*Creative Economics and New Business Management Approaches*
*Volume 9, Issue 1, May 2026, PP 101-115*
*www.bmjournal.ir ISSN: 3060-5962*

# Technical and Economic Evaluation of the Charavimaq Lead and Zinc Mine to Determine the Ultimate Pit Limit

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***Abstract:*** *Technical and economic evaluation alongside the determination of the ultimate pit limit is fundamental in open-pit mine planning to maximize profitability while adhering to operational constraints. This research conducts a comprehensive technical and economic assessment of the Charavimaq lead and zinc mine in Iran to identify the optimal extraction boundary and production schedule. A three-dimensional geological block model of the deposit was constructed using Datamine software based on exploratory drill hole data, lithology, and element grades. Subsequently, GEOVIA Whittle software, utilizing the Lerchs-Grossmann optimization algorithm, was employed to generate nested pits and determine the economically optimal ultimate pit limit. The strategic evaluation revealed that the selected optimal pit, characterized by a specific stripping ratio and operational lifespan, yields a highly positive Net Present Value and a robust Internal Rate of Return, confirming the project's financial viability. Furthermore, a comprehensive sensitivity analysis demonstrated that the project's economic sustainability is most vulnerable to fluctuations in the global price of zinc and mining operational costs. The integration of advanced block modeling with dynamic economic optimization provides a reliable framework for risk mitigation and strategic decision-making in similar small-scale, polymetallic open-pit mining operations.*

***Keywords:*** *Ultimate pit limit, pit optimization, Geovia Whittle, technical-economic evaluation, Lead and Zinc.*

## I. Introduction

One of Because open-pit mineral extraction requires substantial capital investment and extensive operational timeframes, the continuous design and optimization of these operations are of paramount importance to secure financial viability. The ultimate pit limit is fundamentally defined as the spatial boundary where a specific economic parameter, typically the overall profit, is maximized and optimized under a given set of constraints. The gradual depletion of high-grade near-surface reserves, inherently increasing stripping ratios over time, and highly volatile global economic conditions have rendered financial analyses and the precise determination of ultimate extraction limits far more complex and sensitive than in the past. In contemporary mining engineering literature, the economic cut-off grade defining this boundary is characterized as a strictly dynamic variable that remains heavily dependent on fluctuating metal prices, shifting mining and processing costs, and variable metallurgical recovery rates (Ramazan & Dimitrakopoulos, 2018). Despite this academic consensus on dynamic modeling, a significant proportion of active mining operations, including the Charavimaq lead and zinc mine, continue to determine their ultimate extraction limits based on relatively static approaches that lack the inherent flexibility to adapt to rapid macroeconomic shifts.

While classical mine design methodologies are theoretically founded on rigorous economic optimization principles, they predominantly incorporate fixed economic parameters into their long-term computational models (Ataei, 2023). However, advanced studies in mineral economics explicitly demonstrate that the economic cut-off grade must be continuously revised and recalibrated in direct response to fluctuating operational costs and market prices to maintain validity (Lane, 1988; Oraei, 2002). Neglecting this crucial dynamic behavior frequently leads to the critical misclassification of economically viable reserves as waste material, thereby causing a significant and irreversible loss of natural mineral resources. Mining projects, by their very nature, are profoundly susceptible to the volatility of global metal prices and sudden changes in operational expenses. Leading authoritative references in mine management emphasize that the continuous monitoring, forecasting, and updating of operational costs are fundamental pillars of sustainable economic mine management (SME Mining Engineering Handbook, 2011). Furthermore, domestic literature strongly advocates for the mandatory integration of economic sensitivity analysis and market risk considerations in the foundational evaluation of all mining projects (Ataei & Hosseini, 2011; Kolahdoozan & Viseh, 2007). Particularly within the specific economic climate of Iran, which is characterized by notable currency exchange rate fluctuations and unpredictable inflation in basic production inputs, relying on traditional static models exposes mining projects to severe risks of unexpected unprofitability. Over the evolution of pit optimization, various algorithms such as the floating cone, modified Korobov, and two-dimensional dynamic programming have been utilized, but the Lerchs-Grossmann algorithm remains the mathematically proven standard for identifying the true three-dimensional optimum pit limit. Building upon this, the introduction of nested pits parameterized by revenue factors revolutionized strategic production planning by allowing for dynamic scenario analysis (Whittle, 1988). Recent regional studies further corroborate this, emphasizing the optimization of cut-off grades in polymetallic deposits under inflationary conditions (Azadi et al., 2021) and the critical impact of economic uncertainties on production scheduling and pushback sequencing (Mirzaei et al., 2023).

During the terminal stages of a mine's life cycle, the unavoidable combination of an escalated stripping ratio and a progressively declining average extracted ore grade invariably raises the marginal cost of production. If the operational cut-off grade is not dynamically adjusted based on current, real-time expenditures, the probability of engaging in loss-making extraction increases dramatically, threatening the entire project's financial integrity (Hustrulid & Kuchta, 2006). Therefore, relying solely on maximizing the deterministic Net Present Value without rigorously accounting for operational sustainability and sensitivity to volatile economic variables can precipitate a severe operational deadlock. Consequently, this research deliberately departs from the conventional reliance on a single, fixed cut-off grade by employing comprehensive sensitivity analysis to calculate a dynamic range of break-even cut-off grades. This adaptive approach allows the extraction boundaries to be continuously redefined across various optimistic, most likely, and pessimistic cost scenarios, systematically preventing unprofitable mining during the critical final phases. The fundamental inquiry of this research revolves around designing the economic boundary and extraction sequence in a manner that secures maximum economic value while simultaneously guaranteeing operational resilience against unforeseen cost escalations and market volatility. The primary objective is the precise evaluation of technical and economic parameters to determine the ultimate pit limit at the Charavimaq mine, aiming to maximize project profitability and formulate an optimal production scheduling pattern for a sustainable, risk-averse extraction plan. It is hypothesized that computational optimization using advanced Lerchs-Grossmann algorithms will successfully identify segments of the deposit that traditional methods erroneously deem uneconomic, and that utilizing an adaptive pushback strategy will yield significantly greater production stability than conventional, purely profit-centric paradigms. Furthermore, this study asserts that global metal price fluctuations and domestic inflation substantially impact the break-even boundaries, absolutely necessitating a dynamic re-evaluation of the cut-off grade throughout the mine's lifespan to neutralize the adverse effects of rising production costs.

## II. Theoretical Background and Methodology

In the feasibility studies of mining operations, comprehensive technical and economic evaluation stands as one of the most critical stages for informed investment decision-making. This rigorous assessment aims to determine the extractability of the reserve, select the optimal exploitation method, accurately estimate associated revenues and operational expenditures, and ultimately measure the overarching profitability of the project. Particularly in metalliferous deposits such as lead and zinc, global metal price fluctuations, grade variability, complex geological and geotechnical conditions, and stringent environmental constraints act as decisive factors in determining economic viability. Historically, the determination of ultimate pit limits was performed manually using laborious heuristic methods. However, the paradigm has shifted entirely toward advanced computational algorithms because traditional techniques, relying heavily on subjective designer experience, are inadequate for modern complex requirements. The geometric size and shape of the ultimate pit limit are critical for long-term strategic production planning, determining accessible extractable reserves, defining necessary stripping volumes, and designating locations for waste dumps and processing facilities (Osanloo, 2005). Effective production planning mathematically dictates the exact spatial and temporal sequence of block extraction to deliberately maximize the Net Present Value. Consequently, the strategic extraction of higher-grade ore blocks is heavily prioritized during the initial years of the project, deferring the extraction of lower-grade ores and extensive waste materials to the final stages of the mine's operational lifespan.The foundational element of modern computerized open-pit mine design is the geological block model, an encompassing three-dimensional spatial database where the mineral deposit and the surrounding host rock are discretized into regular or irregular volumetric blocks. Each discrete block contains specifically interpolated geological attributes, including spatial coordinates, lithological classification, in-situ bulk density, and estimated elemental grades derived from exploration drill holes utilizing geostatistical estimation methods. The critical transition from a strictly geological framework to a dynamic economic block model occurs when rigorous technical and economic parameters, including selling prices, mining costs, processing costs, and metallurgical recoveries, are applied to compute an intrinsic financial value for each individual block. Based on these calculated block values, which may be positive, negative, or zero, sophisticated mathematical algorithms are deployed to delineate the optimum extraction boundary. While heuristic approaches like the Floating Cone and its derivatives offer computational simplicity by sequentially generating search cones based on the required safe overall slope angles, they notoriously fail to consistently identify the true global mathematical optimum, particularly in complex ore bodies with overlapping waste extraction requirements. In profound contrast, the Lerchs-Grossmann algorithm, founded firmly on advanced graph theory and dynamic programming principles, is mathematically proven to identify the absolute optimal ultimate pit limit that maximizes total unconstrained profit, despite requiring substantially higher computational resources (Whittle, 1988).Financial valuation and strategic ranking of the defined extraction limits are conducted utilizing standard engineering economic metrics, predominantly Net Present Value and Internal Rate of Return, which critically incorporate the time value of money through an established discount rate (Fazlavi, 2012). The Net Present Value effectively measures the cumulative discounted cash flows generated over the mine's active life, precisely indicating whether the sum of discounted future revenues sufficiently exceeds the discounted capital and operational expenditures. A positive Net Present Value explicitly signifies a financially justifiable and profitable mining endeavor. The foundational mathematical expression utilized to determine the Net Present Value is established as follows:

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+i)^t}$$

In this formulation, CF represents the net cash flow generated at the end of year t, i denotes the predefined annual discount rate reflecting the opportunity cost of capital and inherent project risks, and n indicates the total expected life of the mining project in years. Furthermore, the Internal Rate of Return identifies the specific discount rate at which the Net Present Value exactly equals zero, serving as a critical benchmark that must exceed the investor's minimum attractive rate of return to validate project execution (Dehghani & Ataee-Pour, 2012). Because these deterministic valuations are highly vulnerable to prevailing economic uncertainties, rigorous sensitivity analysis acts as a mandatory diagnostic tool to systematically quantify the operational impact of deviations in key input parameters such as ore grade, processing recovery, capital investments, operating costs, and final product selling prices (Sayadi et al., 2007, Sameni Keivani, F., & Khalili Sourkouhi, Z. 2014) . By applying optimistic, pessimistic, and most likely scenarios, analysts can effectively map the resilient boundaries of the project's profitability and determine crucial break-even thresholds. The break-even point establishes the exact operational volume or sales revenue required to cover all associated fixed and variable production costs without realizing a net loss. The essential quantities for the production break-even point and the required sales revenue break-even point are rigorously calculated utilizing the following algebraic relationships:

$$Q_{BEP} = \frac{F}{P - V}$$

and

$$S_{BEP} = \frac{F}{1 - \frac{V}{P}}$$

In these specific equations, F delineates the total fixed annual costs encompassing depreciation, insurance, and fixed administrative salaries, P represents the unit selling price of the final mineral product, and V quantifies the variable operational costs directly associated with the extraction and processing of each unit of production. Incorporating these comprehensive analytical frameworks ensures that the final engineered mine design remains not only physically executable but robustly profitable across a wide spectrum of fluctuating macroeconomic environments.

## III. Geological Setting and Case Study Description

The Charavimaq coal, lead, and zinc mining district, specifically the Qezel Qaleh mine, spans an expansive area of 12.553 square kilometers and is strategically situated in the southern part of East Azerbaijan Province, adjacent to the northern border of West Azerbaijan Province in northwestern Iran. Geographically, the area is located approximately 35 kilometers south of Qara Aghaj city and is characterized by an ultra-cold regional climate, which significantly restricts the active continuous mining operational window to approximately nine months, or 225 working days, per calendar year.


Figure 1: Geographical location of the Qezel Qaleh mine in East Azerbaijan province

From a macro-structural geological perspective, historical classifications placed the study area within the Alborz-Azerbaijan tectonic zone; however, contemporary lithostratigraphic and structural re-evaluations accurately position the Qezel Qaleh exploration area within the Central Iran sedimentary-structural zone, specifically affiliating it with the Urmia-Dokhtar magmatic sub-zone. The foundational geological environment predominantly consists of Precambrian sedimentary-carbonate rock units in the southern and eastern sectors, distinctly identified as PCsb, PClk, PCsk, and PClb lithostratigraphic units. These ancient basement formations are unconformably accompanied by Cenozoic sequences dating to the Oligo-Miocene epoch, primarily represented by the Qom Formation, which sporadically manifests as purple sandstones, shales, and sandy tuffs in the eastern and northern extremities of the study boundary. A narrow band of Jurassic coal-bearing strata is exposed in the northern sector, making a tectonic contact with the older Precambrian units characterized by a pronounced reverse fault mechanism. The primary lead and zinc mineralization within the Qezel Qaleh deposit is predominantly stratabound, occurring as sulfide and severely oxidized carbonate bodies (calamine/smithsonite) hosted within intensely brecciated and fractured dolomitic limestone and cream-brown dolomites of the Kahar Formation. This mineralization manifests as distinct void-filling and fracture-filling epigenetic textures resulting from hydrothermal brecciation. Crucially for exploration and reserve estimation, the presence of intensely oxidized cream-brown dolomites exhibits substantial supergene enrichment of zinc and lead, serving as an excellent geochemical halo and a definitive pathfinder for underlying unoxidized sulfide ore bodies. Extensive laboratory measurements utilizing representative samples have conclusively determined the average specific gravity of both the run-of-mine ore and the associated waste rock to be 3.2 grams per cubic centimeter, a critical parameter for accurate volumetric tonnage conversions within the subsequent block modeling phase (Asadzade, 2026).

**Technical and Economic Modeling**

The selection of an appropriate mining method is fundamentally dictated by the spatial geometry, depth, thickness, geotechnical properties, and grade distribution of the mineral deposit. Given the near-surface manifestation of the Charavimaq lead and zinc deposit, the overall topographic profile, and the calculated optimal production capacity of 20,000 tons of ore per year over a projected five-year active lifespan, open-pit surface mining was definitively selected as the most viable and economically justifiable extraction methodology. To transition the geological model into a functional operational design, stringent geometric pit parameters were established based on the specific production scale and rock mass mechanics. Because the Qezel Qaleh mine is classified as a small-scale operation with relatively low total material movement, the operational bench height was engineered at 6 meters, facilitating adequate selectivity and accommodating the operational reach of the selected loading equipment, specifically 220-class hydraulic excavators and WA600 wheel loaders. Based on the daily extraction requirement of approximately 49 tons of ore and the necessary maneuvering clearance for 10-ton haul trucks, the minimum working bench width was fixed at 10 meters, supplemented by a 2 to 3-meter safety berm engineered to mitigate rockfall hazards. Geotechnical assessments of the medium-strength metallic ore and host rock permitted an aggressive operational bench face angle of 65 degrees, while the overall final pit slope angle was conservatively designed at 45 degrees in all azimuths to ensure long-term global wall stability. The main haulage ramps were designed with a standard width of 10 meters to safely accommodate two-way traffic of the specified haulage fleet, incorporating a maximum longitudinal gradient of 8 percent. Following the geometric design, the rigorous transformation of the geological block model into an economic block model required the detailed allocation of comprehensive financial metrics to every spatial unit. The total fixed capital investment for the project was robustly calculated at 125,600 million Rials, aggregating 60,000 million Rials for initial exploration studies, 1,000 million Rials for site infrastructure and administrative facilities, and 64,600 million Rials dedicated to the procurement of heavy mining machinery and essential equipment. Operational financial modeling accounted for continuous ongoing expenses, resulting in a total annual operating cost estimated at 24,269.1086 million Rials, which comprehensively covers personnel salaries, consumable materials, fuel and lubricants, machinery maintenance, and contracted drill-and-blast operations. Furthermore, a strict governmental royalty equivalent to 15 percent of the run-of-mine sales value was mathematically integrated into the economic constraint matrix. These highly specific techno-economic input parameters, meticulously tailored for the dynamic Lerchs-Grossmann optimization algorithm within GEOVIA Whittle software, are systematically consolidated in the subsequent table to ensure utmost computational transparency.

Table 1: Key Technical and Economic Parameters for Economic Block Model Construction

| Parameter Description | Value | Unit |
|---|---|---|
| Selling Price of Final Product | 6,200,000 | Rials per ton |

| Parameter Description | Value | Unit |
|---|---|---|
| Overall Mining Cost | 1,000,000 | Rials per ton |
| Governmental Royalty (15 percent of price) | 930,000 | Rials per ton |
| Estimated Mining Dilution | 5 | Percent |
| Estimated Extraction Recovery | 97 | Percent |
| Applied Annual Discount Rate | 20 | Percent |

## IV. Results and Discussion

ears. To prepare the geological block model for rigorous economic optimization within GEOVIA Whittle software, the initial spatial data generated in Datamine Studio RM underwent a critical reblocking process. The foundational block model, initially designed with base dimensions of 10x10x10 meters, encapsulated a total of 84,396 blocks, comprising 69,382 waste blocks and 15,014 ore blocks. Volumetrically, this translated to a total rock mass of 66,195,070 tons, containing 64,456,520 tons of waste material and an estimated 1,738,550 tons of mineralized ore. The geostatistical evaluation of these ore blocks revealed an average lead grade of 2.3534 percent, peaking at a maximum of 4.8025 percent, alongside an average zinc grade of 0.2731 percent, which reached up to 1.1127 percent. Given that the engineered operational bench height was firmly established at 6 meters, the model was subsequently reblocked to a 6x6x6 meter XYZ dimension without subcells to ensure perfect geometric compatibility with the Whittle optimization algorithms.

Applying the Lerchs-Grossmann optimization algorithm, governed by a fixed overall slope angle of 45 degrees due to the absence of exhaustive discrete geotechnical domain data, the software generated a sequence of 18 distinct nested pits. The ultimate selection of the optimal pit from this generated sequence required a careful balancing of maximum Net Present Value, an acceptable stripping ratio, and strict adherence to the predefined annual production capacity target of 20,000 tons of ore over a 5-year operational lifespan.

Consequently, Pit Number 8, corresponding to a revenue factor of 0.245, was definitively selected as the optimal extraction boundary. This highly optimized pit encompasses a total rock inventory of 284,774 tons, which includes 159,805 tons of economically viable ore and 124,969 tons of waste, resulting in an exceptionally favorable average stripping ratio of 0.78 tons of waste per ton of ore.

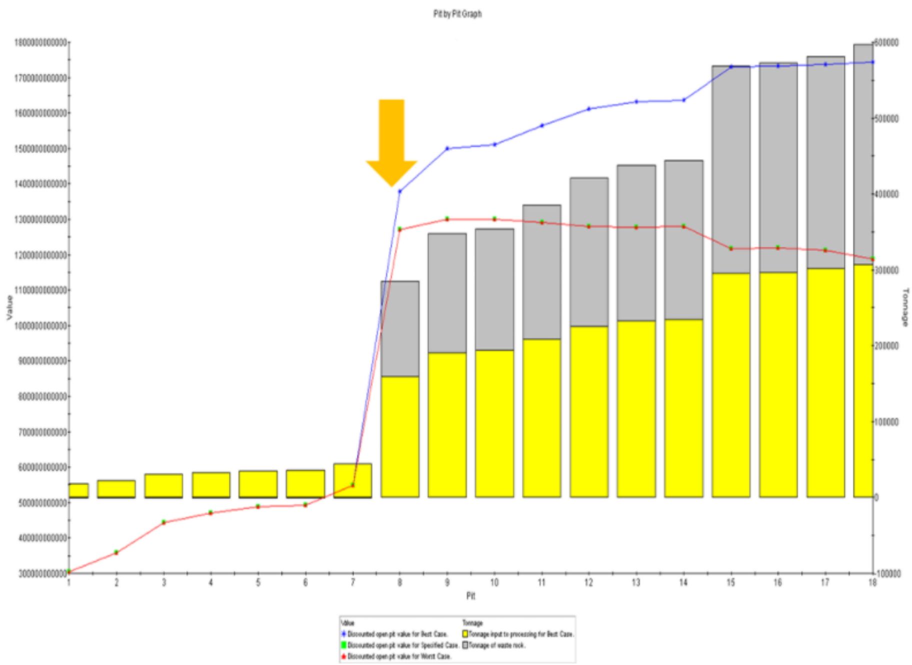


Figure 2: Figure 2: Discounted economic value of nested pits and selection of optimal Pit 8

Within this specific boundary, the average grades were calculated at 3.113 percent for lead and 0.328 percent for zinc, theoretically yielding 4,974 tons of refined lead metal and 524 tons of zinc metal.

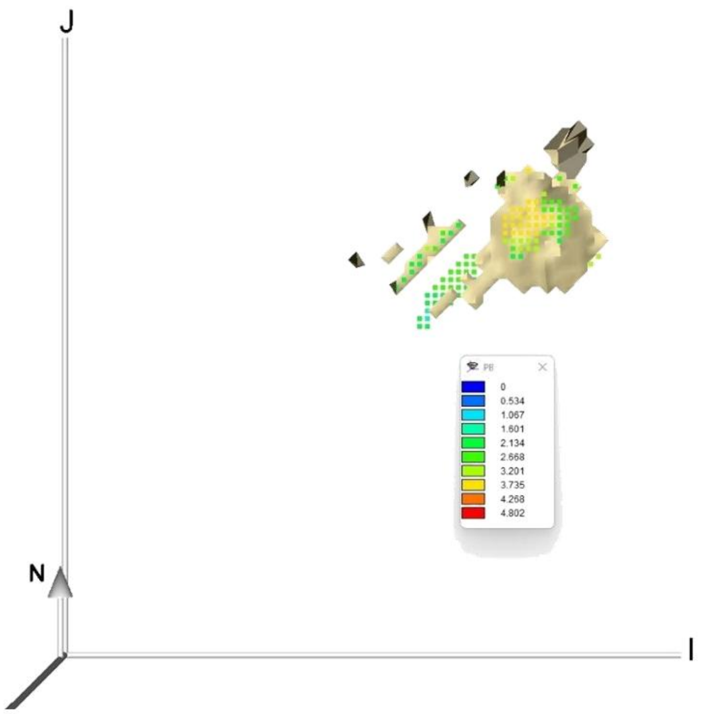


Figure 3: Three-dimensional schematic view of the economic ore encapsulated within the optimal pit boundary

Following the geometric definition of Pit 8, strategic long-term production scheduling was executed utilizing the Milawa-Balanced algorithm, targeting a combined annual material movement (ore plus waste) of 50,000 tons. This advanced scheduling demonstrated a systematically decreasing stripping ratio as the mine progresses; initial periods require higher waste removal to expose the orebody, but subsequent years benefit from enhanced ore accessibility, dropping the stripping ratio from 3.25 in the second year to a mere 0.02 in the final operational year, thereby drastically improving cash flow dynamics in the terminal phases of the project.

| | Rock | Ore | Waste | Strip ratio | PB | ZN |
|---|---|---|---|---|---|---|
| Period | tonne | tonne | tonne | t/t | % | % |
| 1 | 49,769 | 27,365 | 22,404 | 0.82 | 3.143 | 0.209 |
| 2 | 49,610 | 11,672 | 37,938 | 3.25 | 2.855 | 0.376 |
| 3 | 49,702 | 20,790 | 28,912 | 1.39 | 3.037 | 0.325 |
| 4 | 49,735 | 23,964 | 25,771 | 1.08 | 3.158 | 0.309 |
| 5 | 49,904 | 40,597 | 9,307 | 0.23 | 3.159 | 0.369 |
| 6 | 36,053 | 35,417 | 636 | 0.02 | 3.135 | 0.370 |
| Total | 284,774 | 159,805 | 124,969 | 0.78 | 3.113 | 0.328 |

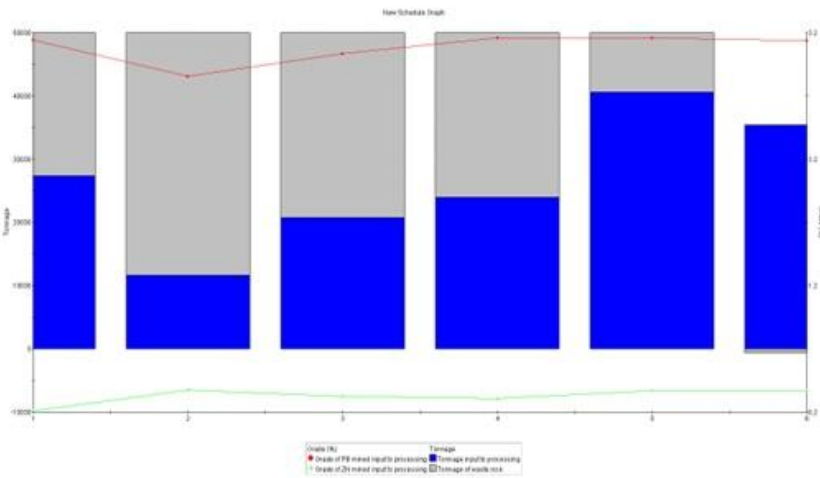

Figure 4: Annual extraction statistics and strategic production scheduling derived from the optimal pit.

Because mining projects are inherently susceptible to volatile market forces, a comprehensive sensitivity analysis was conducted on the optimized Pit 8 to ascertain the project's financial resilience against adverse economic shifts. This analysis meticulously evaluated the impact of +/- 10 percent fluctuations in primary economic drivers, specifically the overall mining costs and the final product selling price, on the total extractable economic tonnage and the stripping ratio.

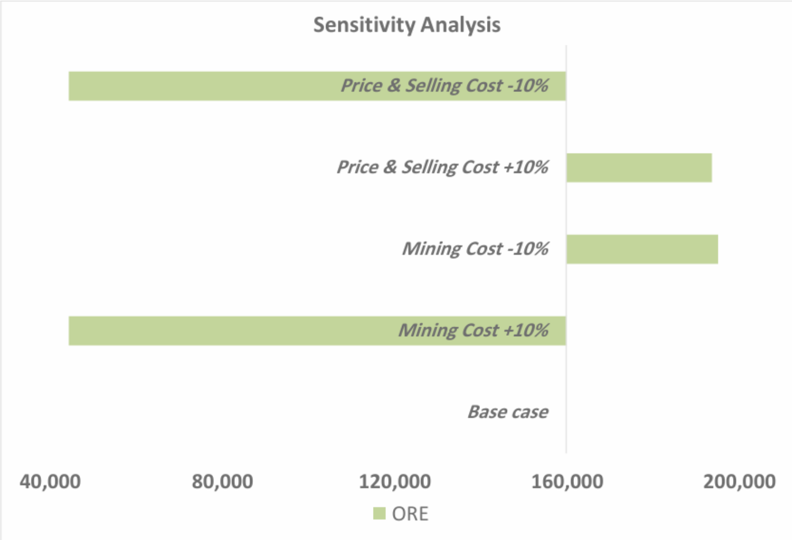


Figure 5: Dynamic changes in economically viable ore tonnage within the optimal pit relative to analyzed financial parameters.

As illustrated in Figure 5, the empirical results unequivocally demonstrated that a 10 percent increase in mining costs, or a 10 percent decrease in the selling price, severely constricts the economic boundary, causing a drastic 72 percent reduction in economically extractable ore and entirely eliminating waste stripping (reducing it by 100 percent), essentially rendering the original Pit 8 configuration financially unviable. Conversely, a 10 percent decrease in mining costs or a 10 percent increase in selling prices expanded the economic envelope, increasing the viable ore tonnage by 21 to 22 percent and the waste tonnage by 28 to 30 percent, thereby moderately increasing the stripping ratio to 0.83 while substantially boosting overall profitability. Financial projections aggregated over the life of the mine, considering an average annual gross income of 124,000 million Rials against annual operating costs of 24,269 million Rials, depreciation of 17,478.8 million Rials, and average annual taxation of 13,269.8 million Rials, confirmed the robust economic health of the operation. The finalized discounted cash flow analysis, applying a minimum attractive rate of return (MARR) of 25 percent, yielded a highly positive Net Present Value (NPV) of 14,947.7 million Rials, an Internal Rate of Return (IRR) of 30.7 percent, and a rapid capital payback period of just 3.3 years.

Table 2: Results of Sensitivity Analysis on the Optimal Pit (Pit 8)

| Parameter | Base Case | Mining Cost +10% | Mining Cost -10% | Price & Selling Cost +10% | Price & Selling Cost -10% |
|---|---|---|---|---|---|
| Revenue Factor | 0.245 | 0.245 | 0.245 | 0.245 | 0.245 |
| Total Rock (tons) | 284,774 | 44,351 | 357,350 | 353,894 | 44,351 |
| Total Ore (tons) | 159,805 | 44,351 | 195,004 | 193,596 | 44,351 |
| Total Waste (tons) | 124,969 | 0 | 162,346 | 160,298 | 0 |
| Stripping Ratio | 0.78 | 0.00 | 0.83 | 0.83 | 0.00 |
| Ore Change (%) | 0 | -72 | 22 | 21 | -72 |
| Waste Change (%) | 0 | -100 | 30 | 28 | -100 |

## V. Conclusion and Recommendations

The primary objective of this exhaustive research was the rigorous technical and economic evaluation of the Charavimaq lead and zinc mine to accurately delineate the ultimate extraction limit and formulate a highly viable exploitation strategy. The sequential integration of Datamine for precise spatial block modeling and GEOVIA Whittle utilizing the Lerchs-Grossmann algorithm for economic boundary optimization proved to be an exceptionally reliable and robust methodological framework for open-pit mine design. From the extensive array of 18 nested pits generated, Pit 8 was definitively identified as the absolute optimum, encapsulating approximately 160,000 tons of high-grade ore with an average lead concentration of 3.11 percent and zinc concentration of 0.33 percent. The operation's remarkably low average stripping ratio of 0.78, combined with a strategically balanced 6-year production schedule characterized by progressively declining waste removal requirements, ensures highly favorable cash flow dynamics throughout the terminal phases of the project. The definitive economic viability of the Charavimaq mine is mathematically substantiated by the exceedingly positive Net Present Value of 14,947.7 million Rials, and an Internal Rate of Return of 30.7 percent, which comfortably exceeds the stringent 25 percent minimum attractive rate of return threshold. Furthermore, the accelerated payback period of 3.3 years severely mitigates long-term capital exposure, categorizing the investment as highly acceptable and profitable from a stringent financial perspective. However, the advanced sensitivity analysis starkly highlighted that the project's sustained profitability remains hyper-dependent on global zinc price stability and the strict containment of operational mining costs. Any unforeseen escalation in extraction expenses or a sustained drop in metal market prices will critically contract the economic pit boundary, thereby drastically reducing the total extractable reserves. Consequently, it is imperative to implement stringent cost-control mechanisms and continuous market monitoring protocols. Moving forward, it is highly recommended that the ultimate pit limit and all foundational economic parameters be subjected to periodic dynamic revisions aligned with real-time macroeconomic indicators. Future feasibility studies must actively incorporate dynamic cut-off grade calculations to allow seamless adaptation of the economic boundaries under volatile inflationary environments. To further mitigate investment risk, subsequent analyses should integrate advanced probabilistic risk assessment techniques, such as Monte Carlo simulations, alongside comprehensive environmental impact assessments to guarantee that future expansions strictly adhere to the fundamental principles of sustainable mining development.

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