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Feasibility Study for Investment Decision in Silica Sand Mining Through Comparative Analysis of New Machine Purchase, Machine Refurbishment, and Joint Operation

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Abstract

This study evaluates the feasibility of three investment alternatives for PT Naga Mas Sulawesi in the development of silica sand mining operations: the purchase of new machinery, the refurbishment of existing machinery, and operational cooperation. The main objective is to identify investment strategies that provide the best economic value by considering the financial performance and risk profile of each alternative. The analysis was conducted using PESTEL and VRIO frameworks to assess the company's external environment and internal capabilities, as well as the Discounted Cash Flow method with Net Present Value, Profitability Index, Payback Period, and Internal Rate of Return indicators to evaluate financial feasibility. Risk assessments were conducted using a risk matrix that identifies operational, financial, regulatory, and environmental exposures. The results show that the New Machine scenario provides the highest financial performance, with an NPV of IDR 2.15 trillion, a Profitability Index of 233.23, an IRR of 71%, and a Payback Period of 1.67 years, even though it entails greater operational risks. The Machine Refurbishment scenario generates moderate profits with medium-to-high risk, while the Joint Operation scenario offers stable royalty income with low risk but no operational control. Overall, the New Machine scenario is the most optimal choice, considering financial and risk aspects. Recommendations include strengthening operational planning, cost control, preventive maintenance, regulatory compliance, and long-term contract agreements to enhance competitiveness and long-term sustainability.

INTRODUCTION

The silica sand mining industry holds a strategic and vital position in the global economy due to its wide applications across various industrial sectors. Silica sand serves as a fundamental raw material in manufacturing glass, ceramics, semiconductors, photovoltaic solar cells, water filtration systems, and numerous other high-value industrial products. Indonesia possesses abundant silica sand reserves, widely distributed across provinces such as Bangka Belitung, Aceh, North Sumatra, Riau, Riau Islands, South Sumatra, Lampung, North Kalimantan, North Sulawesi, and Southeast Sulawesi. This potential extends beyond raw material supply to opportunities for developing downstream industries that produce high-value products, such as silicon wafers.

In this national context, PT Naga Mas Sulawesi—a private mining company based in Southeast Sulawesi—plays an important role. With measured reserves of 44,106,792 tons of silica sand at a purity of 96–99 percent, the company has significant potential to increase production and expand operations. However, it currently faces strategic challenges from limited production capacity, with monthly output around 25,000 tons. Although this supports commercial operations, it falls short of meeting rapidly growing market demand. These

constraints hinder the company's ability to fully utilize its resources and strengthen its competitive position in domestic and international markets.

Overcoming these challenges requires sound investment decisions to ensure PT Naga Mas Sulawesi's sustainable growth. Investments to boost silica sand processing capacity would not only raise production rates but also enable fulfillment of contracts with larger buyers, entry into higher-value markets, and expanded revenue streams. Such decisions must rely on comprehensive, evidence-based evaluations of available options to allocate capital efficiently and maximize long-term economic value (Koller et al., 2020).

PT Naga Mas Sulawesi is evaluating three main strategic investment alternatives to expand production capacity. The first involves purchasing new machines, which promise substantial output increases, greater operational efficiency via modern technology, and lower long-term unit processing costs. However, this requires large initial capital outlays and entails financial risks from high upfront expenses. The second alternative—refurbishing existing machines—is more affordable, demanding far less capital than new equipment purchases. Refurbishments can restore reliable operation and extend machine life, enabling production gains without massive investments. Yet, they introduce uncertainties around long-term performance, ongoing maintenance, and breakdown risks. The third alternative entails forming joint operations with established silica sand processors, allowing PT Naga Mas Sulawesi to leverage partners' technical expertise, resources, and market access without bearing full investment costs.

PT Naga Mas Sulawesi faces a critical strategic dilemma in optimally allocating capital for capacity expansion amid a competitive silica sand market (Fajar et al., 2025; Indonesia, 2025). The core research problem stems from uncertainty over which pathway—new machine purchase, machine refurbishment, or joint operation—yields the highest long-term economic value at acceptable risk. This decision grows urgent due to converging factors: first, Indonesia's mineral downstreaming policy mandates greater domestic processing and value addition, creating opportunities alongside regulatory pressures; second, global demand for high-purity silica accelerates, driven by renewable energy, semiconductor growth, and construction; third, the company's 25,000-ton monthly capacity utilizes only a fraction of its 44-million-ton reserves, incurring opportunity costs and competitive disadvantages; and fourth, delays risk market share loss to rivals with superior processing (Mammadova & Agayev, 2025; Markovic et al., 2025).

This urgency intensifies given Indonesia's role in regional and global silica supply chains, where firms with high-purity reserves (96–99% SiO_2) and modern infrastructure command premium prices and long-term contracts. Without prompt, evidence-based investments, PT Naga Mas Sulawesi risks resource underutilization, stagnant revenues, and eroded competitiveness at a time when market conditions favor expansion.

Existing literature on mining investment decisions documents diverse methodological approaches for capital projects. Brigham and Ehrhardt (2020) outline foundational capital budgeting principles, emphasizing discounted cash flow (DCF) techniques as the gold standard, while Koller et al. (2020) advance valuation frameworks with risk-adjusted discount rates and scenario analysis. In mining specifically, Fajar et al. (2025) apply DCF to operational expansions, and Maulana et al. (2024) address cash flow estimation in mineral processing. Strategic assessments employ frameworks like PESTEL (Bui & Tran, 2023; Mansour & Hassan, 2024) and VRIO (Ferreira & Fernandes, 2021; Acosta & González, 2023) to evaluate external opportunities and internal capabilities.

Risk assessment methodologies have advanced notably, with Mammadova and Agayev (2025) proposing systematic operational risk evaluation in extraction, and Markovic et al. (2025) analyzing technical complexity and risk in mining. However, key research gaps remain.

First, studies often evaluate alternatives in isolation, not via comparative frameworks. Second, few integrate financial evaluation with risk assessment in emerging-market mining amid regulatory uncertainty, infrastructure limits, and volatility (What, 2023). Third, empirical evidence on trade-offs between capital-intensive modernization and low-cost refurbishment in silica processing is scarce. Fourth, partnership models like joint operations—leveraging external capabilities without direct capital outlays—are underexplored.

This study fills these gaps with a comprehensive comparative framework integrating external analysis (PESTEL), internal assessment (VRIO), financial valuation (DCF via NPV, IRR, PP, PI), and risk evaluation (multi-dimensional matrix) across three pathways. Its novelty includes: (1) an integrated framework tailored to Indonesian silica mining contexts; (2) empirical comparisons of capital-intensive, moderate-cost, and partnership models, quantifying returns and risks; (3) guidance for reserve-rich firms with capacity limits under constraints; and (4) practical insights for emerging-market miners balancing growth against capital, expertise, and uncertainty risks.

This research's primary objective is to identify the most financially viable and strategically sound investment for PT Naga Mas Sulawesi's silica sand capacity expansion via systematic comparison of new machine purchase, machine refurbishment, and joint operation. Specific objectives are: (1) business situation analysis using PESTEL and VRIO to pinpoint external opportunities/threats and internal strengths/weaknesses; (2) DCF analysis quantifying value via NPV, IRR, PP, and PI; (3) structured risk assessment of operational, financial, regulatory, market, and environmental factors per scenario; (4) integrated comparative analysis of financial and risk profiles for evidence-based decisions; and (5) actionable recommendations on implementation, mitigation, and optimization.

The research yields key benefits. For PT Naga Mas Sulawesi, it offers quantitative justification for capital decisions, bolstered by financial and risk analysis, fostering confident expansion with stakeholder buy-in. For mining broadly, it provides a replicable framework for uncertain investments, ideal for emerging-market SMEs. Academically, it extends appraisal literature via integrated tools in real mining cases. For policymakers, it reveals how regulations, downstreaming, and markets shape investments, informing sustainable development policies.

RESEARCH METHOD

This study adopted a quantitative approach to ensure objective and measurable analysis of the investment alternatives available to PT Naga Mas Sulawesi. The research design was structured into five main chapters that systematically addressed key components of investment evaluation. The first chapter outlined the strategic context of the silica sand industry and the operational challenges faced by PT Naga Mas Sulawesi, explaining the need to evaluate the three investment pathways and formulating research questions and objectives that guided the entire study. The second chapter presented the theoretical basis, including concepts of feasibility studies, internal and external analysis frameworks, financial valuation theory, and risk assessment principles. The third chapter described the methodological approach, including the quantitative research design, types of primary and secondary data collected, and analytical tools applied—such as PESTEL, VRIO, Discounted Cash Flow (DCF), and structured risk matrices. The fourth chapter analyzed the data to assess financial feasibility of each investment option using metrics such as Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PP), and Profitability Index (PI), while evaluating operational, financial, regulatory, market, and environmental risks for each scenario. The fifth chapter consolidated the findings and identified the investment alternative offering the strongest long-term value, with strategic recommendations for successful implementation.

Data collection was carried out through a combination of primary and secondary data to ensure comprehensive and accurate evaluation of investment alternatives. Primary data were obtained directly from PT Naga Mas Sulawesi via interviews and observations with key personnel—such as operational managers, finance managers, and project managers—providing in-depth insights into current operational capacity, cost structures, production challenges, and strategic investment plans. Secondary data were gathered from credible sources to complement and validate primary information, including the company's internal operational and financial documents (e.g., production records, cost reports, historical financial data, machine maintenance logs); industry reports and market studies from government agencies, industry associations, and research institutions on silica sand demand, price trends, export markets, downstreaming policies, and domestic/international growth trends; regulatory and policy documents on mining operations, environmental compliance, industrial downstreaming, and mineral exports; and published academic literature, such as books, journals, and articles on feasibility studies, investment analysis, valuation models, and risk management.

The data analysis method consisted of several key steps to evaluate the financial feasibility and strategic suitability of each investment alternative. The first step involved data collection and preparation, where primary and secondary data from interviews, internal documents, industry reports, and academic sources were compiled, organized, and verified for accuracy and consistency through cross-checking to ensure reliability for financial analysis and risk assessment. Business situation analysis provided a comprehensive overview of PT Naga Mas Sulawesi's current operational and strategic position by examining external and internal conditions affecting investment decisions. External analysis applied the PESTEL framework to identify macro-environmental opportunities and threats across political, economic, social, technological, environmental, and legal factors impacting project feasibility. Internal analysis used the VRIO framework to evaluate the value, rarity, imitability, and organization of the company's resources and capabilities, determining competitive strengths and gaps relevant to investment implementation.

Discounted Cash Flow (DCF) calculations determined the present value of future cash flows expected from each investment alternative. This process began by projecting annual free cash flows over a ten-year period for each scenario, based on assumptions for production volume, silica sand selling prices, direct operating costs, fixed costs, and tax liabilities. Future cash flows were discounted to present value using the Weighted Average Cost of Capital (WACC), derived from the company's capital structure and risk profile. Key financial indicators included NPV, which measured absolute economic value; IRR, which indicated expected project return; PP, which determined initial investment recovery time; and PI, which assessed return per unit of capital invested. All three alternatives were evaluated in parallel using the same DCF framework for fair, consistent comparisons.

The risk analysis step developed a structured risk matrix to identify, categorize, and evaluate key risks for each investment alternative. It began with risk identification across five categories: operational, financial/economic, regulatory/compliance, market/revenue, and environmental/social. Each risk was assessed for likelihood and impact using a structured scale to determine severity. A likelihood-impact matrix visualized each alternative's risk profile, categorizing risks as low, medium, high, or very high. A detailed risk register documented causes, consequences, existing controls, and mitigation strategies for each alternative. This produced a comprehensive risk assessment, enabling PT Naga Mas Sulawesi to understand uncertainty profiles and prioritize actions to minimize exposure.

Comparative analysis served as the final, integrative evaluation stage, combining financial outcomes and risk profiles of the three alternatives to identify the best overall value. The first dimension evaluated financial attractiveness using DCF indicators (NPV, IRR, PP,

PI) to compare economic performance and pinpoint the most profitable, fastest-returning option. The second dimension integrated risk matrix results: even alternatives with strong financial returns could see reduced feasibility if paired with high operational, financial, or regulatory risks. By synthesizing financial and risk data, the analysis clarified overall viability—options with high NPV/IRR but substantial operational risk or partner dependency warranted closer scrutiny than those with moderate returns and lower risks.

RESULTS AND DISCUSSION

Business Situation Analysis

A comprehensive analysis of the business situation shows that PT Naga Mas Sultra operates in a favorable strategic environment that supports long-term growth in silica mining. Through PESTEL's analysis, this study identifies that the political environment in Indonesia supports the mining industry through a national downstreaming policy that prioritizes domestic processing and increased mineral added value. Despite the challenges associated with regulatory revisions and changes in export policies, overall government policies create incentives for companies to invest in modern and efficient production capacity.

Economically, Indonesia's growing domestic demand for silica as a result of the growth of construction, property development, infrastructure expansion, automotive glass production, and national manufacturing created a growing market share for PT Naga Mas Sulawesi. The positive outlook is strengthened by the sustainable infrastructure development under national projects and Indonesia's commitment to the renewable energy transition which directly increases the demand for high-purity silica. On a global level, the shift towards renewable energy systems, electric mobility, and advanced electronics has triggered a strong and sustained increase in demand for high-purity silica especially for solar cell applications and semiconductor production. This trend benefits PT Naga Mas Sulawesi as the company's silica reserves reach very high purity levels of up to 99 percent, putting it in a good position to enter the premium market.

From a socio-cultural perspective, regional development in Southeast Sulawesi including increased industrial activity and economic participation supports the growing demand for extracted minerals. Local communities increasingly recognize the economic contribution of mining operations and expect companies to provide stable employment opportunities and transparent social engagement. PESTEL's analysis also highlights the technological advancements that fundamentally shape the competitiveness of silica mining operations. Modern technologies including more efficient processing equipment, automation, digital monitoring systems, and predictive maintenance tools allow companies to achieve higher outputs with lower energy consumption and reduced operational costs per unit. Investments in improved machines offer advantages not only in throughput but also in environmental compliance as modern systems incorporate better dust control, water recycling, and environmental impact mitigation technologies.

Internally, VRIO's analysis shows that PT Naga Mas Sulawesi has several valuable strengths including strategic access to high-purity silica resources, proximity to the port of Moramo (3.6 km), and well-established quality certification. These advantages give the company a strong competitive position and allow it to meet domestic and international market standards. However, the company currently faces limitations in processing capacity that limits its ability to significantly increase production without additional investment in machinery. To realize its full potential, PT Naga Mas Sulawesi must address this capacity gap through

strategic upgrades that align its operational capabilities with the scale of its available resources and evolving market demands.

When the external opportunities and challenges identified in the PESTEL review are considered along with the internal advantages highlighted in the VRIO assessment, several important implications arise for investment decisions. First, the overall external environment supports expansion where political, economic, and technological factors provide a favorable foundation for increasing production capacity. Secondly, the company's internal strengths especially the quality of reserves and strategic location provide a strong foundation for growth-oriented investments. Third, gaps in processing capacity must be overcome so that PT Naga Mas Sulawesi can take advantage of favorable market conditions and achieve its strategic goals.

Discounted Cash Flow Analysis

The Discounted Cash Flow approach was used in this study to evaluate the financial prospects of PT Naga Mas Sulawesi's investment alternatives by estimating future cash flows and translating them into present values. DCF's analysis relies on a set of structured assumptions that reflect the operational characteristics, financial requirements, and market conditions relevant to each investment alternative considered. These assumptions include capital expenditures, assumptions of operational production, assumptions of revenue, assumption of costs, assumptions of taxes, and discount rates.

The capital expenditure structure for the investment of the new machinery represents the most substantial financial commitment among the available alternatives with a total capital requirement of IDR 9.15 billion. Precise cost breakdowns are critical to understanding how capital is allocated across infrastructure and operational components. The largest allocation in the capital expenditure structure is the purchase of the machinery itself which is worth IDR 5.3 billion or 57.9 percent of the total capital expenditure. This investment includes the acquisition of advanced processing equipment designed to handle high throughput volumes and achieve consistent quality output that is aligned with market standards. The allocation towards water treatment systems highlights another critical dimension of the investment where silica processing inherently depends on effective washing and impurity removal and without an adequate water treatment system, the quality of output cannot be reliably maintained. Land acquisition and further preparation complement the infrastructure required for smooth operations by ensuring that the site has adequate space for machine installation, material flow, inventory storage, and logistical accessibility. The inclusion of office facilities although relatively simple in financial terms complements the operational arrangement by providing the necessary administrative environment for coordination, supervision, and documentation management that ensures that information systems and support personnel can work efficiently.

Existing machine repairs represent a cost-conscious investment path that focuses on restoring the operational capabilities of current equipment while extending its useful life with a total capital requirement of IDR 1.3 billion or approximately 14.2 percent of the cost of new machines (Mansour & Hassan, 2024). The distribution of repair expenses reflects a deliberate and highly focused effort to restore operational reliability without committing to full-scale capital reimbursement where the dominant allocation towards engine overhaul and component replacement reaches IDR 800 million or 61.5 percent of the total repair expenditure. The remaining expense categories complement the mechanical recovery by handling the supporting environment in which the machine's operation takes place. Minor improvements to the existing land area ensure that the physical infrastructure remains functional and conducive to efficient operation. The improvement of office facilities reflects the understanding that effective

operations depend not only on machinery but also on administrative coordination, record-keeping, and supervisory functions.

The Joint Operations Alternative represents the least capital-intensive option among the three investment paths considered in this study with a total capital requirement of zero. In contrast to the purchase of new machinery or repair of existing machinery, this arrangement does not require PT Naga Mas Sultra to provide an upfront capital investment as the partner is responsible for providing, operating, and maintaining the processing equipment within the company's concession area. PT Naga Mas Sultra receives royalty income based on the volume and value of production generated by partners. Since the Joint Operations arrangement relies on a revenue sharing framework rather than a capital spread, the financial evaluation focuses on projected royalty inflows and their stability over the projection period (Bui & Tran, 2023).

Operational production assumptions form a critical component of the Discounted Cash Flow analysis as it determines the volume of silica output that each investment alternative is expected to generate over the projection period. The scenario of the new machine represents the most ambitious and capacity-boosting operational path among the available investment alternatives assuming the installation of modern processing equipment with a capacity of 200 tons per hour (Doc, 2025). The operational pattern begins with a cautious start-up period in which the machine operates six hours per day during the first year to allow for commissioning, calibration, and training of personnel. In the second year, working hours increased to eight hours per day as the system stabilized and personnel acquired operational skills. From the third to fifth year, operations were expanded to twelve hours per day to reflect growing confidence in system performance and increased market demand. From the sixth year onwards, operations reached full speed at sixteen hours per day to maximize capacity utilization and optimize output.

The repair scenario represents an operational path that focuses on restoring the performance of existing machines without changing their fundamental processing capacity with an assumed capacity of 150 tons per hour. Working hours per day increased from eight hours in the first year to twelve hours in the following years representing a transition from a cautious initial phase of operation to a stable and sustainable production phase. The total number of hours of operation available increased from 2,920 in the first year to 4,380 hours from the second year onwards. An important characteristic of this scenario is the production of sand exclusively where the repaired equipment is assumed to process only fine materials to ensure consistent operation and avoid mechanical stress or excessive wear that may arise from the handling of different material gradations. This production stability provides a predictable output of 657,000 tons per year from the second year onwards.

The joint operation scenario represents an operational arrangement in which PT Naga Mas Sultra collaborates with partners who provide, manage, and operate production equipment within the company's concession area. The production assumptions in a joint operation scenario are very similar to the new machine alternatives because the partners are assumed to provide equipment with the same technical capacity of 200 tons per hour. Working hours follow the same gradual expansion pattern as seen in the new machine scenario where operations begin with six hours per day, increase to twelve hours the following year, and finally reach sixteen hours per day starting in the sixth year. The total available operating hours per year therefore increase in the same pattern as the new machine scenario. The production volume produced follows the same trend with the new engine alternatives where output starts at 438,000 tons, increases to 584,000 tons, then reaches 876,000 tons in the third year, and finally reaches 1,168,000 tons from the sixth year onwards.

The revenue projections for the new machine scenario are obtained by combining the annual production volume with the corresponding selling price of gravel and sand reflecting the full operational potential of the high-capacity processing system. The selling price of silica applied in this study incorporates annual escalation factors that reflect realistic market dynamics and ensure that revenue projections remain consistent with long-term economic trends (Alert, 2025). In practice, silica prices in Indonesia are experiencing a gradual upward movement influenced by expansions in glass manufacturing, ceramic production, water treatment infrastructure, and construction activities. The price projections applied reflect these regional market conditions and incorporate conservative growth rates based on historical data and industry consultations. The inclusion of price projection percentages further reinforces the realism of revenue models where this percentage represents an estimate of the annual price growth rate based on regional market analysis and inflation expectations in the minerals sector.

The revenue projections for the existing machine repair scenario are driven by a stable production profile combined with a gradually increasing selling price that reflects realistic market dynamics in the Indonesian silica industry. Although the production volume remains stable, the selling price of silica sand increases over time in accordance with the assumption of conservative price escalation. The initial price of 170,000 rupiah per tonne gradually increased to around 239,616 rupiah per tonne at the end of the projection period reflecting expectations of moderate inflation and growth in market demand. Although there was no growth in production volume, the increase in selling prices resulted in a steady upward progression of revenue over the eleven-year horizon where revenue increased from 74.4 billion rupiah in the first year to around 157.4 billion rupiah in the eleventh year.

The revenue projections for the joint operating scenario are based on the royalty arrangement where PT Naga Mas Sultra receives income derived from the production activities of partners within the company's concession area. This financial arrangement follows a structure in which the company is not directly involved in the production of silica but instead earns income solely through the payment of royalties from partners based on the volume and value of the output produced. The first driver of the revenue projections is the partner's production volume, which reflects the production pattern of high-capacity machinery as seen in the new machine scenario where the output of gravel and sand increases gradually as operations expand from six hours per day in the first year to sixteen hours per day starting in the sixth year. The second driver is the royalty price per ton for gravel and sand which increases gradually over the projection period. The initial royalty rate of 33,248 rupiah per tonne for gravel and 24,936 rupiah per tonne for sand reflects a reasonable market rate for concession-based royalty arrangements. These prices increase gradually each year according to the projected escalation of inflation and the market.

The cost framework used in this study is constructed from three core components that together define the full cost structure of a silica mining operation. The direct cost of approximately 66,667 rupiah per ton includes operational elements that vary directly with production volume including transportation, port handling, excavator rental, and contractor costs. The annual fixed costs required to support compliance, environmental management, and administrative obligations associated with silica mining operations remain constant regardless of production volumes including HSE and environmental programs and Danramil support costs. The tax structure consists of three key components that together represent the fiscal obligations applicable to silica mining operations including a 5 percent local levy, a 22 percent corporate income tax, and a 3 percent sector-based tax.

The discounted rate represents the required rate of return that is used to convert future cash flows into their present value in a Discounted Cash Flow analysis that reflects the time value of money as well as the risks associated with the investment. The Weighted Average

Cost of Capital in this study is driven entirely by the cost of equity because the project does not use debt financing. Equity costs are calculated using the Capital Asset Pricing Model which combines the risk-free rate based on the yield of Indonesian government bonds, the market risk premium that reflects the extra return expected from investing in the equity market versus risk-free assets, and beta which measures the sensitivity of a project's return to broader market movements. For PT Naga Mas Sulawesi's silica mining project, the WACC is calculated at 11.81 percent which represents the minimum acceptable rate of return that an investment must generate to justify the use of capital.

The results of the Discounted Cash Flow analysis present the financial performance of each investment alternative after applying predetermined assumptions for production, revenue, costs, taxes, and discount rates. Key indicators from DCF's analysis for new engine alternatives show very strong financial viability with a Net Present Value of IDR 2.15 trillion discounted at 11.81 percent indicating strong value creation and far exceeding the initial capital investment of IDR 9.15 billion. The Profitability Index of 233.23 shows a very high return relative to the invested capital where every rupiah invested produces a present value of more than 233 rupiah. The Internal Rate of Return of 71 percent indicates a very high rate of return that substantially exceeds the discount rate of 11.81 percent indicating that the project generated a substantial economic surplus. The Payback Period of 1.67 years indicates that the initial investment will be recovered in less than two years indicating excellent liquidity and a low financial risk profile.

Financial indicators for the corrected machine scenario show that these options generate strong economic value with minimal capital expenditure. Net Present Value of IDR 267.54 million discounted at 11.81 percent shows that the investment generates positive economic value albeit on a much smaller scale compared to the new machine scenario. A profitability index of 190.09 indicates that despite a relatively small investment, the project generates strong positive value per unit of capital invested. The Internal Rate of Return of 20 percent indicates that the rate of return exceeds the discount rate of 11.81 percent which indicates financial feasibility. The Payback Period of 7.68 years indicates that the initial investment recovery takes substantial time reflecting lower production capacity and smaller revenue volumes compared to new machine alternatives.

Financial indicators for the Joint Operations scenario highlight the characteristics of royalty-based models that do not require capital expenditures. The Net Present Value of IDR 202.56 million discounted at 11.81 percent shows that this royalty-based arrangement generates positive economic value albeit at a lower level compared to new engine alternatives and improved engines. The Profitability Index cannot be calculated because there is no initial investment which makes this metric unapplicable in this context. The Internal Rate of Return cannot be calculated because there is no initial capital outflow to compare with future royalty inflows. The Payback Period cannot be applied because there is no initial investment that needs to be recovered.

Risk Assessment

The New Machine Scenario offers the highest production capacity and the strongest financial return among all alternatives but also carries the greatest operational exposure and capital-related risks. The main risk categories include operational risks such as equipment malfunction or malfunction during the initial operational years, delays in installation or commissioning, inadequate operator skills, and parts supply disruptions; market and revenue risks such as decreased demand for silica sand, market oversupply affecting selling price stability, and changes in buyers' contract terms; regulatory and compliance risks such as revisions to mining regulations affecting royalties or production quotas, stricter environmental

standards that increase operating costs, and compliance issues related to AMDAL and permits; financial and economic risks such as unexpected increases in operating costs, exchange rate fluctuations affecting imported machine components, inflationary pressures eroding profitability, and inaccurate assumptions in production increases; as well as environmental and social risks such as floods or heavy rains that disrupt production, public protests related to land access or environmental impacts, and ESG oversight that affects partnerships.

The risk profile for the New Machine scenario indicates a predominantly high risk environment driven by operational, market, regulatory, and environmental uncertainty. Some risks fall into the high-impact category with medium to high likelihood that require strict risk management priorities and proactive mitigation strategies. Risks with the highest exposure include equipment failure or downtime, market price volatility, regulatory non-compliance, parts supply chain disruptions, and societal social issues. Although financially superior, the New Machine scenario exposes companies to higher operational and market risks so proper risk mitigation is essential to maintain strong financial performance (Intelligence, 2025a).

The Improved Machinery scenario involves restoring existing equipment to operational condition with significantly lower capital requirements compared to purchasing new machines. While this option reduces capital exposure, it introduces substantial operational and maintenance risks. Key risk categories include operational risks such as repeated equipment breakdowns due to aging components, lower production capacity stability, higher maintenance frequencies, and limited availability of compatible parts; market and revenue risks such as revenue sensitivity due to reduced production volumes and inability to meet increasing demand from buyers; regulatory and compliance risks such as stricter inspection standards that may be more difficult to meet with older machines; financial and economic risks such as increased repair costs over time and potential cost inefficiencies due to lower machine productivity; as well as environmental and social risks such as greater environmental impacts due to older mechanical systems and potential public dissatisfaction if noise or dust levels increase.

The corrected machine scenario shows an overall medium to high risk profile that is primarily driven by equipment failures, parts shortages, increased maintenance needs, and regulatory compliance challenges. Improved engine scenarios reduce capital exposure but increase operational and maintenance risks so they are more suitable when capital constraints are high or when risk appetite favors lower initial investments. Strong maintenance planning and parts replacement strategies are essential to maintain output. If market demand increases rapidly, these options may become insufficient to capture the full revenue potential.

The Joint Operation scenario represents the lowest risk investment path among the three alternatives because PT Naga Mas Sulawesi is not involved in direct production activities and does not incur capital expenditure. The company earns royalty income from partners who operate processing equipment in its concession areas. While this model eliminates direct operational risks and capital exposures, it introduces challenges related to partner dependency, contractual governance, and indirect regulatory exposure. Key risk categories include operational and partner-related risks such as poor partner performance or weak management practices and late royalty payments; revenue and contractual risks such as disputes in the interpretation of profit-sharing agreements and uncertainty in contract extensions; regulatory and compliance risks such as changes in the royalty policy of ESDM that affect revenues; market and financial risks such as a decline in market prices that reduce the basis of royalty calculations; as well as environmental and social risks such as poor partner environmental practices that can affect the reputation of PT Naga Mas Sulawesi.

The Joint Operation scenario presents a medium level of risk mainly because the company relies on the performance of its partners and faces uncertainty in future royalty regulations. Although operational and capital risks are low, governance and dependency risks

require careful attention. The Joint Operations scenario offers very low financial risk but introduces governance risks and dependencies so a strong contractual structure, monitoring system, and partner selection criteria are essential. Suitable for low risk appetite or when capital constraints prevent direct investment. Provides stable long-term income but cannot match the scale of income from a direct mining scenario.

Comparative Analysis of Investment Alternatives

Comparative financial results reveal clear differences in performance between the three investment scenarios. The New Machinery scenario shows highly superior financial results driven by high production capacity, operational efficiency, and the ability to capture larger market volumes. Net Present Value of IDR 2.15 trillion represents a huge economic value creation that substantially exceeds the initial capital investment of IDR 9.15 billion. The Profitability Index of 233.23 and the Internal Rate of Return of 71 percent further confirm the strong financial appeal of this alternative. The Payback Period of 1.67 years indicates a rapid capital recovery and an excellent liquidity profile that reduces exposure to long-term financial risks.

In contrast, the Improved Machinery scenario results in moderate financial performance with much lower capital investment. The Net Present Value of IDR 267.54 million shows that this alternative generates positive economic value albeit on a much smaller scale. The Profitability Index of 190.09 still shows strong capital efficiency but the Payback Period of 7.68 years reflects a longer recovery period due to lower production capacity and smaller revenue volumes. The Internal Rate of Return of 20 percent exceeds the discount rate but is still much lower than the New Machine scenario which shows more moderate profitability.

The Joint Operations scenario resulted in the lowest Net Present Value of IDR 202.56 million reflecting a royalty income structure that generated lower revenue compared to direct production operations. Since there is no initial capital investment, metrics such as Profitability Index, Internal Rate of Return, and Payback Period are not calculable or unworkable which makes direct financial comparisons with the other two alternatives limited. However, the capital-free structure of this option means that PT Naga Mas Sultra does not face initial financial exposure and receives stable cash flow without any immediate operational risks.

A comparison of risk levels across all three investment alternatives shows different differences in their exposure to operational and financial uncertainty. The New Machine Scenario presents a high level of overall risk that is primarily driven by operational risks related to machine reliability, installation delays, and reliance on adequate operator skills. Market risk is also substantial because high production volumes make projects more sensitive to market price fluctuations and changes in demand. Regulatory and compliance risks are moderate because large-scale operations require broader permits and stricter environmental oversight. Environmental and social risks are at a moderate level but still require proactive community engagement and responsible environmental practices.

The Improved Engine Scenario shows a medium to high overall risk level that is primarily driven by equipment reliability concerns. Operational risks are high due to aging machines bringing greater possibilities of breakdowns, higher maintenance needs, and potential production disruptions. Market risk is moderate due to lower production capacity reduces sensitivity to price fluctuations but also limits the ability to take advantage of market opportunities. Medium to high regulatory and compliance risks due to older systems may face challenges in meeting evolving environmental standards. Environmental and social risks are moderate but may increase if older machines produce higher dust or noise (Farmonaut, 2025).

The Joint Operations scenario presents the lowest overall level of risk among the three alternatives as PT Naga Mas Sulawesi is not involved in direct production operations. Operational risk is low as partners are responsible for managing equipment and ensuring production reliability. Market risk is also low because the royalty-based model provides stable cash flow regardless of short-term market fluctuations. However, the governance risks and dependency of medium to high partners due to the financial performance of PT Naga Mas Sulawesi depend directly on the operational reliability of the partners and the timeliness of royalty payments. Moderate regulatory risk due to changes in royalty policy or mining regulations could affect future revenue levels (Acosta & González, 2023; Santos et al., 2021).

When the financial results and risk profile are combined, it becomes clear that the New Machine scenario offers the best overall value despite having higher risk exposure. Superior financial performance with an NPV far exceeding that of other alternatives, a very high Profitability Index, and a fast Payback Period provide a strong economic justification for choosing this option. Despite the high level of risk, these risks can largely be managed through proper operational planning, preventive maintenance, adequate personnel training, and proactive regulatory compliance (Brigham & Ehrhardt, 2020). By implementing a robust risk mitigation strategy, PT Naga Mas Sulawesi can protect the strong financial value offered by the New Machinery investment while minimizing exposure to operational and market uncertainty.

The Improved Engine scenario generates positive financial value but at a much lower rate compared to the New Engine. Its medium to high risk profile is primarily driven by uncertain equipment reliability and increased maintenance requirements that make this option less attractive in the long run. Although lower capital investment may be attractive in situations with tight capital constraints, the lower long-term economic value and ongoing operational risks suggest that this alternative is less optimal compared to New Engines (Barney, 2020; Ferreira & Fernandes, 2021; Rodríguez-Escobar et al., 2025).

The Joint Operation Scenario offers the lowest risk profile and does not require capital investment but also results in the lowest financial value and eliminates the operational control of PT Naga Mas Sulawesi. The royalty-based model provides stable and predictable revenue but cannot match the economies of scale or growth potential offered by the New Machine scenario. For companies that have a low risk appetite or face severe capital constraints, this option can provide an acceptable path to generating revenue from concession resources without direct operational exposure. However, for companies seeking to maximize long-term value and harness the full potential of their high-quality silica reserves, the Joint Operations scenario is not an optimal option (Intelligence, 2025b).

Table 1. Comparison of Financial Alternatives to Investment

Indicators	New Engine	Engine Repaired	Joint Operations
Initial Investment (IDR)	9.150.000.000	1.300.000.000	0
Net Present Value (NPV)	2.149.756.047.000	267.543.016	202.559.334
Profitability Index (PI)	233,23	190,09	Uncountable
Internal Rate of Return (IRR)	71%	20%	Uncountable
Payback Period (years)	1,67	7,68	Not applicable

Table 2. Comparison of Investment Alternative Risks

Indicators	New Engine	Engine Repaired	Joint Operations
Overall Risk Level	Tall	Medium-High	Intermediate

Operational Risk	Tall	Tall	Low
Market Risk	Tall	Intermediate	Low
Regulatory Risks	Intermediate	Medium-High	Intermediate
Financial Risk	Tall	Intermediate	Low
Environmental & Social Risks	Intermediate	Intermediate	Low

CONCLUSION

The study concludes that purchasing new machinery represents the optimal investment for PT Naga Mas Sulawesi's silica sand mining expansion, offering superior financial returns with an NPV of IDR 2.15 trillion, IRR of 71%, Profitability Index of 233.23, and a Payback Period of 1.67 years—outperforming refurbishment or joint operation alternatives—while aligning with the company's high-purity reserves and strategic location to meet rising domestic and global demand. Although higher operational, market, and regulatory risks exist, these can be mitigated via preventive maintenance, workforce training, compliance measures, and long-term sales contracts. For future research, expand the framework with dynamic sensitivity and scenario analyses to evaluate impacts from silica price volatility, cost changes, regulatory shifts, and supply chain disruptions; integrate ESG metrics like carbon footprint and community engagement; and explore digital tools such as IoT monitoring and AI predictive maintenance to boost efficiency in emerging markets.

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