Optimising Underground Mining Strategies

A M Ebbels

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Abstract

Underground mine scheduling decision-making has been based on production requirements, equipment productivities and the mine planner's instincts on the best scheduling strategy for the mine to optimise the net present value (NPV) of a project.

In the last few years, innovative software has been developed to optimise underground schedules based on NPV. The schedule optimisation tool (SOT) allows the user to set up scenarios based on grade, metal content, capital and operating costs.

This paper discusses the results of two case studies undertaken using the SOT software to optimise the NPV of the projects.

In each case study, the SOT software has been applied in two ways:

1. Using the original mine planner's scenario and determining whether the NPV could be improved by changing resource capacities

2. Changing the scheduling goals to determine whether a different mining strategy would have a better NPV outcome.

The outcomes of the case studies demonstrate that the mine layout and design were contributing factors to the overall improvement of the NPV and that SOT has a more noticeable impact on the NPV of projects where less sequence constraints are required, such as geotechnical sequencing and access development.

Introduction

The current mining cycle has a number of companies spruiking that they are going to optimise their operation to improve their bottom line. To do this, companies need to operate their assets in such a way that maximises their potential while minimising both capital and operating expenditure.

In underground mining, scheduling decisions have been made based on production requirements, equipment productivities and the mine planner's instincts on the best scheduling strategy for the mine to optimise the net present value (NPV) of a project. The schedule optimisation tool (SOT) allows a large number of permutations to be assessed relatively quickly in order to determine the best schedule outcomes for the operation.

What is Schedule Optimisation?

Schedule optimisation is using the current mine design, existing personnel and equipment resources in various combinations to determine the best schedule to deliver the best possible outcome for the operation. The best possible outcome is defined as the best NPV for the project.

The schedule optimisation problem for underground mining boils down to deciding when to execute a specific mining activity in the future, where an activity could relate to, for example, the excavation of part of an underground drive per unit time or the placement of machinery that will enable the excavation. This is done for all activities to maximise the NPV of the project while taking into account constraints that relate to the physical infrastructure of the mine (eg hoisting capacity) as well as resource constraints such as the available personnel at any given time. However, the most important set of constraints has to do with activity precedence. That is, except for the very first mining activity that would be executed in the mine plan, the execution of all other mining activities depends on whether the previous activities have been completed (Bley and Terblanche, 2012).

How the Schedule Optimisation Tool Works

SOT uses automated genetic algorithms and heuristic rules to create hundreds to thousands of scheduling alternatives that are ranked according to the project's detailed financials (CAE Mining, n/d).

A validated Enhanced Production Scheduler (EPS) schedule and detailed cost inputs for the project are required as inputs into SOT. The cost inputs include both operating and capital costs, discount rate, commodity prices, inflation rates and contaminant (penalty) costs. Capital costs, commodity prices and contaminant costs can be varied over time.

SOT allows the user to set up a number of different scheduling scenarios, as described in Table 1. A level of guidance of between zero and 100 per cent can be applied to each of the scheduling strategies. The guidance determines the amount of flexibility that the schedule has to select a random path. If the guidance is set to 100 per cent, the same schedule will be generated every time, whereas 50 per cent allows SOT to select a path 50 per cent of the time. SOT honours any sequencing links that have been manually created in 5D Planner or Mine2–4D.

Case Studies

The effectiveness of the application of SOT was evaluated using two different deposits:

• case study 1 – multielement, multilens deposit

• case study 2 – multielement, highly constrained deposit.

The evaluation was undertaken to determine the types of projects on which SOT could be effective, hence the selection of one deposit that is highly constrained and another that has multiple ore sources but significant development requirements.

Case Study 1

The first case study is a multielement zinc, lead and copper mine. There were three different scheduling scenarios considered to improve the mine's NPV:

1. highest mineral weight
2. highest mineral grade
3. least access requirements by mineral weight.

The base mine production rate was determined to be 600 kt/a. The deposit has multiple lenses (Figure 1), and a single decline access that splits at 100 m below the surface is used to access the different mineralised areas. The mining method is primarily open stoping with backfill. Ore is hauled by truck via the decline to the processing plant.

The base case schedule estimated the NPV of the project to be A$53.2 M.

The matrix of the scheduling scenarios applied to the project using SOT is shown in Table 2. The scenarios also investigated higher production and development rates of 750 kt/a and 7500 m/a respectively in addition to the base case.

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TABLE 1

Schedule optimisation tool scheduling strategies.

Strategy	Description
Highest mineral grade	Schedules by activities with the highest grade as soon as possible (ASAP) regardless of location
Highest mineral weight	Schedules by activities with the highest mineral tonnes ASAP regardless of location
Least access	Schedules by activities with the least amount of access development ASAP regardless of location
Lowest cost mineral weight	Schedules by activities with the lowest cost per mineral weight ASAP regardless of location
Highest mineral grade mine area	Schedules by activities in the area with the highest mineral grade ASAP
Highest mineral weight mine area	Schedules by activities in the area with the highest mineral tonnes ASAP

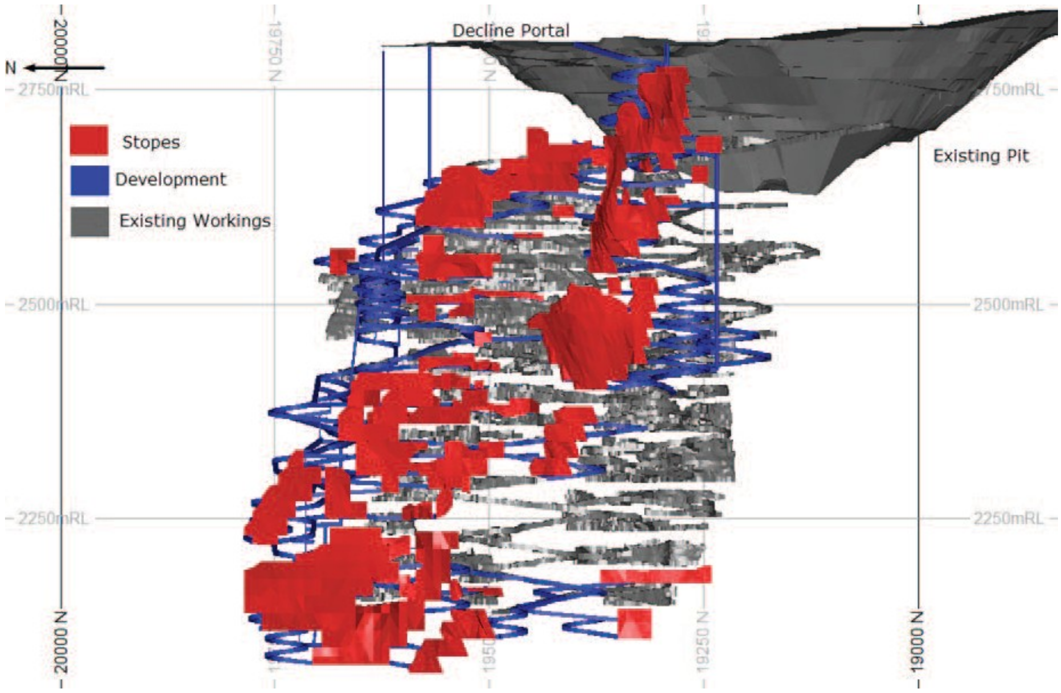

FIG 1 – Case study 1 mine layout.

TABLE 2

Case study 1 scheduling scenarios.

	Scenario	Production rate (kt/a)	Development metres per annum	Guidance (%)
Base case	No guidance	600	5000	0
Schedule 1	A	600	5000	75
Schedule 2	A	750	5000	75
Schedule 3	B	600	5000	75
Schedule 4	B	750	5000	75
Schedule 5	C	600	5000	75
Schedule 6	C	750	5000	75
Schedule 7	A	600	7500	75

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Schedule 8	A	750	7500	75
Schedule 9	B	600	7500	75
Schedule 10	B	750	7500	75
Schedule 11	C	600	7500	75
Schedule 12	C	750	7500	75

The optimisation runs averaged 34 minutes for each scenario, with the quickest at eight minutes and the longest at 68 minutes. An average of 2212 schedules were generated per scenario. Table 3 shows the run time and number of schedules for each scenario.

The SOT results for the different scheduling strategies are presented in Table 4 and Figure 2. The results showed that Schedules 8, 10, 11 and 12 had the largest improvement in NPV of 10.2 per cent, but these scenarios were all at the higher development rate. Of the base case variations, Schedule 3 had the largest improvement in NPV of three per cent. The range of change in NPV was -A$0.1 M to +A$5.4 M. The application of SOT has shown that the project is amenable to the application of schedule optimisation and that with the same resources and expenditure, the NPV can be improved by three per cent by targeting the higher grade area as a priority. By increasing the development capacity of the mine, the NPV could be improved by 10.2 per cent, suggesting that further investigation of the practicality of an increased development capability (ie the jumbo fleet) is warranted.

TABLE 3

Case study 1 statistics for scenarios.

Scenario	No of schedules	Processing time (mins)
Base case	1120	8
Schedule 1	1400	16
Schedule 2	1540	31
Schedule 3	4080	75
Schedule 4	1220	21
Schedule 5	1240	8
Schedule 6	1680	36
Schedule 7	2160	18
Schedule 8	3000	74
Schedule 9	1800	18
Schedule 10	3400	31
Schedule 11	2340	43
Schedule 12	3780	68

TABLE 4

Case study 1 results.

Scenario	Net present value (A$ M)	Difference to base case (%)
Base case	53.2	
Schedule 1	53.3	0.2
Schedule 2	54.3	2.1
Schedule 3	54.8	3.0
Schedule 4	53.6	0.8
Schedule 5	53.1	-0.2
Schedule 6	54.3	2.1
Schedule 7	57.8	8.6
Schedule 8	58.6	10.2
Schedule 9	57.8	8.6
Schedule 10	58.6	10.2
Schedule 11	58.6	10.2
Schedule 12	58.6	10.2

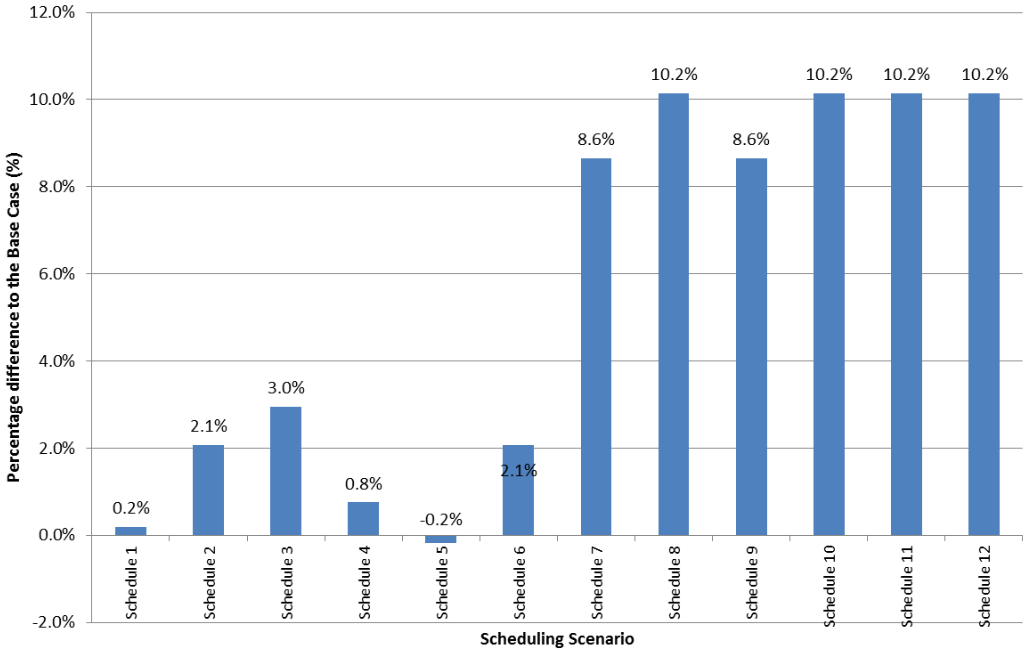

FIG 2 – Case study 1 results: percentage difference to the base case.

Case Study 2

This mine is a highly constrained zinc-lead deposit due to the geotechnical sequence constraints and the orebody geometry. SOT was applied to evaluate whether the project value is enhanced by applying different scheduling strategies to the mine design. Figure 3 presents the orebody layout. The stopes are mined from the hanging wall to the footwall with rib pillars between the stopes, which are to be extracted after the primary stopes have been backfilled with hydraulic fill. Ore is trucked to the surface via decline. Table 5 details the different scheduling strategies applied.

The optimisation runs for this study averaged 39 minutes for each scenario, with the quickest at three minutes and the longest at 65 minutes. An average of 811 schedules were generated per scenario. Table 6 shows the run time and number of schedules for each scenario.

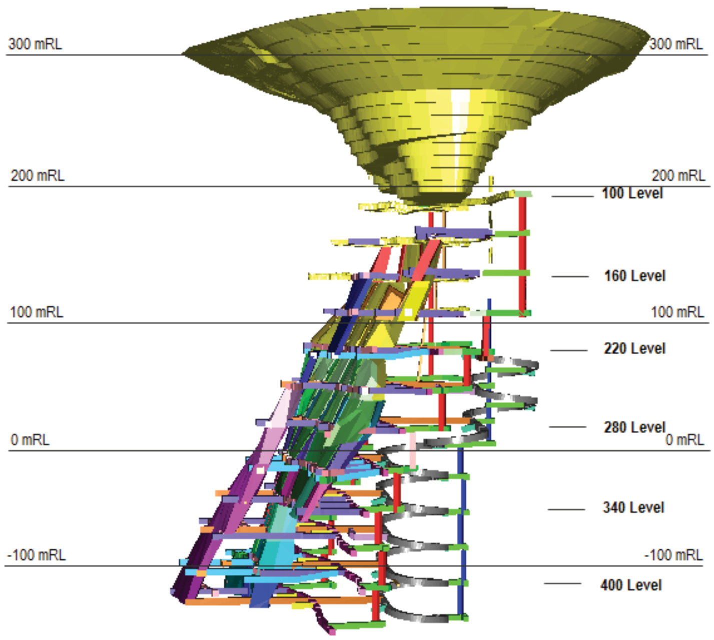

FIG 3 – Case study 2 mine layout.

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TABLE 5

Case study 2 scheduling scenarios.

Scenario	Guidance type	Level of guidance (%)
Base case	No guidance	0
Schedule 1	Highest mineral weight	50
Schedule 2	Highest mineral weight	75
Schedule 3	Lowest cost mineral weight	50
Schedule 4	Lowest cost mineral weight	75
Schedule 5	Highest mineral grade	50
Schedule 6	Highest mineral grade	75
Schedule 7	Lowest cost access	50
Schedule 8	Lowest cost access	75

TABLE 6

Case study 2 statistics for scenarios.

Scenario	No of schedules	Processing time (mins)
Base case	660	3
Schedule 1	1160	33
Schedule 2	460	60
Schedule 3	440	16
Schedule 4	460	34
Schedule 5	1140	45
Schedule 6	1540	60
Schedule 7	640	36
Schedule 8	800	65

The SOT results for the different scheduling strategies are presented in Table 7 and Figure 4. These results show that with less guidance applied to the schedules, there was a small reduction in the NPV of the project. The highly constrained mining sequence required for this mine means that the application of different scheduling strategies had a negligible effect on the NPV of the project because SOT had a limited ability to make random decisions to find a different path for the schedule. The range of change of the NPV was –US$1.7 M to +US$0.5 M.

Conclusions

SOT provides the ability to quickly review multiple scheduling strategies to evaluate the incremental improvement in NPV that can be made from an asset by simply changing the scheduling strategy. This allows operations to maximise the value of their deposit using the existing plan with the same capital and operating expenditure.

The case study results show that the mine designs that have limited flexibility in the mine sequencing, due to overriding needs such as geotechnical demands, don't have the ability to improve

TABLE 7

Case study 2 results.

Scenario	Net present value (US$ M)	Difference to base case (%)
Base case	46.4	
1	45.8	-1.3
2	46.2	-0.4
3	46.9	1.1
4	46.5	0.2
5	44.7	-3.7
6	46.6	0.4
7	46.3	-0.2
8	45.8	-1.3

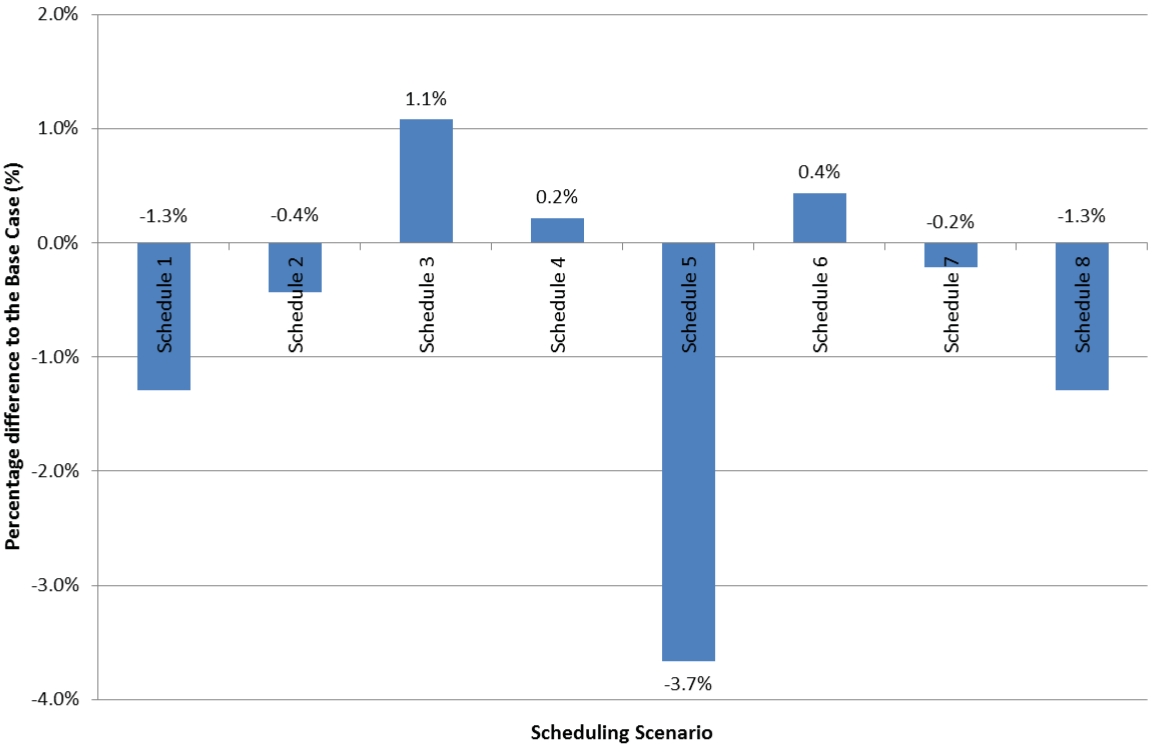

FIG 4 – Case study 2 results: percentage difference to the base case.

the NPV significantly. However, mine designs that allow greater flexibility in the mining sequence have the ability to apply SOT to improve the NPV of the mine. Applying SOT gives the confidence that the applied scheduling scenario is going to give the best outcome or provide operations with the opportunity to improve their bottom lines using what they have by changing their scheduling strategy and without a significant time investment. It also provides the basis for an investigation to spend more (capital) and return superior value to the project and its shareholders.

References

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