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Practical Applications of the Hill of Value Approach in Strategic Planning for Openpit Mining

R. Benito
MINSYS, Tucson, AZ

J. Lopez
MINSYS, Lima, Perú

H. Gamarra
MINSYS, Lima, Perú

ABSTRACT

This article describes three practical applications of the Hill of Value (HoV) methodology within different stages of strategic planning for open-pit mining operations and projects.

In the pursuit of optimal mine planning, this study establishes a comprehensive case study during the (i)design phase, by refining key parameters for efficient decision-making. (ii)production planning, where the HoV is used to define achievable production rates, enhancing operational effectiveness through a nuanced consideration of mining and processing capacities. (iii)Additionally, the study introduces a conceptual framework for orchestrating the optimal sequence of multiple pits during the planning phase, with a focus on maximizing project value.

INTRODUCTION

In recent years, significant acceptance, and utilization of the HoV methodology within the mining industry has been noted. This methodology facilitates improved decision- making, grounded in solid and comprehensive evaluations of multiple scenarios.

The HoV methodology leverages advanced modeling and three-dimensional graphical capabilities to depict the influence of each factor on NPV (Net Present Value). This enables the explanation of optimal decision alternatives with a robust analytical basis.

One way to comprehend this methodology is by considering NPV alongside two independent variables, typically the cutoff grade (CoG), and another key value factor, such as the production rate. Adjusting the CoG entails a redefinition of the mining sequence, resulting in modifications to the final pit design as one of its effects. Similarly, changes in plant feed demand are directly dependent on mine production demands, which in turn impact the Life of Mine (LOM). Thus, unless a Hill of Value surface is generated, there is no way to conclude and base our selection on the best combination of variables for the potential creation of value in our operations.

JUSTIFICATION FOR THE RESEARCH

The cornerstone of the value chain in mining companies is strategic planning, as it enables quantification of value and provides the operational foundations for their development (Hooman, 2019). This process requires multiple input parameters such as costs, prices, grades, tonnages, recoveries, among others. Generally, these parameters are estimated using deterministic methods, and some inherently carry uncertainty from their conception, which in turn stems from various sources (geological, operational, external). Consequently, this uncertainty introduces risk into the planning outcomes (Seguel, 2017) and potential value loss associated with incorrect decision-making. The

HoV methodology facilitates a robust and comprehensive evaluation by analyzing different practical combinations and scenarios of all available strategic options (B. Hall, 2014). This approach provides a holistic perspective of the variables under analysis, enabling decisions to be made with reduced uncertainty.

GENERAL OBJECTIVE

Applying the HoV Methodology at Different Stages of the Strategic Mine Planning.

SPECIFIC OBJECTIVES

- Optimal sizing of phase sizes.
- Optimization of mining and processing capacity.

This article conceptualizes the optimal mining sequence for multi-mine phases and operations.

METHODOLOGY

The work procedure involves the application of the HoV strategy through three case studies. Each case study (CS) has different parameters, as depicted in Figure 1.

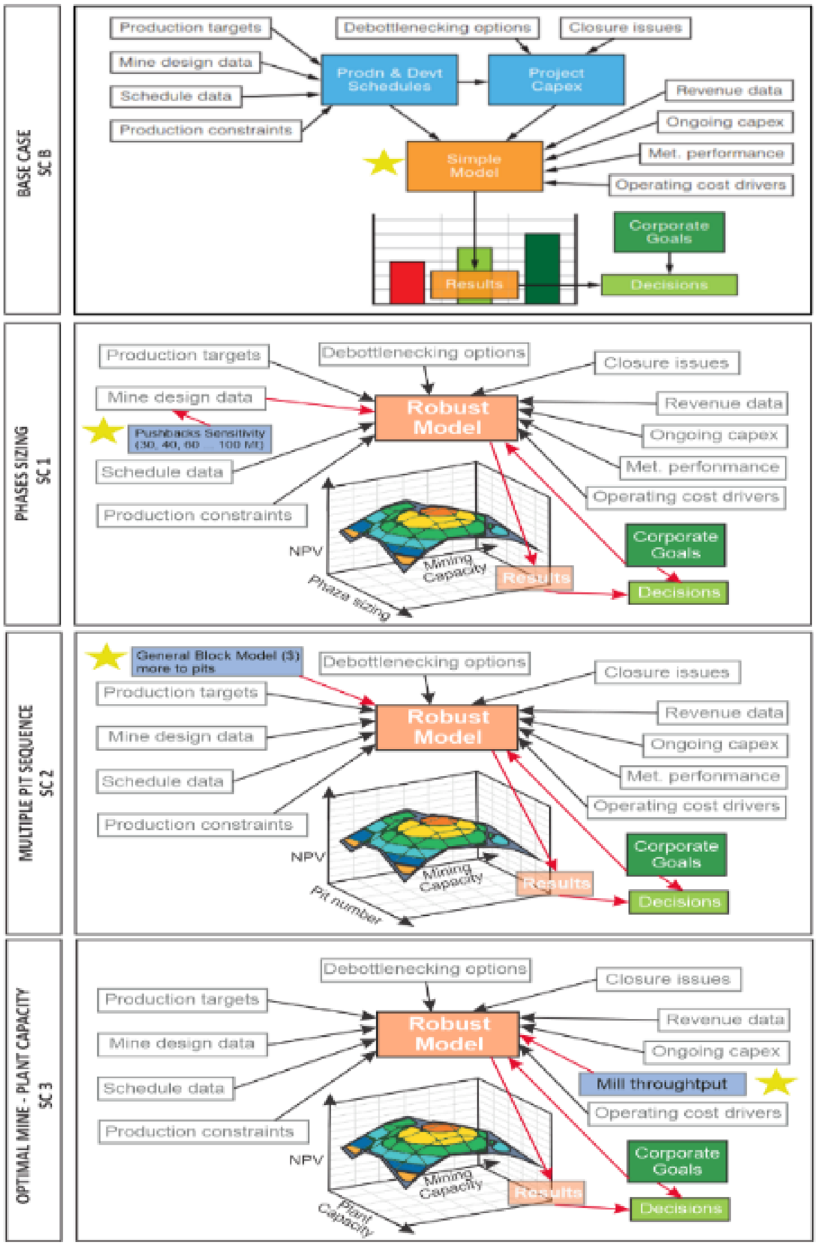

Figure 1. Deterministic Strategy vs. Process Optimization Strategy (Based on B. Hall, 2019, pp. 119)

CASE STUDY 1—
SIZING OF MINING PHASES

One of the stages that consumes the most analysis time and is among the most critical is the pit sizing. This is because all subsequent analyses are contingent upon this feature. Consequently, a pre-sizing methodology at the block level is proposed based on the L&G algorithm of nested or directional pits, also known as DBS (Depth-Based Search). This methodology involves conducting a sensitivity analysis on the phase sizes of the mineral, expressed in tonnages. For instance, phases ranging from 60 Mt to 110 Mt. Once the tonnage is defined, it serves as the input data for grouping the nested or directional pits, forming "pushbacks" based on the established sensitivity.

Subsequently, a mining plan for each scenario will be developed, calculating the NPV for each case.

Methodology—Case 1

The methodology carried out for the development of this case is presented.

Results—Case 1

A. Review of Phases

From the current review of phases, the analysis range was determined to be from 60 to 120 Mt of ore.

B. Generation and Sensitivity of Cones

Based on the analysis range of the phases, the final pit was obtained, aiming for the target of 247 million tons of ore. This will serve as the starting point for the various scenarios to be analyzed.

Once the final pit is obtained, we will group pushbacks according to the analysis range obtained in point (A).

C. Analysis of Results

Instead of generating various sets of mining pit designs, which would take a considerable amount of time, the pushbacks from Table 1 were utilized for this purpose, which are based on cones. This allows for the flexibility in a short period of time.

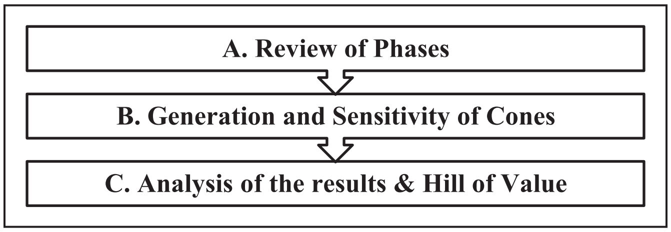

Figure 2. Process optimization strategy (proposed by the authors)

Table 1. Selection of pushbacks

Case	Ore	Pushbacks
60	247	5
70	247	4
75	247	4
85	247	3
95	247	3
110	247	3

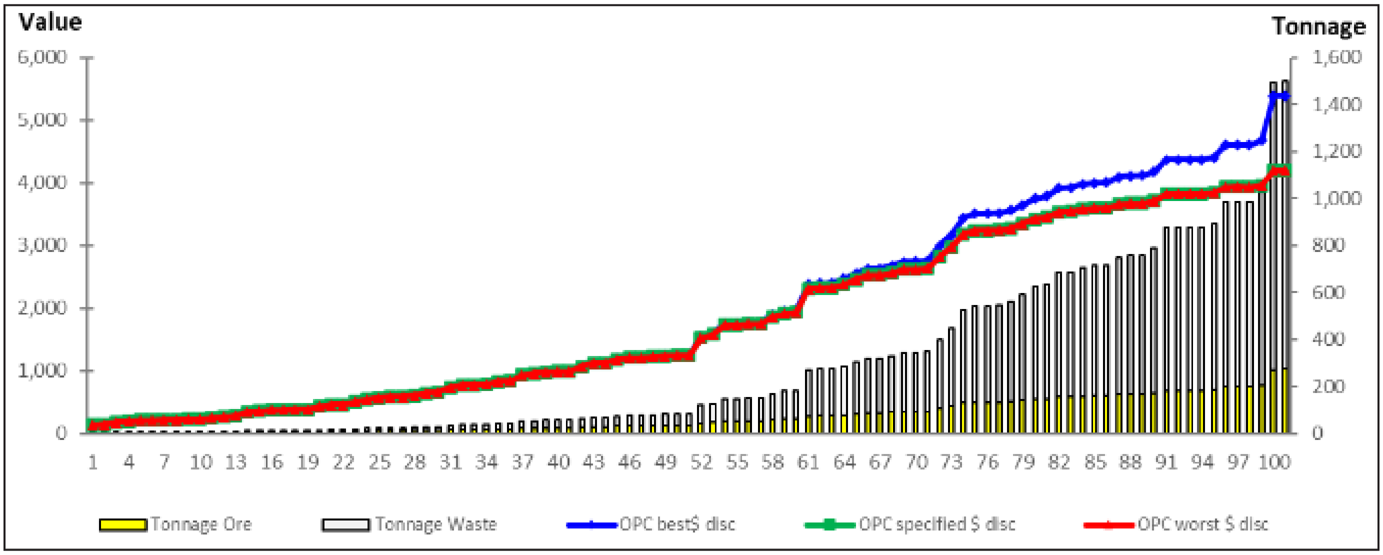

Figure 3. Nested pits inside pit final

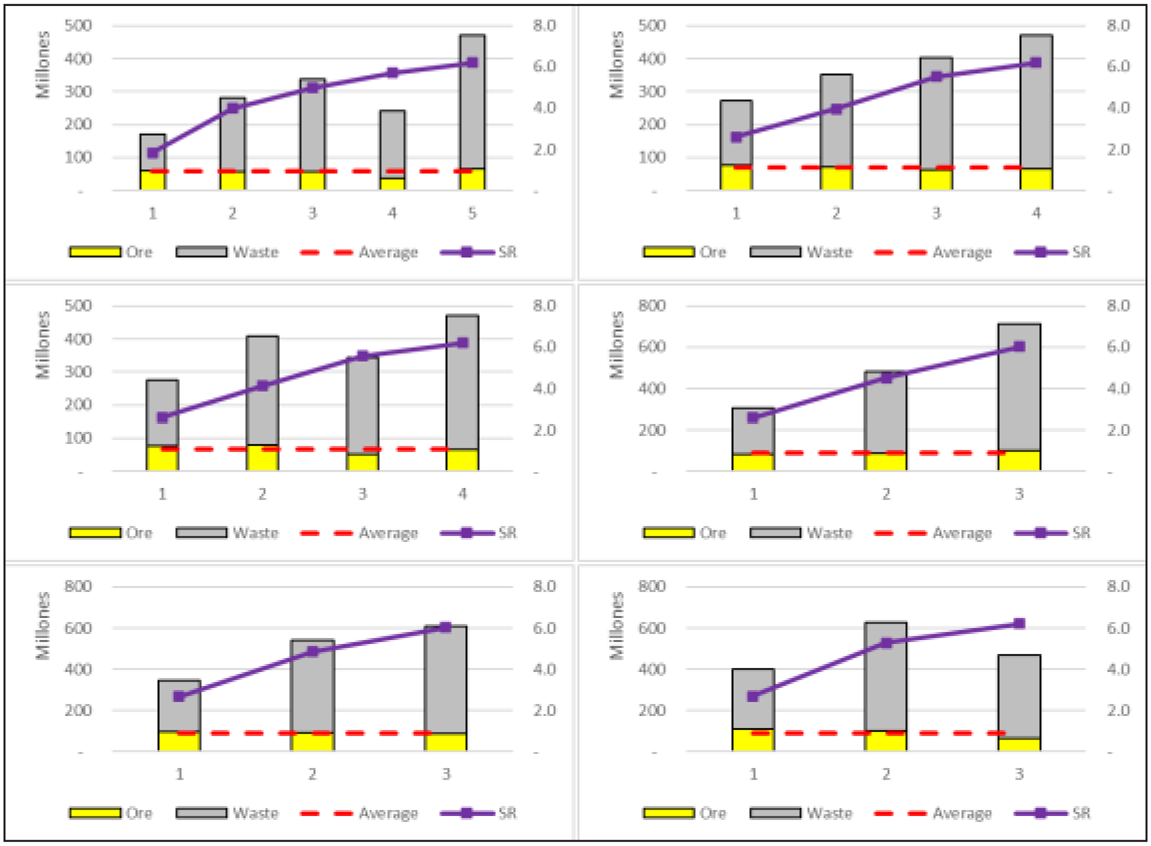

Figure 4. Pushback optimization inside pit final

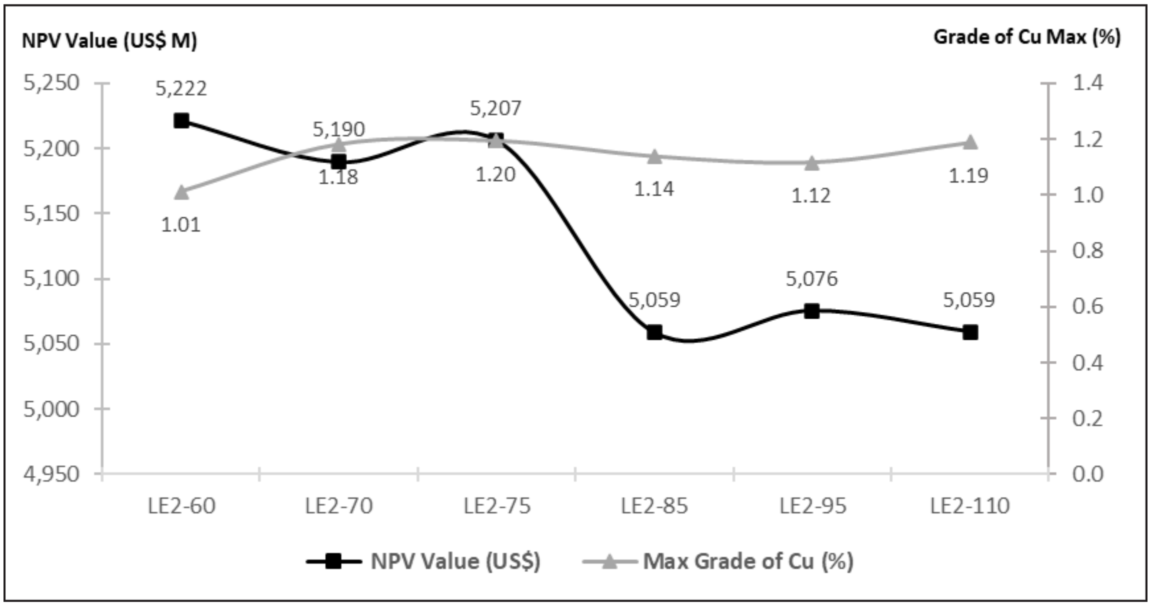

Figure 5. NPV

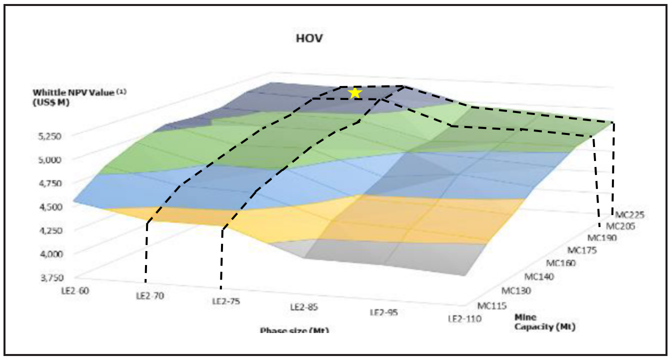

Figure 6. Hill of Value

We observed optimal outcomes within the phase size range of 60 Mt to 75 Mt. Subsequently, we explored variations in mine capacity, ranging from 110 Mt to 225 Mt.

Conclusions—Case 1

This methodology, centered on concentric pits, exhibits adaptability to specific requirements.

By employing an optimization approach with minimal constraints, except for sensitivities, we gain a comprehensive insight into the deposit's behavior.

The optimal mining phase size ranges between 70–75 Mt of ore, accompanied by a recommended mine capacity of 205- 225 Mt.

CASE STUDY 2—
MINE-PLANT CAPACITY OPTIMIZATION

The key variables in the development of a mining project are the determination of Mining Capacity (CM) and Processing Capacity (CP). In this regard, sensitivity analysis is carried out with respect to various processing rates (and potential mining capacities with operational increments that may include the capacity of the primary loading equipment, such as electric shovels (~30 Mtpa) or hydraulic shovels (~12 Mtpa)).

Methodology—Case 2

The methodology carried out for the development of this case is presented.

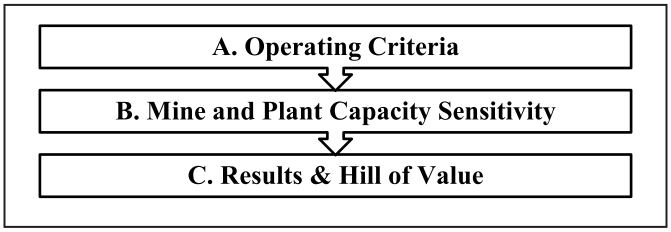

Figure 7. Process optimization strategy. Cut-off Grades and Optimising the Strategic Mine Plan, B. Hall (2014)

A. Operational Criteria

Our analysis commences from a foundational standpoint, based on the following operational criteria:

Table 2. Criteria

Criterion	Und	Value
Cap. Mine	Mta	150

B. Mine and Plant Capacity Sensitivity

In pursuit of constructing a value curve, we take into account the following sensitivities:

Table 3. Sensitivity

Criterion	Start	End	Steps
Mine Capacity	135	240	8
Plant Capacity	65	100	5

C. Results and Hill of Value

The obtained results, along with the graphical representation of the "Hill of Value," indicate that the optimal feed for the plant is at 72.5 Mt, with a recommended mine capacity starting from 180 ktpd.

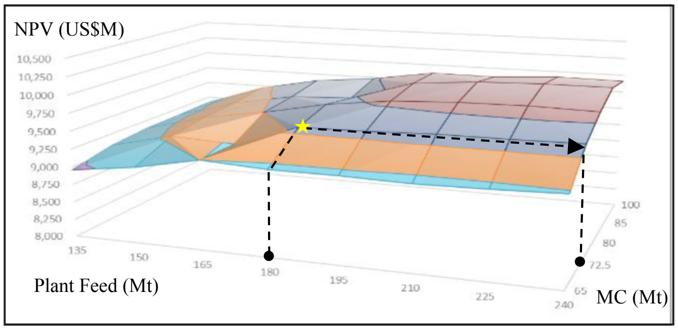

Figure 8. Hill of Value

Conclusions—Case 2

The application of this methodology supports the determination that the optimal feed for the plant is achieved at 72.5 Mt, with a recommended mine capacity starting from 180 ktpd to maximize process efficiency and performance. This approach provides a solid foundation for strategic decision-making within the scope addressed by this case.

CASE STUDY 3—
MULTI-MINE PIT SEQUENCING

HoV is proposed for application in the pursuit of optimal sequencing for multi-mine operations, with the aim of identifying the initial pits that contribute the highest value, thereby maximizing NPV. In addition to determining the starting point of mining, it also facilitates decision-making regarding the strategic placement of infrastructure, such as the processing plant, heap leach pads, tailings dam, among others. While the methodology is outlined, it is yet to be fully developed.

RECOMMENDATIONS

For Case Studies 2 and 3, in the mine plan optimization substage, it is necessary to run multiple iterations using various mathematical algorithms with minimal constraints to achieve improved results.

In Case Study 2, optimal sizing of mining phases requires modeling the optimal sequence of pushbacks through directional or mixed pits to represent operational phases.

CONCLUSIONS

The HoV methodology provides a broad spectrum of solutions represented through a net present value surface, which aids in making strategic decisions in long-term planning.

For the case of multiple pit sequencing, the HoV methodology is proposed to establish the commencement of mining operations, focusing on key variables such as mining capacity and the sequence in which pits are mined.

In the optimization of mine-plant capacity and mining phase sizing, not only were more robust results achieved, but also the NPV of the projects case studies was optimized.

REFERENCES

[1] Hall, B A, 2014. Cut-off Grades and Optimizing the Strategic Mine Plan, pp. 101–124.

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Pressure Balancing Tests at a Colorado Coal Mine

Karoly (Charles) Kocsis
University of Utah, Salt Lake City, UT

Felipe Calizaya
University of Utah, Salt Lake City, UT

Jeff Johnson
University of Utah, Salt Lake City, UT

Tulio Dias
University of Utah, Salt Lake City, UT

Natanna Nunes
University of Utah, Salt Lake City, UT

ABSTRACT

Two pressure balancing chambers were constructed at a Colorado coal mine to reduce the risk of spontaneous combustion. Each chamber was established by installing a Kennedy stopping at about 10 ft (3 m) in front of an isolation seal, and equipped with two safety doors, a nitrogen injection system, and a set of environmental monitors. Several pressure balancing tests for different ventilation conditions were conducted in these chambers. During each test, pressurized nitrogen was injected into the chamber and the pressure differentials across the stoppings and seals monitored. This study presents a summary of the results achieved, lessons learned, and the basic requirements to operate a pressure chamber effectively.

INTRODUCTION

The problem of spontaneous combustion (Sponcom) has been associated with coal mining for many years. It is estimated to be the cause of more than 20% of coal mine fires in the U.S. (Timko & Derick 1995). Some of these fires continue for a long time and result in the loss of large amounts of coal. Besides causing the waste of valuable coal, such fires also pose a danger to life. From a safety point of view, even a small incident of spontaneous combustion can take a heavy toll in terms of injuries and fatalities to mine personnel, and expenses incurred in attempting to extinguish the fire.

Depending on the characteristics of the coal seam and the ventilation conditions, self-heating of coal can start at temperatures as low as 35 °C. If the heat is not removed it will increase the coal temperature, leading to ignition and fire. Adequate ventilation is the primary control method used to prevent fires and explosions in underground coal mines. Another control method is pressure balancing. Pressure balancing is a ventilation technique used mainly to neutralize the pressure differences around and across caved areas. If these differences are reduced to zero, then there would be no leakage of air through the stoppings and seals, thus there would be no oxygen to start and sustain the self-heating of coal.

Pressure balancing has been used in many coal mining countries, but not in the US coal mines. Australia, the United Kingdom, South Africa, India, and some European countries have been utilizing this technique to combat as well as to prevent fires in underground mines for many years (Ray 2007, Chalmers 2008, and Grubb 2008). Except for a few passive pressure balancing cases, this technique has not been used within the United States (Smith & Lazzara 1987, and Bessinger et al. 2005). Pressure chambers are not used in the US coal mines because of the need to inspect the gob isolation seals on regular bases. This practice, would require a special chamber design to comply with MSHA regulations.