Works on Global Optimizer – What is it now?

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ABSTRACT

GEMCOM Software promotes the concept of simultaneous optimization – maximizing the value of a mining business by simultaneous optimization of the entire value chain (schedule, cut-off strategy, stockpiles and blending).

Among the steps we have undertaken to increase the business value are reducing the pit size (reserves), increasing cost, reducing equipment utilization, diminishing resource recovery and shortening the mine life.

All of these decisions look like counterintuitive and would have been resisted by the managers involved. This proves how misguided conventional management objectives can be.

The business value (NPV) is generated by combining mechanisms to whether or not bring cash flows forward. These mechanisms consider increasing the cash flow (e.g. increasing production during high price period); reschedule the same cash flow by increasing the NPV; reduce cash flow, but bring it forwards to improve NPV (e.g. reducing the size of the ultimate pit, and raising the cut-off grade). It is these mechanisms that people have the most trouble accepting though not necessarily based on a logical rationale.

Early cash flows mean earlier capital payback, less risk, higher possible debt levels, more options for expansion, exploration, acquisitions, etc. and more ambitious social or environmental programs.

Of all the mechanisms involved, many mining companies are optimizing only 2 or 3 of them as separate initiatives. The benefits of optimizing them as a whole remain has not yet been explored.

The above can make the difference between ordinary returns or spectacular returns. It can be the decisive factor in determining whether a project gets approved, or survives once it has started.

The benefit of simultaneous optimization lies not only on the extra value it can generate regarding what stockpile/cut-off optimization can achieve but it also makes cut-off grade optimization more accessible to parties who have restrained from applying it yet.

INTRODUCTION

GEMCOM Software promotes the concept of simultaneous optimization (SIMO), i.e., maximizing the mining business value by simultaneous optimization of the entire value chain. Simultaneous optimization allows unlocking significant additional NPV from projects by optimizing the mine schedule, cut-off grade, stockpiles, and blending in a single step. Thus it leverages the interdependencies between these mechanisms to release additional NPV.

BACKGROUND

Whittle (2009) states that different organizations usually work focused on local sub-objectives, such as maximizing the size of the resource, maximizing life-of-mine, minimizing mining costs, and maximizing processing recoveries. While being well-meant, in many cases these sub-objectives can be proved to be counter-productive to the overall corporate objective of value maximization. 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.

Trying to optimize parts of the mining value chain in isolation is not an acceptable practice. 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 counter-productive to the overall outcome.

SIMULTANEOUS OPTIMIZATION

Simultaneous optimization seeks the maximization of the economic value of the business. To that effect, GEMCOM Software has elaborated a methodology mainly focused on a wide-spectrum characterizing the material in the plant and the downstream pass to the business. Thus SIMO is an interesting approach for different types of materials in terms of the cost, recovery and throughputs characteristics since their definition affects the pit design, phases, characteristics, scheduling, etc.

The economic value of the business is measured by the Net Present Value (NPV) which is the sum of discounted cash flows (DCF). The NPV technique recognizes the time value of money, which is driven by the opportunity cost of money and risk involved in the project. There is no doubt that determining the discount rate is difficult and can be subjective.

The concept behind SIMO is the study and the understanding of how value flows through the system, and what we can do to increase it and speed it up. This new value is generated by combining multiple optimization mechanisms to bring forward positive cash flows.

CASE STUDY

This is a fictitious but realistic case, developed with the purpose of clearly demonstrating the mechanisms involved without client confidentiality issues.

- Copper/Gold pit with 7 phases

- 30Mtpa mining from year 1 to 3, 25Mtpa mining from year 4 to 6 and 40Mtpa mining from year 7 and so on.
- Mining cost US$ 0.9/ton
- 20Mtpa crushing limit
- Processing cost US$ 4/ton
- Recoveries: Copper 88%, Gold 60%
- Producing 28% Cu Concentrate with Gold contained
- Gold price US$ 375/oz.t
- Copper price US$ 0.907/lb.
- Selling cost Gold US$ 6.22/oz.t
- Selling cost Copper US$ 0.326/lb
- 10% discount rate
- Initial capital cost MUS$ 230
- Replacement capital cost MUS$ 20 from year 7.

Optimization technology (Whittle Three-D Lerchs-Grossman) has been used to get the ultimate pit to revenue factor = 1.

Pit summary for pit 42

Movement	tonne
Ore	315,117,804
Waste (reject)	33,539,798
Waste (other)	226,030,744
Total	574,688,346
Strip Ratio	0.82

Product	Input	Recovered	Input grade	Pit util. %
Au (gram)	170,374,440	102,224,664	0.541	57.9%
Cu (%m)	176,180,016	155,038,414	0.559	85.1%

Measures	Best	Specified	Worst
NPV (US$)	503,640,324	454,411,459	297,551,884
Life (year)	15.85	15.86	16.17
Payback (year)	3.04	3.86	6.33
Payback ratio	0.19	0.24	0.39
IRR%	38.17	31.48	20.12

Final pit analysis recommended use pit 31 as final pit. With seven phases these are pits 11, 12, 14, 16, 20, 25 and 31. Though the above improves the NPV at the same time it does reduce the size of the ultimate pit (and reserves) and shortens the mine life.

Pit summary for pit 31

Movement	tonne			
Ore	277,496,414			
Waste (reject)	27,821,908			
Waste (other)	144,899,403			
Total	450,217,725			
Strip Ratio	0.62			
Product	**Input**	**Recovered**	**Input grade**	**Pit util. %**
Au (gram)	156,632,853	93,979,712	0.564	58.0%
Cu (%m)	157,217,217	138,351,151	0.567	85.4%
Measures	**Best**	**Specified**	**Worst**	
NPV (US$)	492,431,513	448,214,258	341,905,470	
Life (year)	13.87	13.87	14.02	
Payback (year)	3.04	3.86	5.53	
Payback ratio	0.22	0.28	0.39	
IRR%	38.12	31.52	22.94	

Base Case

The base case is the mining plan to be optimized and is based on the Milawa algorithm used for scheduling purposes in GEMCOM-Whittle. It determines the best bench lead for each phase, for each period. Milawa is very effective at delaying waste stripping and focusing mining on phases with the best tonnes and grades of material contained.

As we can see (Figure 1) the base case is not a bad plan. Mining starts modestly, in fact not all the mining capacity is required for the first 6 years, all economic material is sent to the plant. The plant feed grades reflect the structure of the deposit, good gold grades near the surface, better copper grades as depth is achieved, for a 15 year mine life.

Movement	tonne			
Ore	277,496,414			
Waste (reject)	27,821,908			
Waste (other)	144,899,403			
Total	450,217,725			
Strip Ratio	0.62			
Product	**Input**	**Recovered**	**Input grade**	**Pit util. %**
Au (gram)	156,632,853	93,979,712	0.564	58.0%
Cu (%m)	157,217,217	138,351,151	0.567	85.4%
Measures				
NPV (US$)	449,140,743			
Life (year)	14.15			
Payback (year)	3.91			
Payback ratio	0.28			
IRR%	32.17			

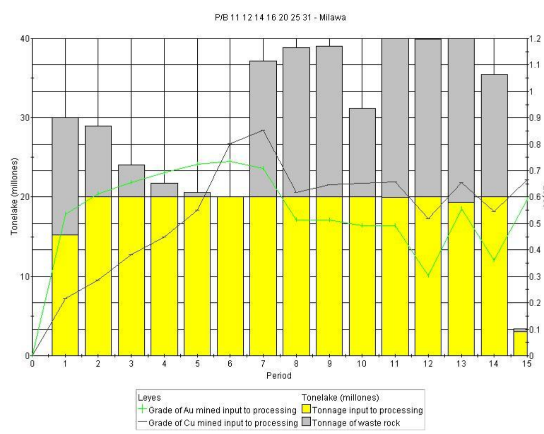

Figure 1: Mining plan - Base case - Milawa algorithm

Cut-Off grade optimization

Ken Lane (1988) published a book on cut-off grade optimization. Lane showed that if the plant is the bottleneck in the system, it is better to increase the mining rate, raise the cut-off grade above the marginal (breakeven) cut-off grade, discard lower value material so that higher value material can be processed. This reduces overall recovery of the resource and shortens the life of mine further, but can significantly increase NPV.

The result is generally higher cut-off grades early in the life of the mine when the time value of money is the highest, reducing back to the marginal cut-off grade at the end of the life of mine when the plant bottleneck is no longer of any consequence.

Cut-off grade optimization is not as widely practiced as it should be. This is possibly because it is very hard to calculate even with software tools, and also it goes against the grain of geologists and miners to discard economic material.

The next step of the work was applying the cut-off grade theory to the base case (Figure 2). The resulting mining plan reduces the resource recovery in 5% but the NPV increases around 3%. The life of mine is practically the same. The lack of stockpile prevents the plant from being completely full in year 11 – that warrants some attention.

Movement	**tonne**			
Ore	263,331,879			
Waste (reject)	41,986,443			
Waste (other)	144,899,403			
Total	450,217,725			
Strip Ratio	0.71			
			Input	**Pit**
Product	**Input**	**Recovered**	**grade**	**util. %**
Au (gram)	152,792,922	91,675,753	0.580	56.5%
Cu (%m)	153,694,511	135,251,170	0.584	83.5%
Measures				
NPV (US$)	462,779,785			
Life (year)	14.11			
Payback (year)	3.73			
Payback ratio	0.26			
IRR%	33.67			

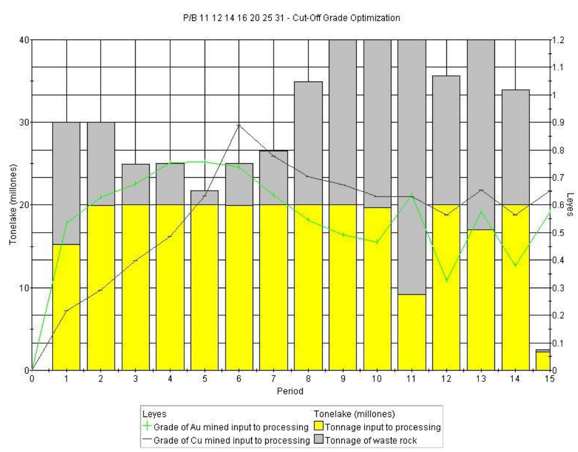

Figure 2: Mining plan - cut-off grade optimization

Stockpile and Cut-Off grade optimization

Stockpiling material below the optimal cut-off grade rather than discarding it, and then processing it, adds value and rejuvenates the mine life.

Our purpose is to measure the impact of stockpiles on the business (Figure 3). In this case, and as we expected, the use of stockpiles helps keep the plant completely full allowing the recovery of additional ore. The NPV increases in 1%.

Stockpile reclaim is not considered in the mining limit (the way the graph is presented gives the idea the mining limit is exceeded but it is not).

Movement	tonne			
Ore	274,349,671			
Waste (reject)	30,949,057			
Waste (other)	144,918,996			
Total	450,217,724			
Strip Ratio	0.64			
Stockpile				
In	20,374,874			
Out	20,355,279			
Remaining	19,595			
Product	**Input**	**Recovered**	**Input grade**	**Pit util. %**
Au (gram)	155,897,489	93,538,494	0.568	57.7%
Cu (%m)	156,540,339	137,755,499	0.571	85.1%
Measures				
NPV (US$)	467,204,370			
Life (year)	13.96			
Payback (year)	3.75			
Payback ratio	0.27			
IRR%	33.88			

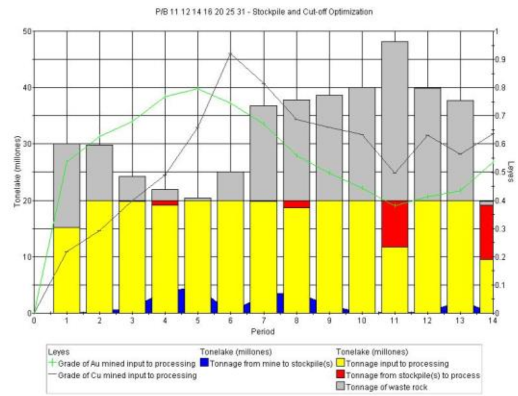

Figure 3: Mining plan - stockpile and cut-off grade optimization

Simultaneous Optimization

SIMO (Figure 4) increases the NPV 2%. This is the same data, same assumptions, same constraints and the same objective – just a better optimization.

The mining plan increases the total ore processed, the plant is completely full in almost all periods with the aid of stockpiles. The exception is the first year where waste stripping of phase 1 prevents the plant from being completely full.

Almost all material of stockpiles is sent between year 2 and year 12.

In years 7 - 9 the optimizer is using the high grade ore stockpiled in earlier years, at the same time it is putting more ore on the low grade stockpiles.

Stockpiled medium grade ore is used during years 11 - 14. Finally, stockpiled low grade ore is used in year 15. In year 11 more than 50% of the plant feed is from stockpiles while the mining is focused on waste stripping of the long phase 6.

Movement	tonne			
Ore	279,945,213			
Waste (reject)	25,357,019			
Waste (other)	144,915,492			
Total	450,217,724			
Strip Ratio	0.61			
Stockpile				
In	47,957,816			
Out	47,941,726			
Remaining	16,090			
Product	**Input**	**Recovered**	**Input grade**	**Pit util. %**
Au (gram)	157,197,661	94,318,596	0.562	58.2%
Cu (%m)	157,711,138	138,785,801	0.563	85.7%
Measures				
NPV (US$)	476,945,698			
Life (year)	15.00			
Payback (year)	0.00			
Payback ratio	0.00			
IRR%	0.00			

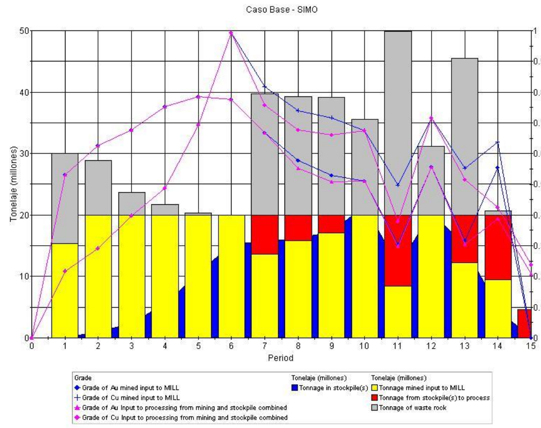

Figure 4: Mining plan - simultaneous optimization

Bringing Forward Cash Flows

Business value (NPV) is generated by combining mechanisms and criteria to whether or not bring cash flows forward. Some of these mechanisms are:

- Increase cash flow (e.g. increasing production in high price period).
- Reschedule the same cash flow – increasing NPV.
- Reduce cash flow, but bring it forward to improve NPV (e.g. reducing the size of the ultimate pit, and raising the cut-off grade).
- Avoid delaying the mining of the remaining resource since this could reduce the NPV.

Early cash flows means:

- Earlier capital payback.
- Less risk.
- Higher possible debt levels.
- More options for expansion, exploration, acquisitions etc.
- More ambitious social or environmental programs.

As shown on Figure 5, the curve of discounted cash flow of SIMO makes the difference in years 5 and 6, where it succeeds in bringing cash flows forward.

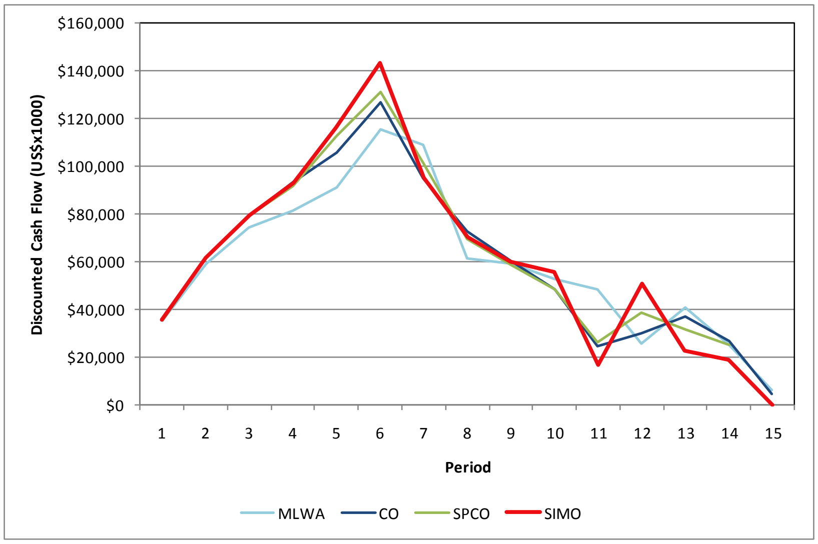

Figure 5: NPV increased by bringing forward cash flows

CONCLUSIONS

Consider what we have done to improve the business value: reduced reserves, increased mining costs, reduced resource recovery and shortened the life of mine.

All of these decisions are counterintuitive and would have been resisted by the managers involved. This proves how misguided conventional management objectives can be.

Of all the mechanisms involved, many mining companies are optimizing only 2 or 3 of them as independent initiatives. The benefits of optimizing all together using SIMO remain untapped. In this study SIMO increases the NPV to 6%.

The benefit of SIMO resides not just the extra value it can create over what Stockpile/Cut-off can do but also on the fact that it can make cut-off grade optimization more accessible to those parties who have been reluctant to do it yet.

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