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Research Article

Net Present Value Optimization Approach for Nickel Laterite Open Pit Mines at Southeast Sulawesi, Indonesia

Bayu S.P. Soemarsoem*, Rini Novrianti Sutardjo Tui, Aryanti Virtanti Anas
Department of Mining Engineering, Hasanuddin University, South Sulawesi, Indonesia
**Corresponding author:* rini@eng.unhas.ac.id

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ABSTRACT

Introduction: The optimization of the mine boundary is crucial for maximizing profitability in open-pit mining operations. This study focuses on determining the optimal mine boundary for PT Makmur Lestari Primatama (MLP) in Southeast Sulawesi, Indonesia, using a Discounted Cash Flow (DCF) analysis to maximize the Net Present Value (NPV). The analysis incorporates the economic factors affecting mining, such as ore tonnage, nickel grade, market prices, and mining costs.

Objectives: The primary objective of this study is to determine the most economically viable pit design for MLP's nickel laterite mining project by utilizing the Lerch-Grossmann pit optimization algorithm. Additionally, the study aims to assess the sensitivity of the project's viability to fluctuations in ore prices and mining costs through a detailed sensitivity analysis.

Methods: This research employs the Lerch-Grossmann pit optimization algorithm to generate multiple pit designs and calculate their respective NPVs. An economic model incorporates key parameters, including ore tonnage, nickel grade, market prices, and mining costs. A spreadsheet-based NPV model is used to conduct sensitivity analysis, assessing the impact of varying ore prices and mining costs on the project's financial performance.

Results: The results demonstrate that pit OPT_07 remains economically viable, even under fluctuating market conditions, with variations of up to 30% in ore prices and mining costs. This analysis highlights the robustness of the selected pit design in managing market uncertainties, emphasizing its economic sustainability in the face of external financial fluctuations.

Conclusions: The NPV-based optimization approach significantly contributes to enhancing the economic sustainability of nickel laterite mining. The study introduces a novel method to optimize mining operations by combining the Lerch-Grossmann algorithm with NPV-based economic modeling and sensitivity analysis. This approach not only maximizes profitability but also assists in managing financial risks associated with market fluctuations. The methodology can be applied to other nickel laterite mines, offering valuable insights for strategic decision-making in mine planning and enhancing overall profitability and risk management.

Keywords: Nickel Laterite, Optimization, Lerch-Grossmann, Discounted Cash Flow, Net Present Value

INTRODUCTION

Nickel is one of the most critical metals in the global economy, primarily used in the production of stainless steel, batteries, and other industrial applications [1-4]. The two biggest contributors to the growing demand for nickel are electric vehicles and lithium-ion batteries. This has led to the important recovery of nickel from laterite ores [4], [5]. Nickel laterite deposits, which are the primary source of global nickel production, are found in tropical regions. While these deposits are rich in nickel, they also have unique extraction challenges [1], [2], [4]. The extraction of these ores through open pit mining requires careful planning and optimization to ensure economic feasibility and environmental sustainability [6], [7].

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PT Makmur Lestari Primatama (MLP), located in North Konawe, Southeast Sulawesi, Indonesia, is one such company engaged in the mining of nickel from laterite deposits. The location of PT MLP's concession area is shown in ***Figure 1. Location map of MLP concession area*** This region has abundant nickel laterite resources, however, the mining sector faces several challenges, including fluctuations in global nickel prices, environmental concern, and the efficiency of resource management [6]. Modern mining techniques such as open pit extraction are widely used to mine laterite deposit, making pit optimization a key factor to ensure both profitability and sustainability [6], [8].

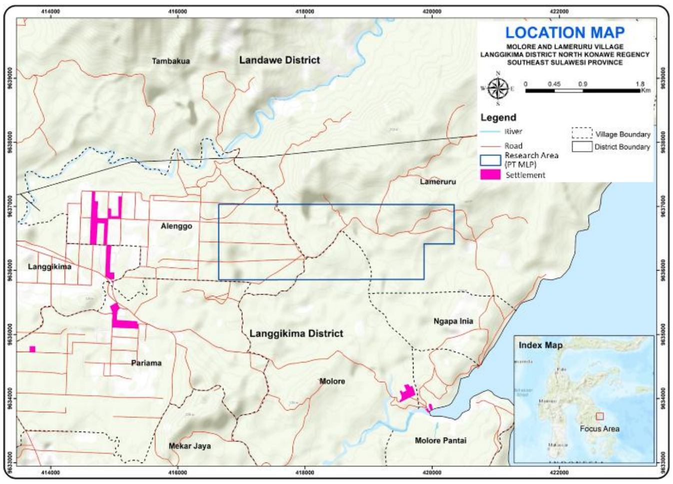

Figure 1. Location map of MLP concession area

One of the critical components in the extraction of laterite nickel ores is optimizing pit design [7], [9]. The complex distribution of grades within nickel laterite deposits makes defining pit limits a challenging task. There are two main approaches to pit limits determination that will be used in this study:

1. Maximize undiscounted profits, where revenues are computed without discounting for the time value of money, which will be done by applying the Lerch-Grossmann (LG) Method.
2. Optimizing Net Present Value (NPV) which will uses the results of LG Method and calculate considering revenues and costs over time adjusted to their time value of money [10], [11].

The NPV usually needs to be maximized to determining optimal pit shell and extraction schedule [7], [11], [12]. Mining companies rely on NPV Optimization as a means of determining the optimal pit design and extraction schedule against a revenue stream that varies with ore grades, costs, and commodity price fluctuations. This approach offers a more accurate estimation of long-term profitability compared to maximizing undiscounted profits [6].

The purpose of this paper is to analyze an NPV-based optimization strategy for open pit mining operations at PT Makmur Lestari Primatama. The study aims to maximize mine profitability by addressing key factors such as ore quality, transportation costs and market fluctuations. Using pit optimization algorithms, the research evaluates extraction schedules, pit design and haulage strategies to maximize long-term financial returns. In this way NPV as a decision-making tool, this study provides valuable insight into economically sustainable nickel laterite mining, not only for PT Makmur Lestari Primatama but also for similar operations across Sulawesi, Southeast Asia and other tropical mining regions.

This paper offers a comprehensive overview of the NPV optimization process by considering the geological data, operating costs and economic factors to develop an optimal mining strategy. It highlights the significance of financial optimization in modern mining and demonstrates how resource management can be enhanced to maximize profitability while ensuring environmental sustainability.

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METHODS

The distribution of laterite nickel ore is geographically constrained due to their geological formation and the availability of drilling data, particularly the spacing of drill holes. This study focuses on measured and indicated resource zones, which are classified as nickel ore, while inferred zone is considered waste. The classification for nickel ore is based on economic cut-off grades (COG), with 1.1% Ni for limonite ore and higher cut-off grade of 1.5% Ni for saprolite ore.

The selling price is based on London Metal Exchange (LME) market rate, set at $18,000 per ton. This price is converted using the Harga Patokan Mineral (HPM) formula, which adjusts the LME nickel price for ore valuation. In compliance with Indonesia government regulations, the HPM calculation is required for economics feasibility of laterite nickel mining in the country.

This study conducts detailed cost analysis, by using direct and indirect cost to provide a comprehensive evaluation of financial viability [13]. Direct costs include waste removal, ore getting and hauling to stockpile, and shipping cost. Indirect costs cover mine reclamation and general administration cost (Table 1). All cost estimates are adapted from the mining company calculations, with necessary adaptations for this study.

To determine the optimal pit shell, the Lerch-Grossman (LG) algorithm was applied for pit optimization [14], [15]. This approach generates multiple nested pit shells, each representing different economic scenarios based on fluctuating revenue and costs [15], [16]. These pit shells help identify the most economically viable pit shell and also show pattern in mine planning. By analyzing the pit shells, it is possible to determine the economically optimized pit shell, considering its geological characteristic and fluctuating market conditions. The final optimum pit shell is the one that has higher Net Present Value (NPV), ensuring both financial stability and long-term operational sustainability throughout the life of mine [7], [17].

The procedures for determining the pit optimization parameters listed in Table 1 are based on the LG method. These parameters guide the economic evaluation of different pit shells by factoring in ore prices and mining costs. Through maximizing key economic variables, this method will ensure the most profitable pit shell for extraction, making a balance between ore extracted and profitability. This is shown by the maximum NPV values associated with each pit shell as a key indicator of economic viability.

Table 1. Pit optimization parameters

Parameter	**Value**
Mining Recovery	95%
Ore Dilution for %Ni	2%
Ore Moisture Content	35%
Overall Slope	45°
Model Block Size (x,y,z)	12.5 m x 12.5 m x 1 m
Ore Price	
LME Nickel Price	18.000 $/t
Limonite Ore Grade	1.12% Ni
Limonite Ore Price	16.02 $/wmt
Saprolite Ore Grade	1.59% Ni

Saprolite Ore Price	31.6	$/wmt
Mining Cost		
Direct Mining Cost		
- Waste Removal Cost	2.0	$/bcm
- Ore Getting & Hauling Cost	4.95	$/wmt
- Ore Barging (shipping cost)	1.56	$/wmt
Indirect Mining Cost		
- Mine Reclamation	0.25	$/wmt
- General and Administrative	1.24	$/wmt
Capital Cost	27.38 m$	
Ore Production		
Limonite Ore Production	1,200,000 wmt/yr	
Saprolite Ore Production	2,100,000 wmt/yr	
Total Ore Production	3,300,000 wmt/yr	

RESULTS

Technical Analysis

Pit optimization process is a fundamental process in maximizing the profitability of an open pit mine. It requires a comprehensive assessment of multiple economic and technical factors that can directly impact resource extraction. Two of the most critical aspects are the cut-off grade (COG), and the block model, which ensures that only economical materials are included in the mining plan. This provides the framework for converting mineral resources into reserves, ultimately influencing both resources extraction efficiency and financial return.

A. Optimizing The Cut-Off Grade

The cut-off grade (COG) is a crucial parameter because it will determine the economic threshold that differentiates ore from waste. This classification is determined by economic factors such as mining costs and market price fluctuations [17], [18], [19]. For nickel laterite mining, the COG is strategically determined to ensure only economically viable ore as mineable reserves.

The COG is a key concept in mineral economics. It is the first step in the conversion of mineral resources to reserves and become basis in mine planning [20]. The COG must correspond with critical economic parameters including mining cost, ore price, recovery ratio, and parameters of pit design [19], [21]. It sets the boundary between economic and uneconomic material, ensuring that the ore extracted within the final pit design generates a positive return on investment. The reserve estimation converts resources into mineable reserves, which are fundamental for evaluating the financial viability of the mining operation [16], [18].

The two main ore types that are limonite and saprolite ore, have different COG, varies due to the deposit grade quality and the economic parameter such as mining cost and ore price fluctuations. The COG is used for pit optimization to determine the most profitable ore blocks to extract. Table 2 presents the determination of COG for each ore type.

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Table 2. Resources in pit optimization process

Ore Type	Cut-off Grade	Wet Tonnes (Million)	Ni (%)	Co (%)	Fe (%)
Limonite	Ni ≥ 1.0	11.39	1.12	0.11	42.43
Saprolite	Ni ≥ 0.9	19.31	1.56	0.03	16.17
Total		**30.71**	**1.40**	**0.06**	**25.91**

B. Modification of block model for pit optimization

To enhance the accuracy of pit optimization, the block model is adjusted by applying attribute at measured and indicated resource classification, which describe the data confidence level, ensuring that only economically viable material is included in the pit optimization process. Figure 2. Resource classification limitations in the modelillustrates that only measured and indicated zones will be considered for the pit optimization process.

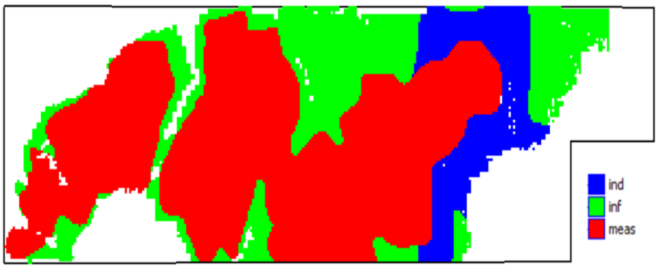

Figure 2. Resource classification limitations in the model

Blok outside the measured and indicated zones (inferred zone) are considered waste and assigned a 0% Ni grade. All this data is fed into pit optimization process to ensure that only economic blocks are used, avoid the inclusion of waste material (dilution) and would inflate the resource and negatively impact the pit design and reserve estimation.

Lerch-Grossman (LG) algorithm is used to generate practical pit layout (pit shell) by ignoring waste and utilizing only economic ore blocks. By utilizing this methodology, ore blocks with higher grades are prioritized while ensuring all blocks with a positive financial will be mined.

By applying this methodology, it underlies all the resource-to-reserve conversions and project viability. It ensures that the optimum pit shell only includes blocks that have positive economics which ultimately improves the profitability and sustainability of the mining operation.

With this method, PT MLP can optimize the mining operation, minimize waste extraction, and increase project profitability, leading to a more efficient and profitable mining operation.

Pit optimization analysis

Pit optimization generates multiple pit shells corresponding to different ore price scenarios, ranging from low to high input prices [10], [22]. This approach allows detailed analysis at each pit shell, thereby providing essential information on how market fluctuations impact the mine economics. By analyzing these scenarios, the optimal pit shell can be identified to provide economic viability at different mining costs and ore prices. Figure 3 shows the pit shell optimization at different pricing scenarios with the progressive development of pit shells throughout the optimization process, with OPT_01 being the smallest and OPT_11 the largest. This expansion reveals how parameters in the optimization process, such as ore prices and mining costs, affect the extent of the pits shell. First,

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at OPT_01, the pits are smaller, covering only the richest ore zones. As optimization progresses to OPT_11, the pits shell expands to include more ore zones as long as they remain economic.

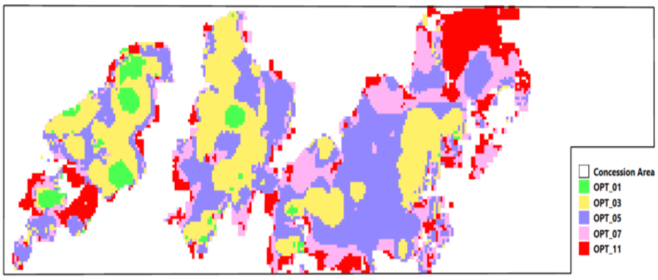

Figure 3. Pit shell result of pit optimization process

The transition from smaller to larger pit shells demonstrate how economic factors - such as higher nickel prices or lower operating costs - can make previously uneconomical ore bodies into economic. Larger pit shells allow for increased tonnage and higher ore recovery. However, this also leads to higher stripping ratios and operational challenges, which must be carefully managed to maintain profitability.

Lerch-Grossman (LG) method is non-discounted cash flow approach, meaning it calculates gross profit for each pit shell without considering for the time value of money. To enhance this analysis, the gross profit is calculated in a spreadsheet for NPV calculations. The NPV analysis is essential in evaluating the economic viability of each pit shell, by considering operating costs and ore prices.

Financial and sensitivity analysis

The pit optimization process generates a series of pit shells and then analyzed using NPV for each ore type (limonite and saprolite) under varying market conditions. The key parameters are ore tonnage, grade, and waste material are calculated for each pit shell. The NPV is the primary criteria for selecting the most optimal pit design. The pit shell with the highest NPV is the most favorable as it maximizes the economic return for the mining operation [17], [23].

The results of the pit optimization process are shown in Table 3 providing the NPV of each pit shell as well as the ore grades, tonnage, waste material and the SR (strip ratio). Further pit shell information shown separately in Table 4 such as life of mine (LOM) for limonite and saprolite, incremental changes in NPV, ore, waste and conversion factor for resource-to-reserve.

As shown in Figure 4, the NPV follows through the various optimization stages (OPT_01 to OPT_11), shown as blue line. Initially, the NPV increased consistently until it reached its peak at OPT_07, representing the best economic pit shell. Beyond OPT_07, the NPV trend is almost flat and showing decreasing economic return from further pit expansion.

The Optimum Pit Shell (OPT_07) is projected over 9 years mine life is shown in

Table 5. The table shows data such as mining production, mining cost, mining sale and operating profit for waste, limonite and saprolite materials. The total NPV on Optimum Pit Shell (OPT_07) is $195.82 million, showing the most financially viable pit shell. The table also shows the quantities of limonite and saprolite ore, along with associated the costs and revenues associated, as well as the economic feasibility over life of mine.

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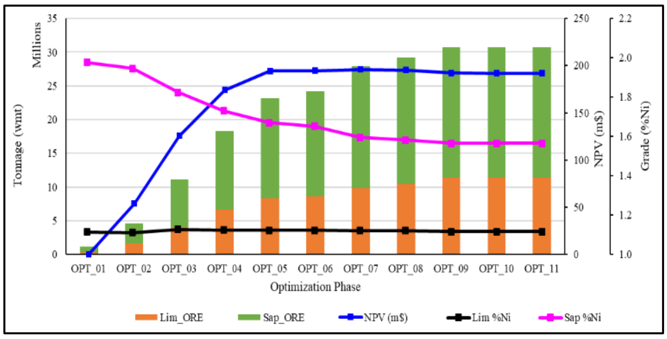

Figure 4. Optimization results of the relationship between NPV and ore tonnage

Table 3. NPV calculation based on pit shells

OPT	NPV (Million $)	Limonite Wet Tonnes (Million)	Limonite Ni (%)	Saprolite Wet Tonnes (Million)	Saprolite Ni (%)	Total Ore Wet Tonnes (Million)	Total Ore Ni (%)	Waste (Million bcm)	Stripping Ratio (SR)
OPT_01	0.28	0.35	1.11	0.85	1.98	1.20	1.73	0.35	0.30
OPT_02	53.90	1.61	1.11	2.98	1.94	4.59	1.65	1.29	0.28
OPT_03	125.50	4.02	1.13	7.08	1.82	11.10	1.57	3.27	0.29
OPT_04	174.07	6.64	1.12	11.59	1.73	18.24	1.51	6.00	0.33
OPT_05	194.27	8.37	1.12	14.81	1.67	23.18	1.47	8.44	0.36
OPT_06	194.70	8.67	1.12	15.53	1.65	24.20	1.46	8.93	0.37
OPT_07	195.82	9.87	1.12	18.11	1.59	27.98	1.43	11.53	0.41
OPT_08	195.33	10.47	1.12	18.71	1.58	29.18	1.42	12.62	0.43
OPT_09	192.11	11.35	1.12	19.31	1.56	30.66	1.40	14.37	0.47
OPT_10	191.99	11.38	1.12	19.31	1.56	30.70	1.40	14.45	0.47
OPT_11	191.94	11.39	1.12	19.31	1.56	30.71	1.40	14.49	0.47

Table 4. Pit shells information in optimum pit studies

OPT	LOM Limonite (year)	LOM Saprolite (year)	Inc. NPV (m.$)	Inc. Ore (m.wmt)	Inc. Waste (m.bcm)	Inc. SR	Conversion Factor
OPT_01	0.29	0.40	0.28	1.20	0.35	0.30	0.04
OPT_02	1.34	1.42	53.62	3.39	0.94	0.28	0.15
OPT_03	3.35	3.37	71.60	6.52	1.99	0.30	0.36
OPT_04	5.54	5.52	48.58	7.13	2.72	0.38	0.59
OPT_05	6.97	7.05	20.20	4.95	2.44	0.49	0.75
OPT_06	7.22	7.39	0.43	1.01	0.49	0.49	0.79

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OPT	LOM Limonite (year)	LOM Saprolite (year)	Inc. NPV (m.$)	Inc. Ore (m.wmt)	Inc. Waste (m.bcm)	Inc. SR	Conversion Factor
OPT_07	8.23	8.62	1.13	3.78	2.60	0.69	0.91
OPT_08	8.73	8.91	-0.49	1.20	1.08	0.90	0.95
OPT_09	9.46	9.20	-3.22	1.48	1.75	1.18	1.00
OPT_10	9.49	9.20	-0.12	0.04	0.09	2.50	1.00
OPT_11	9.50	9.20	-0.05	0.01	0.04	3.87	1.00

Table 5. DCV and NPV calculation on Optimum Pit Shells

OPT_07												
DESCRIPTION	**UNIT**	**TOTAL**	**YEAR**									
			0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
ORE PRODUCTION												
Limonite	m.wmt	9.87		1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	0.27
Saprolite	m.wmt	18.11		22.10	22.10	22.10	22.10	22.10	22.10	22.10	22.10	1.31
Waste	m.bcm	11.53		1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	0.65
MINING COST												
Inflation (2.5% / yr)	%											
Ore Mining	m$	252.19		27.06	7.74	8.43	9.14	9.87	0.62	1.38	2.17	5.79
Royalti	m$	82.35		8.77	8.99	9.22	9.45	9.68	9.93	10.17	10.43	5.71
Waste Removal	m$	25.98		2.79	2.86	2.93	3.00	3.08	3.15	3.23	3.31	1.63
TOTAL MINING COST	**m$**	**360.51**		**38.62**	**39.59**	**40.58**	**41.59**	**42.63**	**43.70**	**44.79**	**45.91**	**23.12**
ORE SALES												
Limonite Sales	m$	158.11		19.22	9.22	9.22	9.22	9.22	9.22	9.22	9.22	4.33
Saprolite Sales	m$	572.28		66.36	66.36	66.36	66.36	66.36	66.36	66.36	66.36	41.38
TOTAL SALES	**m$**	**730.39**		**85.58**	**85.58**	**85.58**	**85.58**	**85.58**	**85.58**	**85.58**	**85.58**	**45.72**

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DISCOUNTED CASH FLOW											
(+) Sales Revenue	730.39		85.58	85.58	85.58	85.58	85.58	85.58	85.58	85.58	45.72
(-) Mining Cost	(360.51)		-38.6	-39.6	-40.6	-41.6	-42.6	-43.7	-44.8	-45.9	-23.1
Operating Margin (EBITDA)	**369.88**		**46.96**	**46.00**	**45.01**	**43.99**	**42.96**	**41.89**	**40.80**	**39.68**	**22.59**
(-) D & A	(27.38)		-5.48	-5.48	-5.48	-5.48	-5.48				
Profit Before Tax (EBIT)	**342.50**		**41.49**	**40.52**	**39.53**	**38.52**	**37.48**	**41.89**	**40.80**	**39.68**	**22.59**
(-) Corporate Tax (22%)	(75.35)		-9.13	-8.92	-8.70	-8.47	-8.25	-9.22	-8.98	-8.73	-4.97
Profit After Tax	**267.15**		**32.36**	**31.61**	**30.84**	**30.04**	**29.23**	**32.67**	**31.82**	**30.95**	**17.62**
(+) D & A	27.38		5.48	5.48	5.48	5.48	5.48				
(-) Capex	(27.38)	(27.38)									
(-/+) Working Capital	-	(9.66)	-0.24	-0.25	-0.25	-0.26	-0.27	-0.27	-0.28	5.70	5.78
Net Cash Flow	**267.15**	**(37.04)**	**37.60**	**36.84**	**36.06**	**35.26**	**34.44**	**32.40**	**31.54**	**36.64**	**23.40**

DISCOUNT RATE		**6%**
NPV	**m$**	**195.82**
IRR		**99%**

Table **6** shows sensitivity analysis for optimum pit shells under various nickel price and mining costs scenarios. The table shows how different range about ± 20% of nickel prices from $14,400/t to $21,600/t and mining cost from $6.4/wmt to $9.6/wmt impact both NPV and the optimum pit shell.

Impact of nickel price on NPV and Optimum pit shell selection as follows:

- As nickel prices increase, the NPV will raise and shift the optimal pit shell from OPT_06 to OPT_08.
- At a lower price of 14.400 $/t the optimal pit shell is OPT_06.
- At a higher price of 21,600 $/t the optimal pit shell shift to OPT_08, accommodating a larger area of pit shell

Impact of mining cost on NPV and Pit Shel selection as follows:

- As mining cost increases, the NPV declines, affecting the optimal pit shell.
- The highest NPV of $226.91 million is achieved at OPT_08 with lower mining cost at 6.4 $/t.
- While NPV will decline to $168.55 million at higher mining cost at 9.6 $/t with the optimal pit shell shifting to OPT_05, reflecting more conservative approaches.

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However, in conclusion, in the economic possibility perspective, OPT_07 is the most suitable pit shell, as it can maximize project profitability by balancing between ore tonnage and nickel grade.

Table 6. Optimising pit shell sensitivity to price and cost changes

LME Nickel Price ($/t)	NPV Optimum (m.$)	OPT	Mining Cost ($/wmt)	NPV Optimum (m.$)	OPT
14,400	122.90	OPT_05	6.4	226.91	OPT_08
15,300	140.74	OPT_05	6.8	219.01	OPT_08
16,200	158.58	OPT_05	7.2	211.12	OPT_08
17,100	176.52	OPT_06	7.6	203.43	OPT_07
18,000	195.82	OPT_07	8	195.82	OPT_07
18,900	215.12	OPT_07	8.4	188.21	OPT_07
19,800	234.59	OPT_08	8.8	181.41	OPT_05
20,700	254.22	OPT_08	9.2	174.98	OPT_05
21,600	273.84	OPT_08	9.6	168.55	OPT_05

With this analysis, we can see how the NPV and optimal pit shell selection evolves depending on mining cost variations. As mining costs increase from $6.4 to $9.6 per ton, (±20%) the NPV decreases and shifts the optimal pit shell selection. The NPV achieves its highest value using OPT_07 at $195.82 million but falls to just $122.90 million at the highest cost of $9.6/t, associated with OPT_05.

However, in conclusion, OPT_07 is considered the most economical pit shell optimizing the ore tonnage and grade for the project economics.

DISCUSSION

The pit optimization approached in this study was based on the specific characteristic of laterite nickel deposits, particularly their geological distribution and the constraints of resource classification based on drilling data. The ore was restricted to measured and indicated resources area to ensure that only economically mineable material was included in the calculation and the rest was classified as waste. The market-based definitions of ore grades were a significant role in the analysis, mostly for limonite ore with 1.1% Ni, and saprolite ore with 1.5% Ni. These grades were determined with current industry demand and market conditions, specifically in the Indonesian nickel market.

The pit optimization and its financial analysis performed in this study provides valuable information into the profitability of obtaining various pit shell for laterite nickel deposits at varying market conditions. The results show how variations in ore prices and mining costs affect the pit configuration and ultimately the project profitability.

This research applied the Lerch-Grossmann (LG) method to generate a sequence of pit shells ranging from the most conservative (OPT_01) to more expansive (OPT_11), allowing to analyze changes in economic viability based on variations in market conditions. The optimization results reveal a clear relationship between key market parameters — such as nickel prices and mining costs — and an expanding pit shell. When the price increases or operational costs decrease, additional low-margin ore becomes economically viable, leading to the selection of larger pit shells, such as OPT_07, which make an optimum the project return on investment.

The transition from OPT_01 to OPT_07 reflects broader industry trends, when commodity prices rise, lower-grade ore that would have been previously unprofitable becomes viable for extraction. However, this expansion comes with its challenges, with larger pit area lead to a higher stripping ratio, increasing infrastructure requirements, an increase

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in operational complexity, greater capital investment, and increase operational risk due to an escalating stripping ratio. The optimum pit shell (OPT_07) represents a balance between ore extraction cost and operational efficiency.

The financial analysis shows that with OPT_07 we can reach the optimum NPV at $195.82 million, which is at the maximum value of extracted ore. Beyond OPT_07, the NPV curve flattens, signaling reduced financial returns from further pit expansion. This is consistent with the basic economic law of diminishing returns, whereby the timing of extracting extra ore becomes uneconomic as operating costs increase. As a result, choosing the correct pit shell is to strategically weigh the trade-off between maximizing the ore extraction and the financial and operational risks.

The sensitivity analysis provided key insights into how affected mining projects are in relation to changes in market conditions. The nickel price is having a big impact on the NPV. Increasing nickel prices from $14,400 to $21,600 per ton leads to a major change in NPV, where the optimal pit shell shifting from OPT_05 to OPT_08. The maximum NPV obtained from the ore price of $14,400 per ton is $122.90 million, with the optimal pit at OPT_05. When the ore price increases to $21,600 per ton, the optimal pit is OPT_08 and the NPV increases to $273.84 million. This demonstrates the influence of ore prices can greatly influence the feasibility and profitability of a mining project.

On the other hand, the sensitivity analysis on mining costs indicates that there is an inverse correlation between mining costs and the NPV. When mining costs increase from $6.4/ton to $9.6/ton results in a decrease in NPV and an optimal pit shell size becoming smaller. The maximum NPV decreases from $226.91 million (OPT_08) at $6.4/ton to $168.55 million (OPT_05) at $9.6/ton. This highlights the importance of effective cost management in maintaining profitability, given that higher mining costs reduce the economic feasibility of extracting lower-grade ore and therefore lowering overall economic return. Therefore, efficient operational costs is a key factor in ensuring the feasibility and profitability of a mining project.

NPV and grade trends are further strengthened by analyzing tonnage (t), net present value (NPV) and grade through various optimization phases. The NPV curve is maximized at OPT_07, indicating that this stage represents the most profitable scenario, assuming constant prices and costs. In general, the grades of limonite and saprolite ores are relatively stable, ensuring consistent production of marketable products, tonnage varies with pit size. Despite the variations in tonnage, consistency in ore grade demonstrates the importance of optimizing pit geometry to maintain both profitability and consistent production.

Lerch-Grossman method can be used for analysis of multiple scenarios of pit optimization. These pit shells are then further evaluated using discounted cash flow (DCF) methods to determine their respective NPV. This approach allows development for integrated economics models and reliable pit designs. This study demonstrates the need for more flexible and adaptable mine planning as demonstrated through sensitivity analysis. Mining companies must continuously adjust their pit design for variations in ore prices and operational costs. These adjustments are important to frequently refreshing pit optimization models using current market data. However, commodity prices fluctuation and mining costs are uncertain, adopting dynamic optimization strategies is essential for long-term viability and profitability of mining projects.

CONCLUSION

This study utilizes NPV modeling for pit optimization with Lerch-Grossman method as a balancing tool to enhance long-term mine planning for laterite nickel deposits. The pit optimization for laterite nickel is based on measured and indicated resource classification. In Indonesia, nickel ores considered for the market are limonite ore with 1.1% Ni and saprolite ore with 1.5% Ni, with ore price referenced to the LME Price and converted using the HPM formula.

Sensitivity analysis on ore price and direct mining cost highlights the significant impact of these parameters on pit optimization and overall financial feasibility. Separate spreadsheet-based NPV models were developed to evaluate economic potential under various scenarios. The progress of pit shells, from OPT_01 to OPT_11, shows the influence of eco-nomics scenario, smaller pit shells contain higher ore grades and yield greater profitability, while larger pit shells expand to include more marginal resources as economic conditions improve.

The optimum pit, identified at OPT_07, remained economically viable across various price and cost scenarios. Pit optimization is a critical component in the long-term planning process to ensure that the final pit design maximizes resource extraction and economic returns. This approach demonstrates the importance of integrating market conditions, mining costs and advanced modeling techniques, such as Lerch-Grossman Method can sustain the financial viability of mining operations throughout the life of mine.

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