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Economic evaluation of mobile screening station waterless system operation of nickel laterite ore

A Yustian¹, E Widodo² and M L Singgih³

^{1,2,3}Department of Industrial and System Engineering, Institut Teknologi Sepuluh Nopember. Surabaya, Indonesia.

E-mail: ¹andi.bessi@vale.com

Abstract. The study investigates the economic level of operating the Mobile Screening Station Waterless System (MSSWS) for the first-time application in the nickel laterite mining industry. Three investment alternatives are compared in this study to determine the most economical option, i.e.: maintaining existing Fixed Screening Station/FSS (alternative one), purchasing MSSWS (alternative two), and purchasing new FSS (alternative three). Evaluation is made by performing cost savings analysis, increment cash flow projections, NPV, and IRR calculation. Furthermore, sensitivity analysis of the most economic option will be done as well. The results show that MSSWS gives the highest NPV and IRR. The decreasing of ore hauling distance and water content that are contributed by MSSWS yields significant cost savings in terms of reducing hauled trucks' investment and its operating cost. In accordance with this analysis, the economics of MSSWS is very sensitive to the changed of ore hauling distance. Therefore, this study has been successfully confirmed that purchasing of MSSWS is the most economical option. In addition to this result, a sensitivity analysis will be undertaken based on the situation that the moving of MSSWS over a certain period once the minimum change in the average ore hauling distance occurs.

1. Introduction

A common problem faced in lateritic nickel mining operations is the mining area that moves annually to a new area as the nickel reserves are depleted in the area. When mining moves to a new area causes ore hauling distance will increase farther from the existing fixed screening station. In this case of study, a mining area with ore hauling distance to the fixed screening station has been increased by an average hauling distance from 2 km to 7 km in the last 15 years. Besides, current fixed screening station technology uses a wet screening process (with the addition of water) to separate fractions of the size of -6 inches (containing higher nickel grade) and size of +6 inches (containing lower nickel grade). Thus, it causes water content increased in the screened ore. The increase in hauling distances results decreasing in the overall productivity of mining equipment and an increase in mining operating unit costs each year. Whereas the wet screening process of nickel laterite ore through the use of water causes increasing in carbon combustion energy of the nickel smelting process.

A study of a mobile screening station waterless system (MSSWS) is undertaken to replace the current conventional method of fixed screening station (FSS) with the use of water. MSSWS will move periodically for certain years according to the mine plan but not move perpetually or continuously at any time. MSSWS will increase mining operations flexibility and its productivity by reducing total material hauling distance and water content in nickel ore. So that it will affect on increasing mining costs efficiency over the life of mine.

This study is intended on how to formulate the investment cost and cost savings component resulted from MSSWS operation, and to figure tolerably risk that allows for investment decisions can be made. Three investment alternatives are compared in this study to determine the most economical option, i.e.: maintaining existing FSS (alternative 1), purchasing an MSSWS (alternative 2), and purchasing a new FSS (alternative 3). Evaluation is made by performing cost savings analysis, increment cash flow



projections, NPV, and IRR calculation. Furthermore, sensitivity analysis of the most economic option will be done as well.

2. Mining and Screening Process

2.1 Mining Process

After the ore layer is exposed, the ore is mined by excavators and hauled by trucks to the screening station. The screening station will separate the size of +6 "(oversized) fraction which has a nickel grade below 1.5% and a fraction size of -6" (undersized) which has a nickel grade above 1.5%. Whenever fraction size above +6-inch contents nickel grade above 1.5% or a requirement for ore blending to have on specification ore chemistry, it is fed to the crushing system to produce up to size -1 inch. Then, the crushed material will be mixed with the screen products -6 inches. The screening station product (SSP) is loaded with a loader and hauled by truck to the Wet Ore Stockpile (WOS) area. While rejected +6 materials will be hauled to use for mine road construction. MSSWS operations to replace FSS yields overall hauling distance saving by 5 km ore hauling distance. The mining process and the change of overall material hauling distance by MSSWS operation are shown in Figure 1.

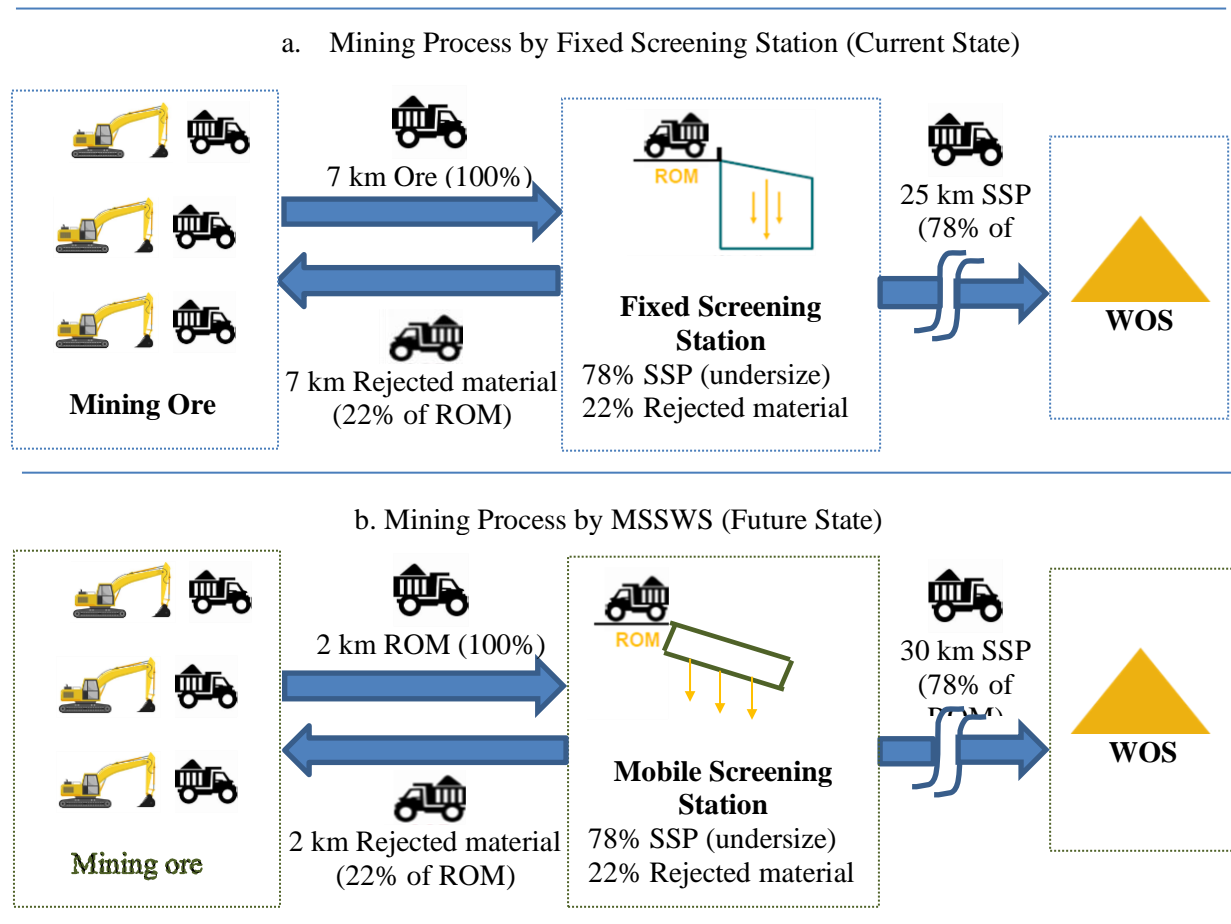


Figure 1. Mining process and material hauling distance.

2.2 Mobile Screening Station Waterless System

The main component parts and material flow of the mobile screening station is shown in Figure 2 [2] and summarized references as follows [1]:

- Bench retaining panels - Fitted to the rear of the heavy-duty main chassis frame, mounted below the feed hopper section and designed for an easy solution to assist with loading, ramp stability, site installation, and reliability. Fully braced and bolted to the main skid – mobile chassis frame.
- Dump truck reversing stop bar - Heavy-Duty and located at the tipping point.
- Main feed hopper with a holding a capacity of 90 m³ (180mT), designed to accept ROM of -2,000mm material from a dump truck.
- Reciprocating feeder system - Designed so that the feeder table never fully empties or ejects all the material. The feeder provides a deep bed of material, cushioning the impact and load of any large material tipped into the main feed hopper, protecting the feeder table. Any sticky material is consistently pushed into the barrel with no surging or barrel overloading effect.
- Primary Screening Section - Fully welded and robust 2.5m diameter x 11.5m long barrel screening section. Designed for efficiently screening out the -6” ore natural feed material. Will perform either with a dry feed and/or a high moisture content feed.
- Secondary Screening section - Fully welded and robust 2.5m diameter x 3m long barrel screening section for screening out from +6” to - 18” ore material. The flow of material screened at each fraction is ejected gravity from the barrel screen through the respective output channel (chute).
- Self-Cleaning Barrel System - A single free-running rotating self-cleaning system is mounted above the first 3m screening section to assist with any potential pegging within the barrel apertures. The rotating cleaner pushes any sticky material back into the barrel for processing on its return cycle.

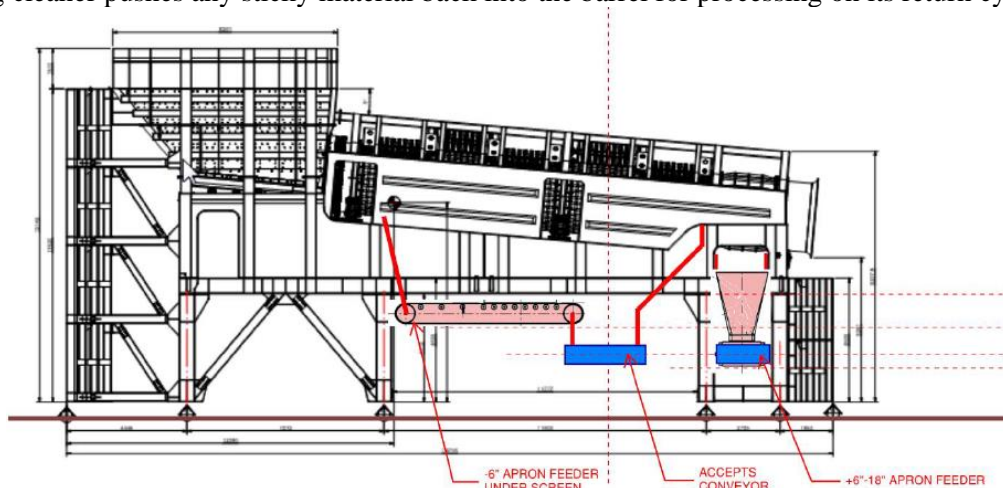


Figure 2. Modular screening station design.

A comparison of screening technology between FSS and MSSWS is shown in Table 1 and Figure 3

Table 1. Screening Technology Comparison.

Description	Fixed Screening Station	MSSWS
Screening Technology	Static grizzly and vibrating steps bar screen (Primary and Secondary Screen)	A barrel of rotary barrel screen (Primary and Secondary Screen)
Static grizzly screening	Yes	No
Rotary barrel screen	No	Yes
Mobile	No	Yes
Feed hopper	Yes	Yes
Transfer conveyors to screen	Yes	No
Stacker belt Conveyor	Yes	Yes
Water added	Yes	No
Feeding capacity	750 Ton/hour	750 Ton/hour

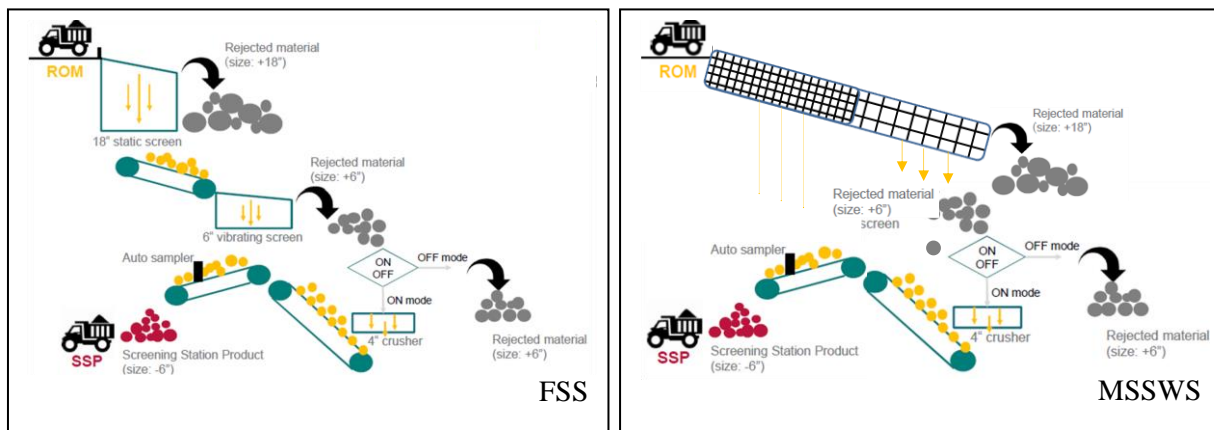


Figure 3. Screening process of FSS and MSSWS.

2.3 Preliminary study MSSWS

MSSWS is a technology that has been applied in mineral rock mining that operates a crushing system to produce aggregate products. However, the screening waterless system has not been applied to screen alluvial or lateritic ore. So that, this MSSWS operation is the first application to the nickel laterite mining industry.

Scoping study (FEL 2) conducted a mini MSSWS trial study with 150 tons/hour feeding rate capacity to examine critical technical and operational issues to screen 6,000 WMT laterite ore samples shows:

- The rotary barrel screen system at mini MSSWS works well to screen laterite nickel ore until -1-inch grain size without added water.
- Rotary barrel screen system at mini MSSWS performs better-screened recovery of -6 inches fraction to compare with FSS. Whereas it requires a longer dimension of rotary barrel screening to produce a fraction until -1 inches.
- The rotary barrel screen system at mini MSSWS produces insignificantly ore dilution both size fraction -6 inches and -1 inches.
- The water content of final products (SSP) by mini MSSWS is lower than FSS. However, the water content is influenced by weather and ore section profile.

3. Economic Evaluation

3.1 Parameter Assumptions

- Depreciation. Based on a statistical analysis of maintenance costs during the operating period of the screening station shows a sharp increase in the cost of screening station maintenance (on average more than doubled) from the 8th year to the 12th year. It occurs due to the span of years had been updated on the main components and building structure reinforcement which causes high maintenance costs in that period. Based on these conditions, the estimated economic life of MSSWS operating that will be used in the analysis of cash flow projections is for an operating of 8 years. While the method and amount of depreciation used in this research are the 25% declined balance of depreciation method [3].
- Income Tax. General rates apply to domestic taxpayers, as well as foreign taxpayers who conduct business or activities in Indonesia through a permanent establishment in Indonesia, are based on the taxable income layer. The amount of the tariff is 25% according to Indonesian government regulation [4].
- Discount rate. Uses the weighted average capital cost (WACC) value which is the cost of capital of a company consisting of shares, use of debt, and retained earnings. The indicator used to measure the variable capital costs is to calculate the WACC using the formula [5]:

$$WACC_{nominal} = D/V \cdot K_d \cdot (1-T_c) + E/V \cdot K_e \tag{3.1}$$

Where,

D = Market value of the firm’s debt

E = Market value of the firm’s equity

V = D + E = Total market value of the firm’s financing

D/V = Percentage of financing that is debt (30%, internal corporate data)

E/V = Percentage of financing that is equity (70%, internal corporate data)

T_c = Corporate tax rate (34% in Brazil)

K_d = Cost of debt = 3.9% [6]

K_e = Cost of equity

While the cost of equity (K_e) is calculated by the formula [5]:

$$K_e = R_f + CDS + \beta_s (R_m - R_f) \tag{3.2}$$

$$K_e = 2.92\% + 1.59\% + 1.31 \times 4.66\% = 10.6\%$$

Where:

- R_f = Risk-free returns expected on the market = 2.92% [7].
- β_s = Sensitivity to market risks from the average beta of the mining sector = 1.31 [8]
- CDS = Country Default Spread of Indonesia = 1.59% [9]
- (R_m – R_f) = The historical risk premium from 1928-2018 = 4.66% [10]

Then the nominal WACC calculation obtained parameter data from the company in 2019 as follows:

$$WACC_{nominal} = D/V \cdot K_d \cdot (1-T_c) + E/V \cdot K_e$$

$$WACC_{nominal} = 30\% \cdot 3.9\% \cdot (1-34\%) + 70\% \cdot 10.6\% = 8.2\%$$

With inflation of 2.13% [11], we get:

$$WACC_{real} = WACC_{nominal} - inflation$$

$$WACC_{real} = 8.20\% - 2.13\% = 6.07\% \text{ or round to } 6.00\%$$

Based on these calculations, the discount rate to be used in this economic analysis is the same as the WACC_{real} value of 6.00%.

3.2 Cost Analysis

All unit cost components are based on 2019 actual data. MSSWS investment cost is based on the 2019/2020 actual data. Cost savings identified in several activities include:

- Ore hauling cost to the screening station by truck is summarized in Table 2. MSSWS results in a reduction of the average ore hauling distance to the screening station from 7 km to 2 km over an 8-years period. Whereas the new FSS results in an average hauling distance reduction of 4 km.

Table 2. Ore hauling cost summary.

Alternative	Distance (a)	Velocity (b)	Ore Tonnage (c)	Truck Load (d)	Unit Cost (e)	Cost ($\frac{2.a}{b} \cdot \frac{c}{d} \cdot e$)
1 (existing FSS)	7 Km	15 Km/hr	3,416,400 T	87 T	\$102/hr	\$ 3,738,402
2 (New MSSWS)	2 Km					\$ 1,068,144
3 (New FSS)	4 Km					\$ 2,136,186

• The hauling cost of screened ore (SSP) to stockpile (WOS) is summarized in Table 3. MSSWS results in an increase of the average SSP hauling distance from 25 km to 30 km over an 8-years period and a 4% reduction of water content in SSP tonnage. Whereas the new FSS results in an average hauling distance reduction of 28 km.

Table 3. SSP hauling cost summary.

Alternative	Distance (a)	Velocity (b)	SSP Tonnage (c)	Truck Load (d)	Unit Cost (e)	Cost ($\frac{2.a}{b} \cdot \frac{c}{d} \cdot e$)
1 (existing FSS)	25 Km	26 Km/hr	2,454,223 T	84 T	\$107/hr	\$6,527,749
2 (New MSSWS)	30 Km		2,356,054 T			\$ 7,519,960
3 (New FSS)	28 Km		2,454,223 T			\$ 7,311,096

• The hauling cost of rejected material +6 " is summarized in table 4. MSSWS results in a reduction of the average rejected material hauling distance from 7 km to 2 km over an 8-years period. Whereas the new FSS results in an average hauling distance reduction of 4 km.

Table 4. Rejected material +6" hauling cost summary.

Alternative	Distance (a)	Velocity (b)	Ore Tonnage (c)	Truck Load (d)	Unit Cost (e)	Cost ($\frac{2.a}{b} \cdot \frac{c}{d} \cdot e$)
1 (existing FSS)	7 Km	15 Km/hr	751,608 T	95 T	\$102/hr	\$753,168
2 (New MSSWS)	2 Km					\$ 215,220
3 (New FSS)	4 Km					\$ 430,440

- Ore screening cost. Due to the time limitations, the MSSWS screening operational costs is assumed to be the same as the FSS cost.
- Relocation and preparation costs of the MSSWS area are conducted every 3 years or twice during the lifetime of the equipment for 8 years with an estimated cost per relocation of \$ 1,500,000
- The reduction in overall material hauling distance results in a reduction of a total truck working hours which has the potential to save on investment cost for replacing equivalent with 3 units of trucks for MSSWS operation and 2 units of trucks for new FSS.

Table 5. Cost analysis summary.

Cost Component	Alternative 1	Alternative 2	Alternative 3
Investment cost	None	\$10,249,700	\$11,442,734
Ore hauling cost	\$ 3,738,402	\$ 1,068,144	\$ 2,136,186
Rejected material hauling cost	\$753,168	\$ 215,220	\$ 430,440
SSP hauling cost	\$6,527,749	\$ 7,519,960	\$ 7,311,096
Screening cost	\$546,524	\$546,524	\$546,524
Relocation cost	0	\$3,000,000	0
Truck Investment cost saving	0	\$3,000,000	\$2,000,000

Where: maintaining existing FSS (alternative 1), purchasing a MSSWS (alternative 2), and purchasing a new FSS (alternative 3).

3.3 Cash Flow Projection and Analysis

Pro Projection and analysis of MSSWS cash flow results in positive NPV of \$ 3,269,700 and IRR of 17.4% with a payback period of 4.0 years. Thus, the purchasing and operation of MSSWS are feasible to run because it brings profits to the company where NPV value above zero and IRR value above the required criteria of 6%.

Otherwise, cash flow analysis of a new FSS results in a negative NPV value of - \$1,960,600 and an IRR of 0.0%. So that the purchasing and operation of new FSS are not feasible to run because it brings harm to the company where NPV value < 0 and IRR value below the required criteria of 6%. It happens because the new fixed screening station is not designed to move periodically over 8-years period of a lifetime as MSSWS. So that the cost savings by reducing the average ore hauling distance that can be optimized to 4 km over the lifetime of new FSS are inadequate to overcome the investment costs required. Whenever a structure of the new FSS can be modified by a modular system so that it is possible to move periodically over 8-years period, then it results in a positive NPV of \$ 845,900 and IRR of 8.7% with a payback period of 5.5 years. However, the NPV and IRR are still lower than MSSWS NPV of \$3,269,700 and IRR of 17.4%. Caused the investment cost of MSSWS is lower than the investment cost of new FSS and as well as a contribution to savings from reducing the water content in the SSP by MSSWS. MSSWS screening process is quietly simple where the primary and secondary screening are tided in one rotary barrel screen that provides a relatively smaller investment cost savings compared to the stratified screening system of FSS from the grizzly station, primary, and secondary decks screening which are connected to each other's by transfer belt conveyors system.

3.4 Sensitivity Analysis

The risk of MSSWS investment cost changes can be caused by increasing commodity prices, various modifications needed to fit operational requirements, and the addition of earthwork material due to inaccuracy in topographic conditions.

Sensitivity analysis is undertaken by changing mining operational unit costs show breakeven point (NPV =0) when mining unit costs decreased around 30%. However, the possibility of decreasing the mining unit cost up to 30% for 8 years is unlikely in regard to inflation and commodity price escalation so that it may be neglected. Sensitivity analysis is undertaken by changing investment cost shows a breakeven point when investment cost increased around 40%. Likewise, the possibility is unlikely unless otherwise there is a major changed to meet operational required.

Sensitivity analysis is undertaken with a fixed discount rate, investment, and mining costs by changing in the ore hauling distance due to changes in the mining plan results in breakeven points when hauling distance increase of 62.5% or ore hauling distance becomes about 3.25 km. Sensitivity analysis by changing water content in SSP shows a relatively small affected on NPV and mining costs. Whenever MSSWS is assumed unsuccessful in reducing the water content in SSP yields NPV value is still positive of \$1,810,100 with IRR of 12.6%. Likewise, the sensitivity analysis of the discount rate shows a relatively small affected on the economic value of MSSWS. Whereas the breakeven point occurs at the same discount rate as the IRR yielded in alternative 2, which is about 17.4%.

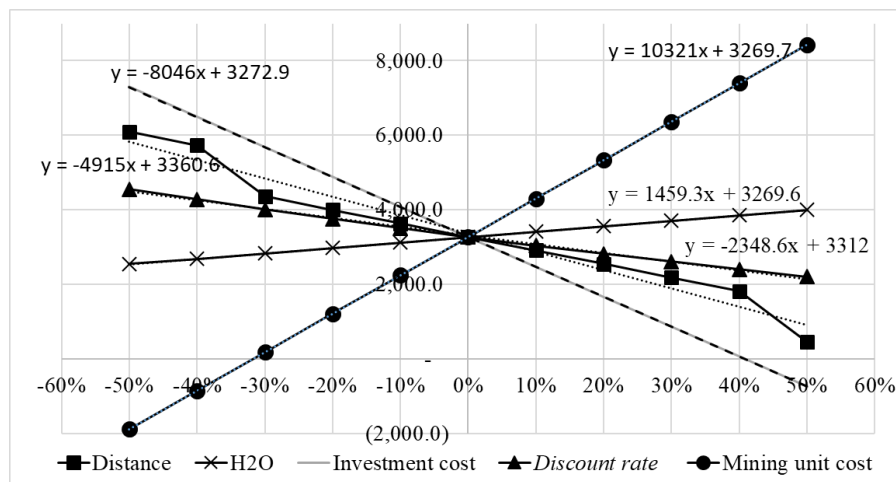


Figure 4. MSSWS sensitivity analysis.

4. Conclusion

An economic evaluation of some selected alternatives shows that purchasing a mobile screening station waterless system (alternative 2) is the most economical option that yields the highest NPV of \$3,269,700 and IRR of 17.4% with a payback period of 4 years. The decreasing of ore hauling distance is contributed by MSSWS yields to a significant cost saving in terms of reducing hauled trucks' investment and its operating cost. In accordance with sensitivity analysis, the economics of MSSWS is very sensitive to the changed of ore hauling distance that is likely to occur because of change in the mine plan. In addition, the major changes in investment cost and mine operational cost may be unlikely, but it is still possible to occur that affects the economical of MSSWS. To overcome these associated risks, it is proposed to develop an accurate mine plan, detail MSSWS engineering design, and well-maturing level on the assessment of MSSWS designed capacity to meet with the mine production rate plan. Furthermore, MSSWS yields on reducing the water content of ore that has potential cost saving in energy efficiency for the next ore drying process with High-Speed Diesel (HSD) in kiln drying has not been included in this study. It is recommended to develop a further study to assess the additional economic value of MSSWS that is implied energy combustion cost-saving at drying kiln. The framework presented in this paper is appropriated for the nickel laterite ore at this particular area. Therefore, further study should be required whenever it will be applied in a different geological environment of nickel ore laterite in others area.

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