.28	0.16	70	28.0	11.0	87	$-	$2	$54	$25	$6	$1
15	0	0	0	0	0	0	0.00	0.00	0			-	$-	$-	$-	$-	$-	$-
16	0	0	0	0	0	0	0.00	0.00	0			-	$-	$-	$-	$-	$-	$-
17	0	0	0	0	0	0	0.00	0.00	0			-	$-	$-	$-	$-	$-	$-
18	0	0	0	0	0	0	0.00	0.00	0			-	$-	$-	$-	$-	$-	$-
19	0	0	0	0	0	0	0.00	0.00	0			-	$-	$-	$-	$-	$-	$-
20	0	0	0	0	0	0	0.00	0.00	0			-	$-	$-	$-	$-	$-	$-
Total	573 789	272 328	111 261	190 201	111 261	301 462	0.75	0.55	7 387	26.9	12.9	10 539	$832	$33	$2050	$2632	$4992	$3404
																	Less capital	$629
																	NPV	**$2775**

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