

# Multi-lifts selection using scenario simulation and financial metrics

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## Abstract

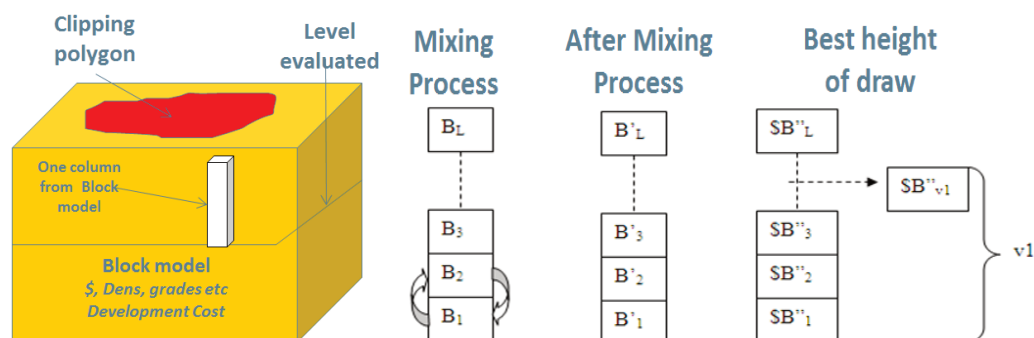
*In evaluating a block caving project, one of the most important strategic decisions is the location of the extraction level. This evaluation is complex for a single lift; therefore, finding the optimum combination of multiple lifts is much more challenging and, in most cases, sub-optimal since the decision is largely influenced by the selection of one of them and not the overall value.*

*This paper proposes the option to simulate as many scenarios as possible, analysing the size of each lift based on multiple evaluations using variable shut off grades and production rates. This analysis enables exploring many strategies and using the hill of value technique to identify areas of optimum solutions in a reasonable time. For example, starting with a small Lift1 extracting high grade with a low production target to reduce initial capital cost and ramp-up to maximum production capacity in the second lift versus the option to achieve maximum production rate since the beginning of Lift1. In addition, the decision will consider financial investment metrics like net present value and internal rate of return. This methodology is demonstrated with a real case to show the potential impact on the value of the project.*

**Keywords:** strategic mine planning, block cave, panel cave, simulation, financial

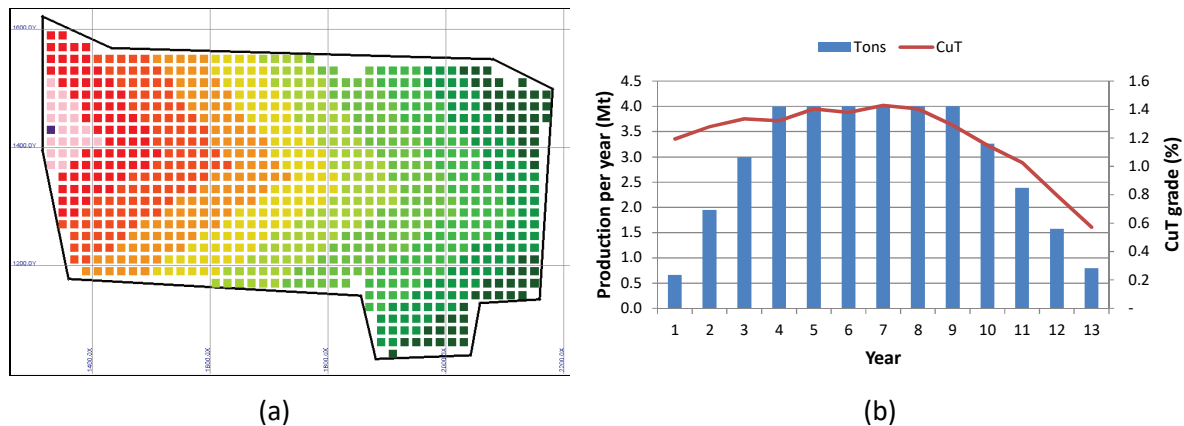
## 1 Introduction

The primary challenge is to try to predict or schedule the ‘best’ tonnages to extract from several drawpoints located in the extraction level for various periods, incorporating variables such as mining sequence, production rate, rate of opening new drawpoints, extraction rates, Depletion method and many more. The location of the production level is one of the most strategic decisions for a block caving project; this defines project timing, capital costs, and resources recovery. This analysis could be done using existing technology such as Footprint Finder (Villa 2014), a quick study using a block model to find the best elevation and orientation for locating an extraction level. All blocks inside the clipping polygons are evaluated for each level selected. Each block represents one drawpoint, and then the system creates a draw column where Laubscher's mixing method (Laubscher 1994) is applied. From there, the best height of draw is calculated based on the economic evaluation maximising the value using a vertical discount rate (Figure 1).



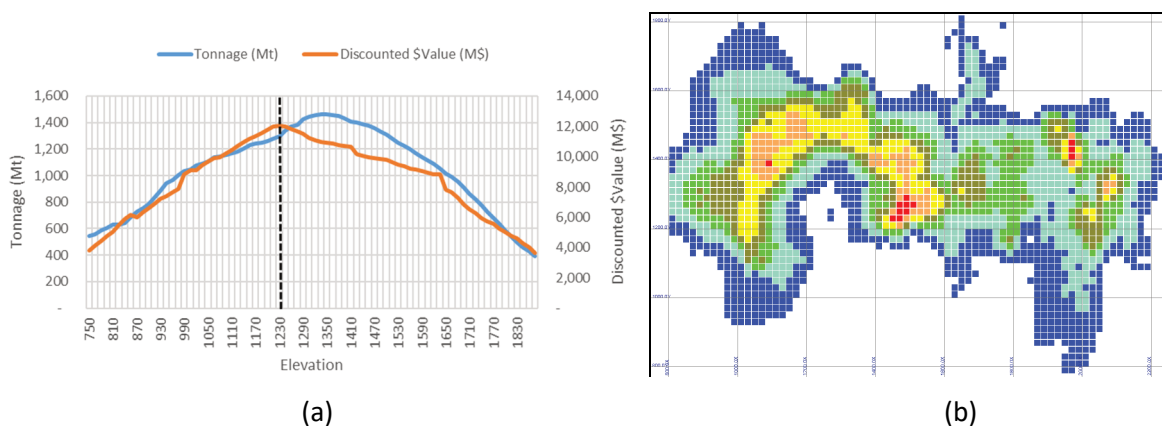
**Figure 1** Footprint Finder's evaluation steps

The extraction for every level will simulate a production schedule where other inputs are used, such as mining sequence (Figure 2a), production rate, numbers of new drawpoints and extraction rates. As a result of this evaluation, tonnage and grade are forecasted by year (Figure 2b). The economic value of that level is estimated by considering the discount rate and optionally a capital cost.



**Figure 2 Production schedule in Footprint Finder. (a) Mine sequence; (b) Tonnage and grade**

After every level is evaluated economically, the results could be summarised as shown in Figure 3a, where tonnage and economic value could be compared to select the optimum location of the extraction level by maximising the discounted cash flow (Geovia 2016). The detail of the economic value could be displayed by level and block to get better visibility of the footprint shape and value distribution as shown in Figure 3b.



**Figure 3 Results from Footprint Finder. (a) Footprint size; (b) Value distribution**

This approach is widely used to identify the best location of an extraction level, generally associated with a single lift; however, when a large deposit offers the option to have more than one extraction level, this approach is not necessarily optimum.

## 1.1 Selection of multi-lift using current approach

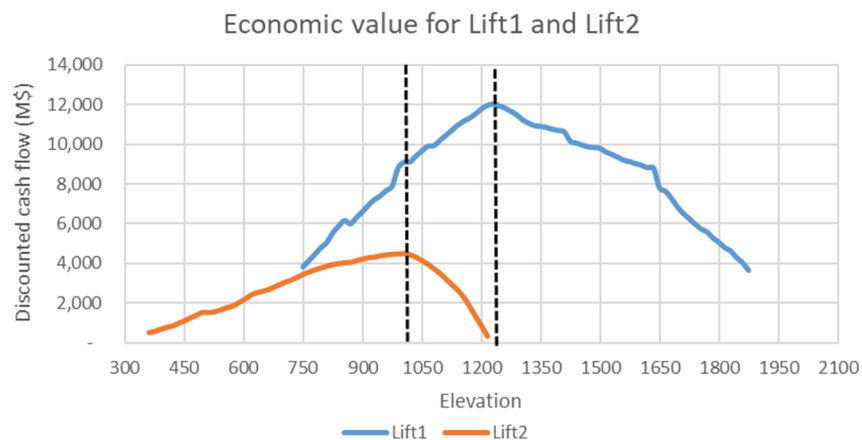
The current approach (Geovia 2016) considers two options for multi-lift selection:

- Select Lift1, replace the grade above with the default value and then select Lift2.
- Assess Lift1 and Lift2 combined, where the second lift will be placed at a given fixed vertical distance below the Lift1.

### 1.1.1 Select Lift1 and then select Lift2

This option prioritises the selection of Lift1 based on the initial inputs. Then, all blocks above Lift1 one are replaced by default value, normally null grade assuming depleted material to create a second analysis trying

to find the best elevation for Lift2. Figure 4 shows an example where the best combination could be located at 1,230 m for Lift1 and 1,000 m for Lift2; in terms of value, Lift2 represents only 30% of Lift1. Considering the location of the topography, Lift1 will be constructed at more than 1 km deep; therefore, this option requires a high initial capital cost and a long time to initiate production.

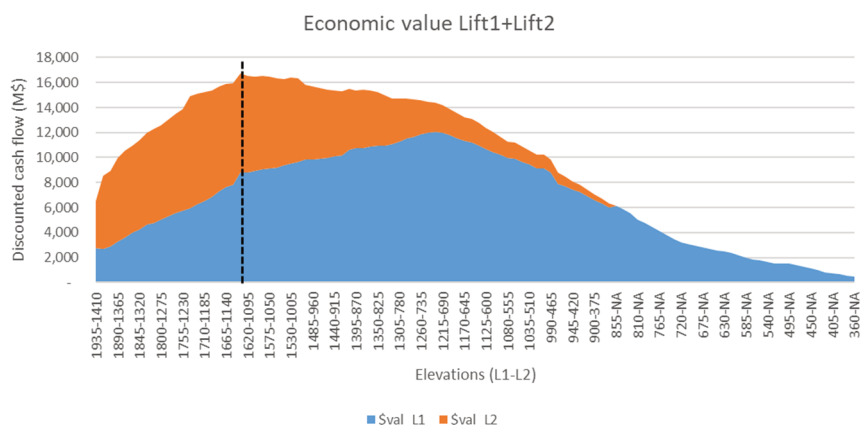


**Figure 4 Selection of multi-lift elevation (option 1)**

The challenge here is to find an option to identify scenarios where the optimum location of extraction level will be obtained finding the optimum combination of both Lift1 and Lift2 and not necessarily establishing the location of Lift1 first and then Lift2. This decision is more complex if the opportunity is to develop this mine combining options of production rate exploring alternatives of constructing a smaller mine at higher elevation and then ramp up to full production after. This could be done simulating combinations of production rate, shut off grade and even adding capital cost associated to the elevation of the production level.

### 1.1.2 Assess Lift1 and Lift2 combined

Consider that we are looking for a two-lift solution in which we know that the second lift will be placed at a given vertical distance below the top lift. The analysis of the first lift can be done using a standard Footprint Finder approach. However, to look at the second lift situation, it would usually be required to adjust the block model to take into account the mining of Lift1. However, if the elevation of Lift1 is not yet known, then we cannot simply edit the block model. This is where this option could be helpful by specifying as a fixed vertical distance below the first lift. An example of this option is illustrated in which Lift2 is located 525 m below the base of Lift1 (Figure 5). It is important to clarify that all discounted values are referred to the same year to make each combination valid as full net present value (NPV) (Lift1 and Lift2) and all combinations are directly comparable.



**Figure 5 Selection of multi-lift elevation (option 2)**

This approach allows to identify the best combination of both lifts by adding the value of Lift1 and Lift2; however, the challenge is to decide what is the optimum vertical distance of the second lift; therefore, it requires more iterations to get a better understanding of the ideal combination optimum Lift1 elevation versus Lift2 location.

## 2 Financial key performance indicators

Strategic mine decisions are complex due to all combinations of inputs and options offered to identify the scenario or reduce the area of feasible solutions. One effective way is to establish key performance indicators (KPIs) and then monitor and measure results against them. In this model, two financial KPIs were used: NPV and internal rate of return (IRR). However, other indicators like capital cost could be utilised as well.

### 2.1 Capital expenditures

Capital expenditures (CAPEX) are the investments incurred by a mining company in their fixed assets to bring a new mineral project into production. One of the main challenges for a block caving project is high capital-intensive operation; most of them upfront typically report a total CAPEX of anywhere from USD 500M to over USD 10B for 'super-caves' (Lovejoy 2012). CAPEX assumptions are based on the size of the footprint associated with the production target and the elevation of the extraction level, since these affect directly development, ventilation, material handling infrastructure, etc. For example if it gets deeper, the CAPEX increases.

### 2.2 NPV

NPV is the value of all future cash flows (positive and negative) over the entire life of an investment discounted to the present. NPV analysis is a form of intrinsic valuation and is used extensively across finance and accounting for determining the value of a business, investment security, capital project, new venture, cost reduction program, and anything that involves cash flow (CFI Education Inc. 2022).

$$NPV = \sum_{n=1}^N (Z_n \cdot (1 + r)^{-n}) - X_0 \quad (1)$$

where  $Z_n$  is the cash flow in time  $n$ ,  $r$  is the discount rate in terms of the period length of  $n$  and  $X_0$  is the cash outflow in time 0 (i.e. the purchase price or initial investment).

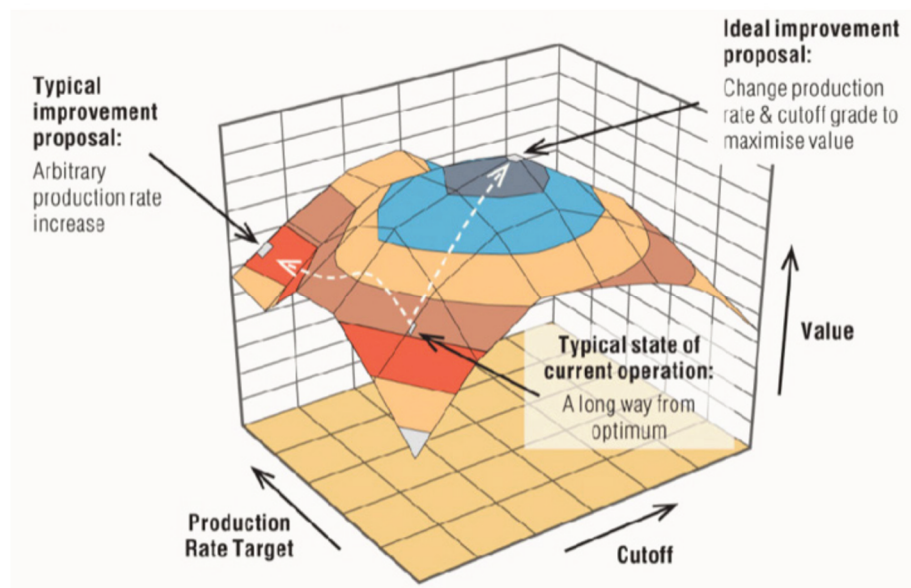
### 2.3 IRR

IRR is the discount rate at which the NPV of an investment is equal to zero. Put another way, it is the compound annual return an investor expects to earn (or actually earned) over the life of an investment. Typically, investors and managers of businesses look at both NPV and IRR in conjunction with other figures when making a decision (CFI Education Inc. 2022).

$$NPV = \sum_{n=1}^N (Z_n \cdot (1 + IRR)^{-n}) - X_0 = 0 \quad (2)$$

### 2.4 Hill of value

The hill of value (HoV) is a methodology proposed by Brian Hall in his book *Cut-off Grades and Optimising the Strategic Mine Plan* (Hall 2017) and used by many authors to work with block caving optimisation (Ovalle 2014), HoV financial metrics used to optimise the Carrapateena project (Hocking et al. 2020). Hall's approach emphasises the need to have an integrated point of view when choosing the cut-off grade (CoG), and the production rate in a mining project. The author achieves this through a 3D representation of the influence of each factor to the NPV, as is shown in Figure 6.



**Figure 6 Hill of value mine optimisation technique from (Hall 2017)**

The main contribution of HoV is that it gives us another perspective when decision-making as a part of the Mine Project Evaluation. As Brian Hall indicates, the CoG and the production rate are commonly two independent decisions in most cases. These values must be optimised in conjunction with obtaining the maximum NPV (Hocking et al. 2020).

### 3 Simulation model

The simulation model created aims to determine the best elevation for two extraction levels combined optimally, solving the sub-optimality of the traditional approach through the multiple executions of scenarios using an automated flow of processes or components.

#### 3.1 Isight description

Isight is a program that allows concatenating activities and tasks of multiple applications/software. In this way, an automated workflow is generated where the output variables of a component are handled as input variables for the next one within the chain of activities. In this way, the risks associated with layer errors are reduced (Dassault Systèmes 2020).

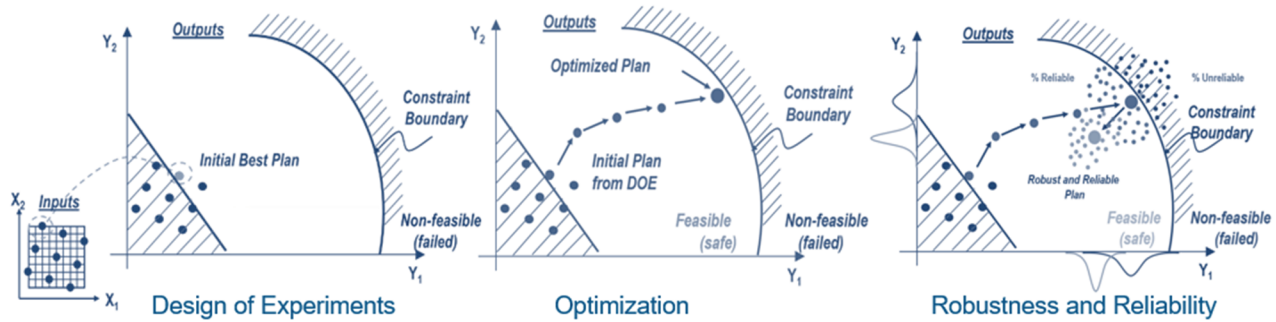
The ability to achieve integration and automation of different applications or tasks accelerates the evaluation of alternatives within mine planning. In addition, it provides post-processing tools that allow the users to compare results and relate the inputs and outputs of the process.

Although Isight has multiple components that provide direct links to software such as Excel, text files, databases, etc., it can also be connected with any application that is executed via command line such as Surpac, Whittle, MineSched, PCBC, PCSLC and Footprint Finder (as data source), the last one is relevant for this work.

Another tool available in Isight is Simcode. This component allows to modify text files and execute scripts simultaneously. An example of these executable text files corresponds to a Python code, detailed in the next section.

Isight is also an optimisation and statistical analysis engine (Figure 7). It allows for the execution of a workflow multiple times. In contrast, the inputs of this workflow are changed and quantify the sensitivity of the results from this variation (design of experiment). Also, using constraints in the evaluation and establishing a configuration of design variables that allow defining optimal results (optimisation), simulating uncontrolled

variables, and finding the combination of design variables that would minimise the expected uncertainty in the results (robustness and reliability). Allowing the user better visibility of the space of feasible solutions and identifying the design parameters that deliver optimal results (Dassault Systèmes 2022).



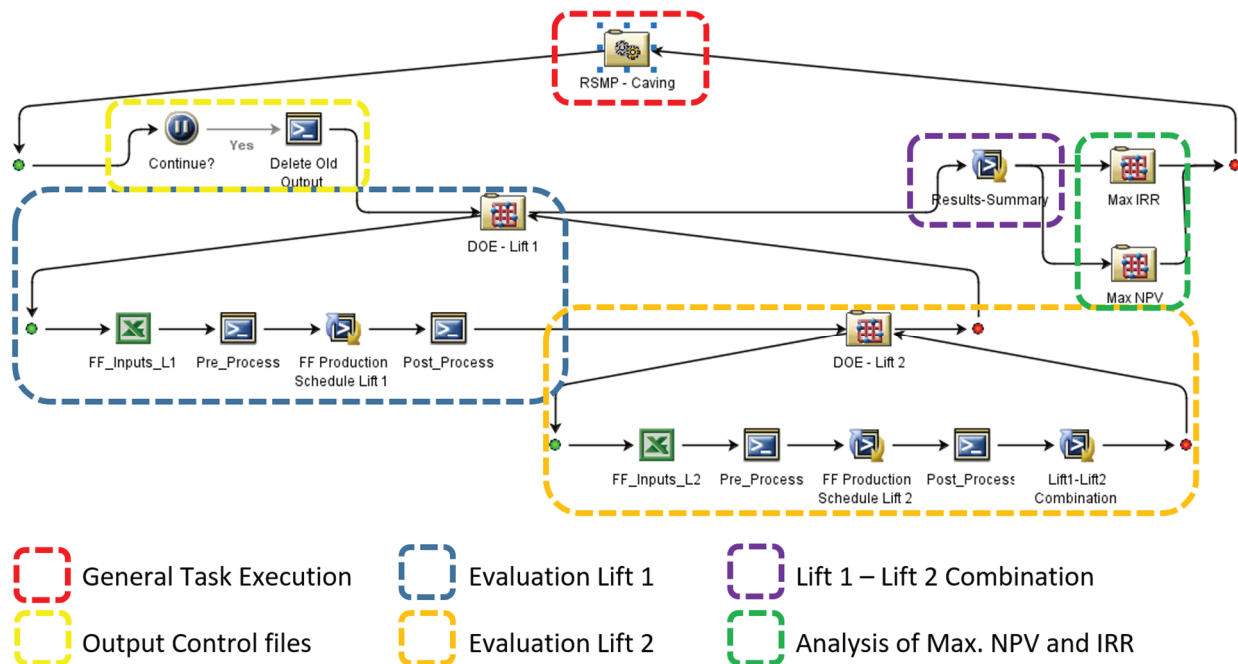
**Figure 7** Design of experiments (DOE) methodology

### 3.2 Isight–Footprint Finder model

Figure 8 describes the workflow used in this work. The relevant tasks within this flow are:

- Evaluation Lift1 (DOE – Lift1).
- Evaluation Lift2 (DOE – Lift2).
- Lift1 and Lift2 combination (result summary).
- Maximise NPV and IRR (max NPV and max IRR).

Each of these components is described in the following sections.



**Figure 8** Footprint Finder and Isight workflow for multi-lift analysis

### 3.2.1 *Design of experiment: Lift1 (DOE – Lift1)*

It is a simulation technique that allows executing a workflow running Footprint Finder by simulating a wide range of alternatives with specific inputs, constraints and engineering considerations.

The purpose of this item is to select the best elevation for Lift1. Using Footprint Finder managed by the Design of Experiment, it will be able to simulate multiple scenarios changing inputs such as production target, cut-off grade, capital cost, mine sequence, mixing parameters, development rate, etc.

### 3.2.2 *Design of experiment: Lift2 (DOE – Lift2)*

In this DOE, the second Lift will be evaluated as a result of the first Lift modelled in the previous step; for example, if Lift1 was modelled at 500 m depth, every block above will be replaced by null grades assuming them extracted from Lift1 and Lift2 will be evaluated from 500 m below for every level creating combinations every combination (L1: 500 m and L2: 550 m; L1: 500 m and L2: 600 m; L1: 500 m and L2: 650 m; etc.) The parameters considered in this DOE were production target, shut off grade, capital cost, etc., for Lift2.

As in the previous cycle, during the execution of this component, a production schedule is created, and then tonnage and grade reported by periods are captured; therefore, this data will be combined with Lift1 to calculate total tonnage and grade simulated, and estimate the combination's economic value. The operation will be simulated assuming Lift2 production starts as soon as Lift1 ramp down starts.

### 3.2.3 *Lift1 – Lift2 combination (results summary)*

This item is responsible for capturing results from Lift1 and Lift2, combining tonnage, grade and economic values to calculate the cash flow per period, also allocating capital cost at the beginning of each lift.

It is important to emphasise that these calculations are done automatically by Isight using a Python code where different rules can be applied. For example, the time for the Lift2 starts could be controlled by an offset depending on the production target used by Lift1. Also, a delay in production could be applied to replicate the additional development required to produce the first ore if the footprint analysed is located in deeper conditions. This option helps associate the level location with the economic value calculated using NPV and IRR for each scenario simulated.

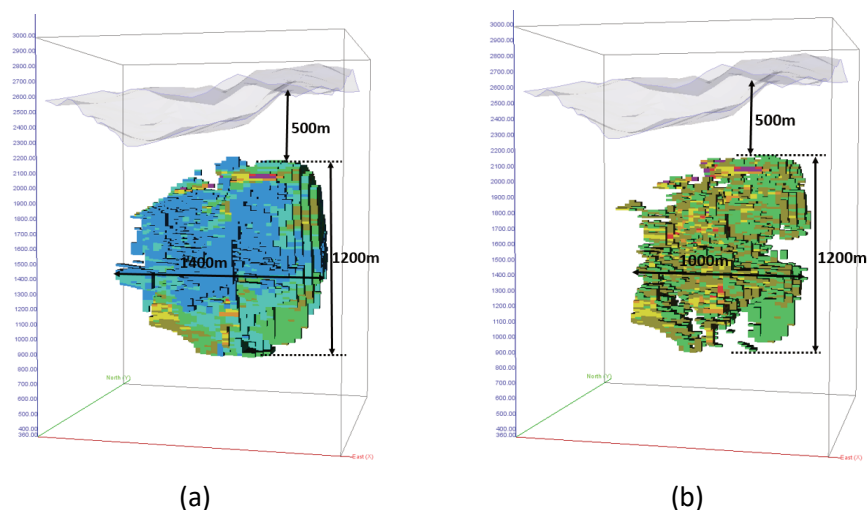
### 3.2.4 *Maximise NPV and IRR (max NPV – max IRR)*

The results from both DOE will be summarised here, reporting tonnage, grade, and financial results (NPV and IRR) of every combination of Lift1 and Lift2, based on the parameters used elevation, production target, and shut off grade. This analysis will generate thousands of scenarios making it difficult to analyse and select the best option; consequently, it was necessary to group them into pairs combining the elevation for each lift and choosing from this group the pair with the highest NPV and IRR. This value will be used in the hill of value map to select zones with the best results.

## 4 Case study

The case study was done using a fictitious orebody; however, the methodology has already been used in some real-world projects to good effect. It is modelled as a massive porphyry copper deposit similar to many large block cave mines currently in operation. The overall view of the grade distribution in 3D using 0.3 and 0.9% cut-off grade are shown in Figure 9.





**Figure 9** Copper distribution. (a) Resources at cut-off grade 0.3%; (b) Resources at cut-off grade 0.9% Cu

Based on the size of this deposit, it could be extracted easily with two lifts of 500 m each; however, the amount of resources depends on the cut-off grade and affects the size of the economic footprint and the production target expected.

#### 4.1 Footprint Finder setup

The economic model is one of the most important inputs for this type of analysis; in this case, it was created based on copper revenue using the values listed in Table 1.

**Table 1** Revenue model

Input	Value
Copper price	USD 4.0/pound
Copper recovery	75%

Footprint Finder inputs are shown in Table 2.

**Table 2** Footprint Finder inputs

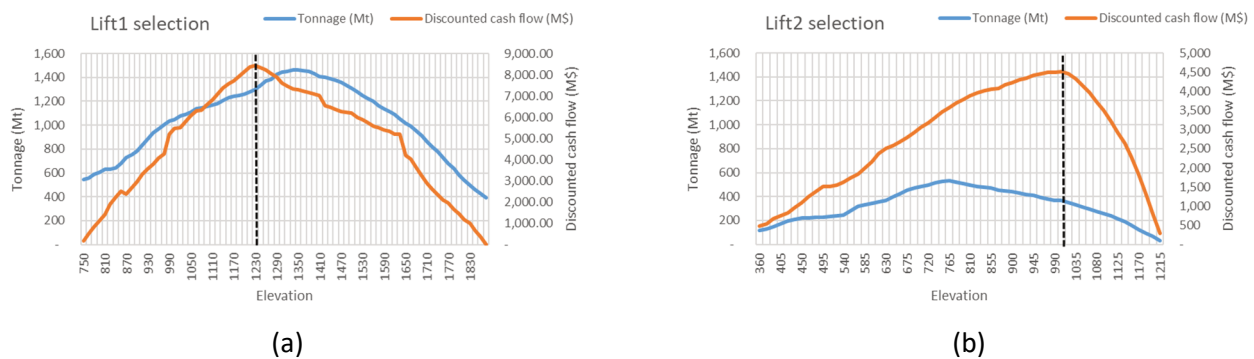
Input	Value
Maximum allowable height of draw	500 m
Vertical mining rate	80 m/year
Height of Interaction zone	100 m
First dilution entry	60%
Discount rate	10%
Development cost	USD 1,000/m <sup>2</sup> → USD 450,000/block
Mining cost	USD 20/tons
Premium cost to shut off	USD 0/tons
Production target	100,000 tons per day
Ramp-up periods	Six years
Opening rate	18 blocks/year → 36,450 m <sup>2</sup> /year



## 4.2 Selection of multi-lift traditional approach

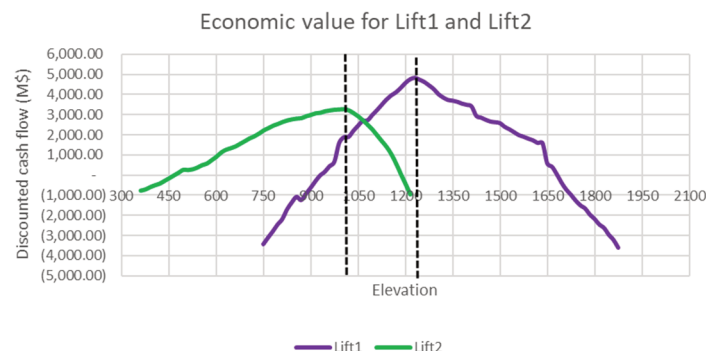
The traditional approach (Lift1 is depleted before starting Lift2) will be applied in this example as follows:

1. Selecting Lift1 by running Footprint Finder and choosing the elevation based maximum discounted dollar value (Figure 10a).
2. Run Footprint Finder enabling the option of multi-lift, specifying the best elevation for Lift1 and then all material above will be considered depleted by Lift1; therefore grade information, and economic value will be replaced automatically in the block model by default value before the evaluation of Lift2 is done, see Figure 10b for Lift2 results.



**Figure 10 Results from Footprint Finder for (a) Lift1 and (b) Lift2**

The combination of both lifts results is shown in Figure 11; using this approach, the best result should be locating Lift1 at 1,230 m and Lift2 at 1,005 m.



**Figure 11 Selecting best elevation for Lift1 and Lift2**

## 4.3 Selection of multi-lift using scenario simulation

This analysis was done including a CAPEX of USD 7,240M based on a production target of 100,000 tons per day. The starting of production will be adjusted according to the depth of the extraction level; this will be reflected in the cash flow calculation; for example, if the reference level is 1,600 m and based on incremental development required by additional access/conveyor decline development and construction, production will be delayed by one year every 100 m.

### 4.3.1 Design of experiment: Lift1

In this example, the objective was to evaluate Lift1 using different production target and cut-off grades, trying to understand the value of the size of the first lift for this deposit, not only aiming for a large footprint for a super cave (100 ktpd) associated with a large capital investment but also assessing a small footprint with high grade working with a small or medium cave operation (25–50 ktpd) initially. Table 3 describes the inputs used for Lift1.

**Table 3** Footprint Finder inputs for Lift1

Input	Value
Production target	25, 50, 75 and 100 ktpd
Capital cost (based on production target)	USD 1.67, 3.48, 5.26 and 7.02B
Premium cost	USD 0, 10, 20, 30, 40 and 50/t
Cut-off grade (based on mining and premium cost)	0.30, 0.45, 0.75, 0.9 and 1.05% Cu

In terms of evaluation every elevation will be modelled as Lift1, for example the economic limits of the block model goes from 2,000–1,000 m and the block size is 15 m; 67 scenarios will be simulated as Lift1 for every combination. In each case a production schedule will be created providing detailed information per year (tonnage and grade).

#### 4.3.2 Design of experiment: Lift2

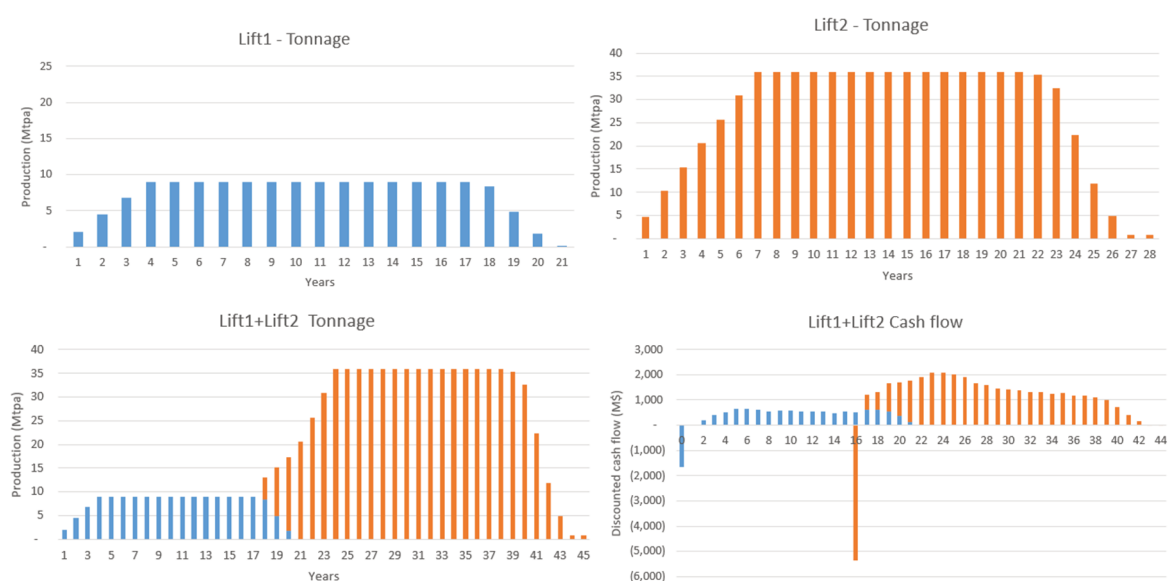
Based on the characteristic deposit, Lift2 was modelled targeting a large footprint, only trying to maximise reserve extraction from the bottom part (Table 4):

**Table 4** Footprint Finder inputs for Lift2

Input	Value
Production target	75 and 100 ktpd
Capital cost (based on production target)	USD 5.26 and 7.02B
Premium cost	USD 0 and 10/t
Cut-off grade (based on mining and premium cost)	0.30 and 0.45% Cu

#### 4.3.3 Lift1 – Lift2 combination

Figure 12 describes an example of the combination of Lift1 and Lift2 tonnage and cash flow calculated per period allocating capital cost at the beginning of each lift based on the production target used. As a general rule for this simulation Lift2 production starts as soon as Lift1 ramp down starts.

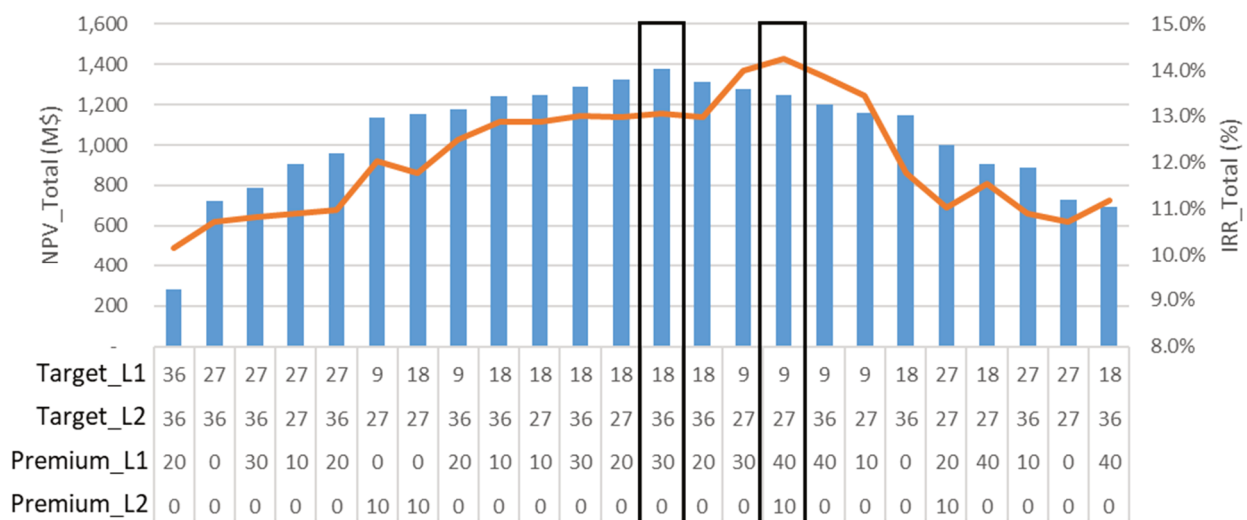
**Figure 12** Lift1 – Lift2 combination and cash flow calculation

#### 4.3.4 Maximise NPV and IRR

As was described in Section 3.2.4, the objective of this item is to be able to group results based on Lift1 and Lift2 combinations to identify the best NPV and IRR for each scenario. Figure 13 describes an example for one option for Lift1 and Lift2 location, where 24 scenarios were evaluated, based on the combination of production target and premium cost, from these results we can conclude:

Best NPV was obtained from premium cost USD 30 and 0/t; production target 18 and 36 Mtpa for Lift1 and Lift2, respectively. This NPV could be a result of the large mine; however, the lower IRR could be reflecting the impact of the more significant capital required.

Best IRR was achieved from shut off USD 40 and 10/t; production target 9 and 27 Mtpa for Lift1 and Lift2, respectively. In this case, both lifts are aiming for a smaller mine, where Lift1 is reducing its size, targeting high grade; therefore, the capital invested is lower, allowing maximum IRR.



**Figure 13 Lift1 – Lift2 combination and cash flow calculation**

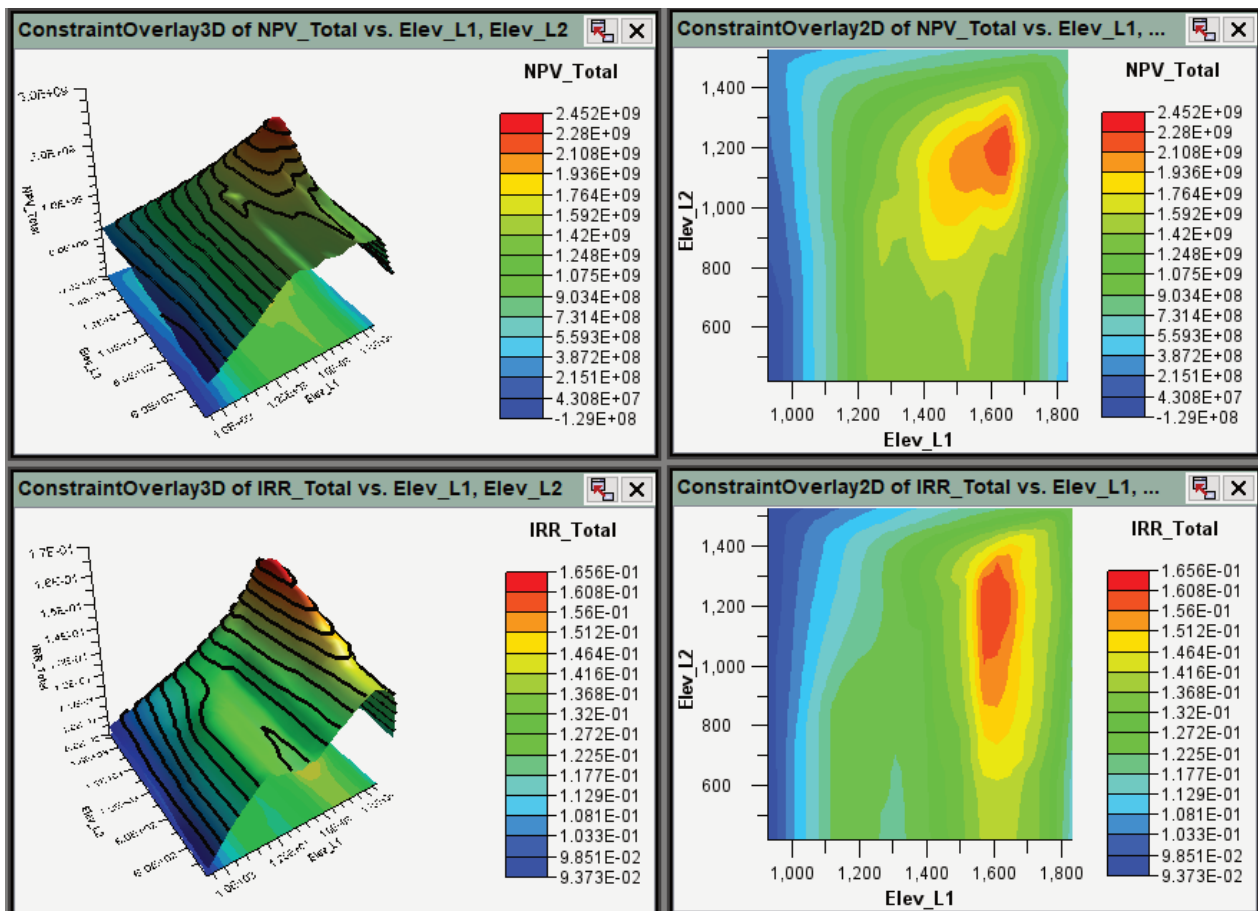
Figure 14 shows an example of the detailed results obtained for the combination of input for this Lift1 at 1,200 m and Lift2 at 900 m, where it is possible to see NPV, IRR, capital, tonnage, Cu grade, net revenue (NR) and years of total production estimated.

L1-L2	NPV_Total (M\$)	NPV_L1	IRR_Total (%)	IRR_L1 (%)	Full_Prof_Full_Prc	Capital_L1 (M\$)	Capital_L2 (M\$)	Ton_L1 (Mt)	Ton_L2 (Mt)	Ton_Total (Mt)	CU	NR_CU4	Premium_L1	Premium_L2	Target_L1	Target_L2
1200-900	281	31	10.1%	9.9%	15	6	7,022	-	731	391	1,122	0.94	62.01	20	0	36,000,000
1200-900	724	711	10.7%	10.7%	41	6	5,257	1,766	1,263	391	1,654	0.81	53.43	0	0	27,000,000
1200-900	787	606	10.8%	10.6%	14	6	5,257	1,766	488	391	878	0.96	63.38	30	0	27,000,000
1200-900	903	853	10.9%	10.9%	31	10	5,257	-	967	391	1,358	0.89	58.70	10	0	27,000,000
1200-900	960	883	11.0%	10.9%	23	6	5,257	1,766	731	391	1,122	0.94	62.01	20	0	27,000,000
1200-900	1,135	1,135	12.0%	13.4%	136	10	1,665	3,592	1,263	391	1,654	0.81	53.43	0	10	9,000,000
1200-900	1,151	1,150	11.8%	11.8%	65	10	3,475	1,782	1,263	391	1,654	0.81	53.43	0	10	18,000,000
1200-900	1,179	1,180	12.5%	13.5%	78	6	1,665	5,358	731	391	1,122	0.94	62.01	20	0	9,000,000
1200-900	1,244	1,243	12.9%	11.9%	49	6	3,475	3,547	967	391	1,358	0.89	58.70	10	0	18,000,000
1200-900	1,248	1,243	12.9%	11.9%	49	10	3,475	1,782	967	391	1,358	0.89	58.70	10	0	18,000,000
1200-900	1,289	1,276	13.0%	12.0%	24	6	3,475	3,547	488	391	878	0.96	63.38	30	0	18,000,000
1200-900	1,326	1,309	13.0%	12.0%	37	10	3,475	1,782	731	391	1,122	0.94	62.01	20	0	18,000,000
1200-900	1,380	1,276	13.1%	12.0%	24	10	3,475	1,782	488	391	878	0.96	63.38	30	0	18,000,000
1200-900	1,313	1,309	13.0%	12.0%	37	6	3,475	3,547	731	391	1,122	0.94	62.01	20	0	18,000,000
1200-900	1,278	1,280	14.0%	14.1%	24	10	1,665	3,592	242	391	632	0.93	61.19	30	0	9,000,000
1200-900	1,247	1,247	14.2%	13.6%	52	10	1,665	3,592	488	391	878	0.96	63.38	40	0	9,000,000
1200-900	1,202	1,280	13.9%	14.1%	24	6	1,665	5,358	242	391	632	0.93	61.19	40	0	9,000,000
1200-900	1,157	1,157	13.4%	13.4%	104	10	1,665	3,592	967	391	1,358	0.89	58.70	10	0	9,000,000
1200-900	1,150	1,150	11.8%	11.8%	65	6	3,475	3,547	1,263	391	1,654	0.81	53.43	0	0	18,000,000
1200-900	1,001	883	11.0%	10.9%	23	10	5,257	-	731	391	1,122	0.94	62.01	20	10	27,000,000
1200-900	905	636	11.5%	11.2%	9	10	3,475	1,782	242	391	632	0.93	61.19	40	0	18,000,000
1200-900	886	853	10.9%	10.9%	31	6	5,257	1,766	967	391	1,358	0.89	58.70	10	0	27,000,000
1200-900	731	711	10.7%	10.7%	41	10	5,257	-	1,263	391	1,654	0.81	53.43	0	0	27,000,000
1200-900	693	636	11.2%	11.2%	9	6	3,475	3,547	242	391	632	0.93	61.19	40	0	18,000,000

**Figure 14 Lift1 – Lift2 combination results**

Based on the best NPV and IRR obtained from each pair of Lift1 and Lift2, a hill of value was created for each Financial KPI (Figure 15). This 3D and the projection in 2D is the best graphic method to display results where: X-axis: Lift1 coordinate, Y-axis: Lift2 coordinate, and Z-axis: NPV and IRR, respectively

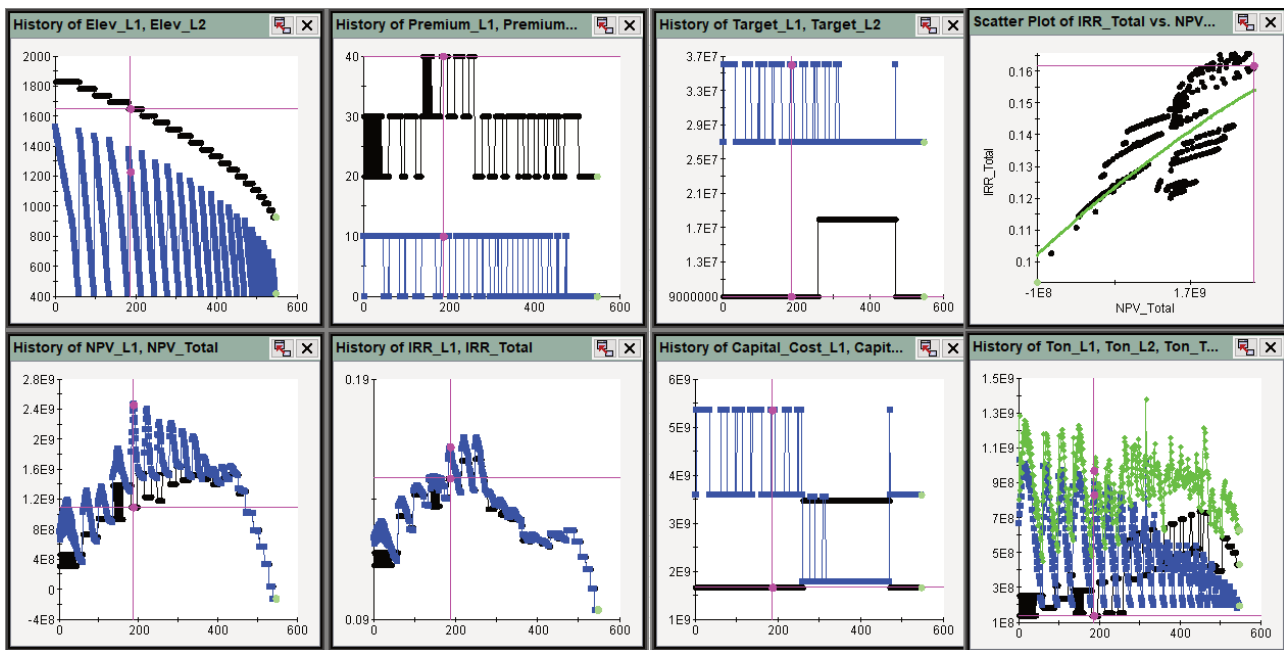
In both KPIs (NPV and IRR) is possible to recognise a specific zone with feasible solutions to maximise NPV and IRR, allowing to do new analysis by reducing the area of study. Also, it presents alternatives where NPV and IRR could be combined to maximise both objectives.



**Figure 15** Hill of value of NPV and IRR for Lift1 and Lift2

Additional analysis could be performed using all sets of results from this model to understand better the correlation between inputs and outputs obtained from 2D statistics analysis; an example is shown in Figure 16, where every pair of Lift1 and Lift2 is analysed in detail.

Interestingly, all maximum KPIs were achieved using a low production target for Lift1 (9 and 18 Mtpa) and high premium cost (USD 20, 30 and 40/t); this reflects the lower capital cost utilised initially and aiming for the higher grade. Also, a good correlation between NPV and IRR is observed; therefore, an additional analysis could be done to find the best combination of inputs to maximise both objectives.



**Figure 16 2D statistics analysis (scatter plots and history graphs)**

#### 4.4 Case study summary

This model was capable of analysing multi-lifts selection using scenario simulation; the following numbers summarised the execution of this case:

- 50,000 scenarios were simulated in approximately five days.
- 700 combinations of Lift1 and Lift2 were selected maximising NPV and IRR.
- Maximum NPV: Lift1 at 1,650 and Lift2 at 1,200.
- Maximum IRR: Lift1 at 1,605 and Lift2 at 1,230.
- Traditional approach: Lift1 at 1,230 and Lift2 at 1,005.

Table 5 provides summary information for these three scenarios.

The NPV and IRR were calculated for the traditional approach using the same criteria as the rest of the simulated scenarios. Therefore, targeting production of 36 Mtpa requires a significant capital invested upfront, which is reflected in the negative NPV and low IRR reported. Also, the location for Lift1 is deeper than the other options delaying the start of production due to the additional development and infrastructure required.

The scenarios simulated to maximise NPV and IRR captured an option to construct this mine in stages, starting with low production in higher elevations, reducing the initial investment and ramping up to total production for Lift2, where the central part of the high grade of this deposit is located.

**Table 5** Footprint Finder summary results

Case	Traditional approach	Max NPV	Max IRR
Elev_L1	1,230	1,650	1,605
Elev_L2	1,005	1,200	1,230
Premium_L1	0	40	40
Premium_L2	0	10	10
Target_L1	36,000,000	9,000,000	9,000,000
Target_L2	36,000,000	36,000,000	36,000,000
NPV_Total (USD)	-1,523,572,311	2,465,350,838	2,376,350,245
NPV_L1 (USD)	-1,556,015,123	1,095,765,541	1,230,499,691
IRR_Total	6.3%	16.2%	16.6%
IRR_L1	6.0%	14.9%	15.6%
Yrs_of_Full_Prod_L1	38	7	15
Yrs_of_Full_Prod_L2	6	19	16
Capital_Cost_L1 (USD)	7,022,140,735	1,664,598,235	1,664,598,235
Capital_Cost_L2 (USD)	0	5,357,542,500	5,357,542,500
Ton_L1	1,298,226,474	138,788,532	154,335,683
Ton_L2	364,873,432	868,811,703	755,293,832
Ton_Total	1,663,099,907	1,007,600,235	909,629,515
Cu	0.82	1.03	1.04
Net revenue (USD/t)	54.47	67.94	68.72

## 5 Conclusion

The option of solving complex problems in block caving projects like finding the optimum location for a multi-lift could be successfully modelled by simulating multiple scenarios. Using financial metrics allows understanding of the project's financial returns.

In this case, this model demonstrated an improvement of discounted cash flow, reduction in capital cost and increased shareholder return, simulating scenarios based on inputs such as production target, shut off grade and capital cost. It demonstrates the value of this new optimisation technique compared with the traditional approach by discovering options not envisioned initially to provide feasible and attractive alternatives in terms of footprint size, mine plan and design at the strategic level to find optimum options before the detailed work is done.

This model also provides flexibility to use additional components in this analysis to value the effect of the time to start production into the cash flow calculation based on the elevation of each lift, creating a more realistic value. It allows a better understanding of the correlation between inputs and outputs by using 2D and 3D data analysis, like the HoV map, where the interpretation of more than 50,000 scenarios could be easily summarised and displayed to compare options, evaluate robustness and making decisions.

In summary, the integration of the workflow and the optimisation components enables a new technique that allows the ability to tie separate mining areas together, including the multi-lift residual improvements;

combines the individual workflow steps (evaluate a lift, schedule, combine lifts and economic analysis) and automates the analysis of thousands of scenarios with built-in optimisation logic.

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