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Article

Recovery of Fine Cassiterite from Tailing Dump in Jarin Tin Mine, Thailand

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Abstract. The beneficiation of cassiterite fines from tailing dumps in the Jarin Tin Mine, Thailand were studied through a wet concentration process and dry electrostatic and magnetic processes. The tailing dumps with the size of mineral smaller than 5 mm was collected through the tin mining in the area 20 years ago with the total amount of 17 million tons. The huge pile of the tailing dump may impact environmental in the area, so they need to be treated and recovered for the valuable heavy minerals and sand tailing for the local construction industry. The grade of the tailing dumps are 0.05% Sn, 0.002% Nb, 0.001% Ta. After the wet processing by the screen, hydrocyclone, spiral concentrator, and shaking table, the concentrate consist the most of cassiterite, ilmenite, garnet, zircon, monazite, xenotime, and quartz, containing 20% Sn with a yield of approximately 0.2%. The following dry processes used rotary dryer, screening, electrostatic separator, magnetic separator to separate cassiterite from the heavy minerals and quartz. The final tin concentrate can be upgraded to 72% Sn which can be sold to the tin smelting plant. The economic analysis of the cassiterite recovery processes was conducted using the discounted cash flow model in order to address the cost and benefit of the processes.

Keywords: Cassiterite, tin tailing, discounted cash flow model 1.

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1. Introduction

Most of Tin mineral found in Thailand is in the form of cassiterite (SnO_2). The occurrence of cassiterite is normally related to western granite formation extending from the north to the south of Thailand. There are two types of accumulation of cassiterite found in Thailand and they are in the form of primary and secondary types. The primary formation of tin is of hard rock type without weathering from the source rock while the secondary one is of weathered rock type, either in situ or some are transported from the source rock by stream or river, to form the alluvial deposit of tin and other associated heavy minerals [1]. Tin deposit is commonly mined by gravel pump (or is some cases by hydraulic) mining as this mining method are cheaper to recovery tin [3].

Primary concentrate: It has been briefly mentioned earlier that the multi-lane palong-jigs system is popularly adopted by gravel-pump miners for primary concentration of cassiterite. The set-up is logical, because it is capable of coping with a high volume of ground slurry (≈ 3,000 gallons per minute at 5 - 10 percent solids) and could maintain a high level of recovery of cassiterite, the result being confirmed by the absence of dulang washers who would usually wash for tin ore in the tailing discharged as shown in Fig.1 and 2. Several studies was conducted to improve the cassiterite to use in the industries in many countries [2, 4, 5, 6, 7, 10].

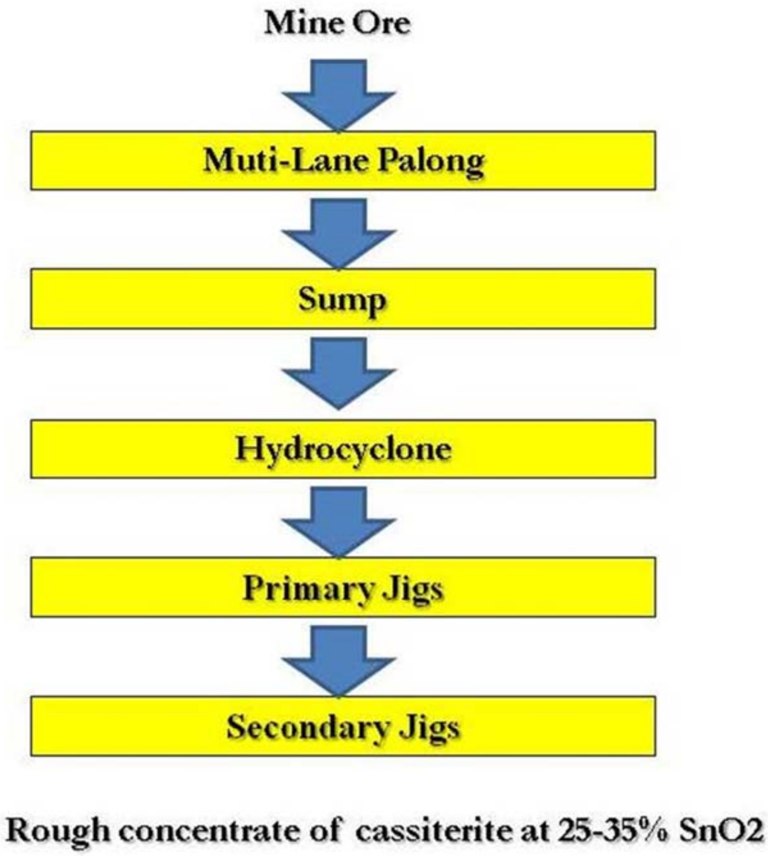

Fig. 1. Treatment of Tin Ore by Palong-Jigs system.

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Fig. 2. Apperance of Palong, Primary Jig and Secondary Jig.

Dressing of tin ore and associated by-product minerals

a) Simple practice

This simple practice has been the basis for cassiterite dressing for a very longtime. It consists of only two mains items, i.e., willoughby classifier and lanchute (see Figs. 3 and 4). A skilled worker would operate the classifier by manipulating water flow and produce feed products of different sizes. The finest cassiterite may be obtained with overflow fraction, whereas the coarse-grains will remain at the bottom of the Willoughby. Through such classification, fine-grained cassiterite will normally report in the fraction with other bigger-grained lighter minerals and gangues. Once treated in the lanchute, water action will more easily wash away other lighter but bigger mineral from the tin ore, thus facilitating the cleaning up process. Therefore, the willoughby classifier is still regarded as a classic and perhaps indispensable piece of equipment, for tin ore dressing. Shaking table may be added to the set-up to assist in treating the fine cassiterite, but it is optional.

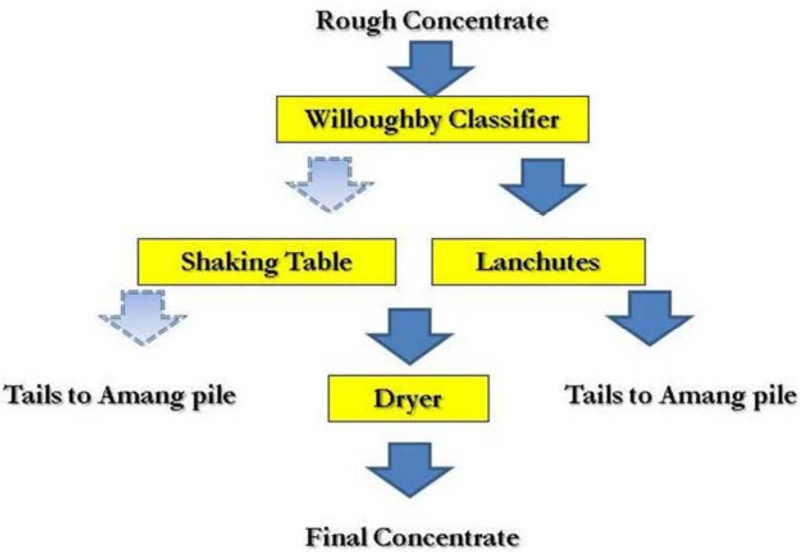

Fig. 3. Simple Dressing of Alluvial Tin Ore.

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Fig. 4. Apperance of Lanchute and Shaking Table.

b) Dressing of tin ore and by-products mineral
Processing of rough casiterite concentration (including tin-shed tailing "amang") to obtain concentrates of cassiterite and valuable by-product mineral were adequately described elsewhere.

Basically, the equipment will include shaking tables, high-tension and magnetic equipment of suitable type, design and number to cope with the feed rate desired. Invariably, willoughby classifier is used for feed classification before subsequent separation stages of gravity concentration. For refining certain by-product mineral such as xenotime and columbite struverite, willoughby can play an important part in improving the grades of the concentrates of mineral concerned.

In treating by-product, or heavy minerals, suitable forms of equipment as well as professional skills are considered essential for the production of concentrates of desirable and marketable grade. Such equipment as air-table can be useful for upgrading certain mineral obtained from the amang as shown in Fig. 5.

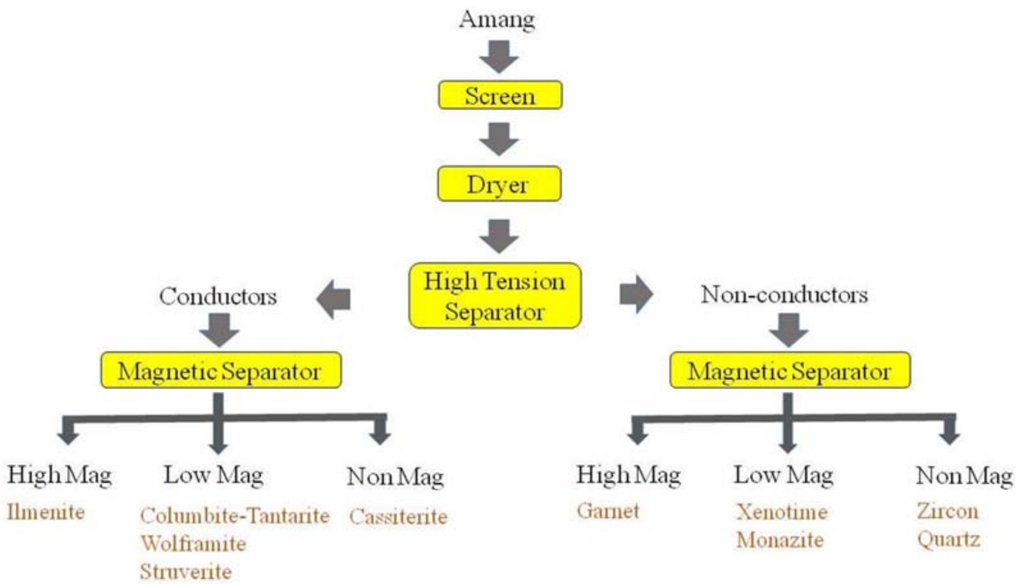

Fig. 5. Typical flow sheet of mineral processing from Amang.

About 1,500 kilograms with 13 drilling holes of Jig tailings were collected from the abandoned Jarin tin mines for this study. The mine is located in Kanchanaburi Province, western Thailand (Fig. 6). The mine used to be operated by dry stripping mining method for quite a period of time in the past. However, the mine is now left abandoned around 17 million tons.

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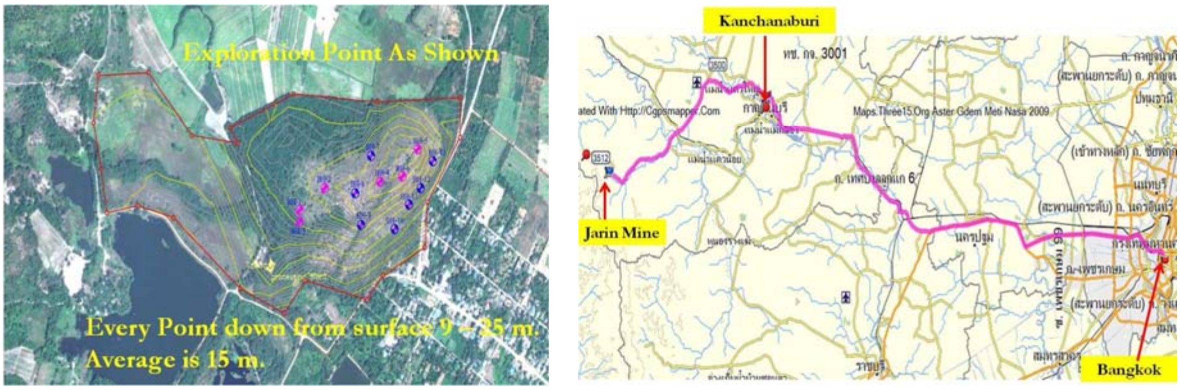

Fig. 6. Map of the study area in the Kanchanaburi province western Thailand.

2. Mineralogical Study

The above-mentioned Jig tailings were sampled by cone and quartering method to obtain about 2 kilograms for mineralogical study. The mineralogical study has been done on the obtained sample according to the flow sheet in Fig. 7.

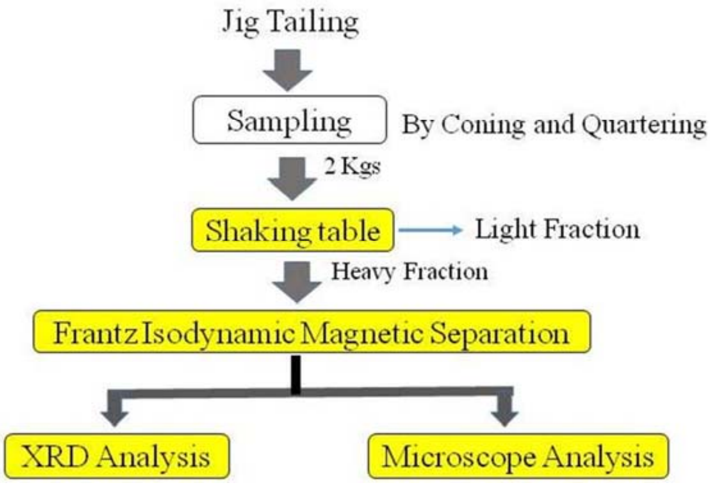

Fig. 7. Flow sheet of mineralogical study of Jig tailings.

Using the combination of Shaking Table, Frantz Isodynamic Magnetic Separator, X-ray Diffractometer and optical microscope, the Jig tailings were found to contain some valuable minerals such as cassiterite, columbite-tantalite, garnet, ilmenite, hydro- ilmenite, xenotime, monazite, tourmaline, zircon and quartz.

3. Study of Distribution of Tin, Niobium-Tantalum and in the Jig Tailings

From the valuable minerals identified in the 13 drilling holes of Jig tailings, chemical analysis was done to see the distribution of some valuable elements i.e. Sn (for cassiterite) and Nb_2O_5+Ta_2O_5 (for columbite-tantalite). Figure 8 shows the flow sheet of the procedure analysis and distribution of these valuable elements.

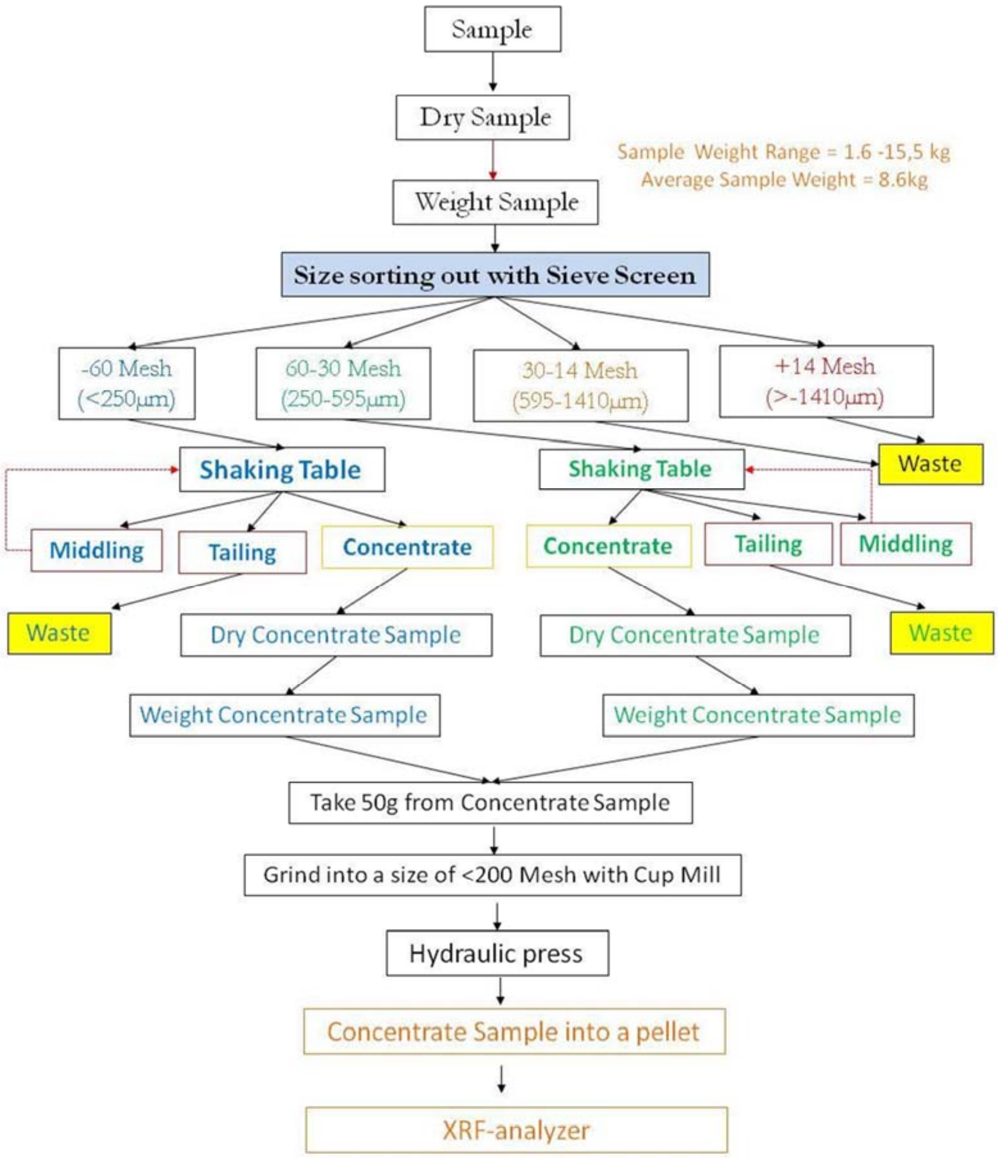

Fig. 8. Flow sheet of the chemical analysis and distribution of some valuable elements in the Jig tailings.

Table 1 shows that the valuable elements Sn, Nb_2O_5 and Ta_2O_5 mostly concentrate in the finer fractions of the Jig tailings. It can be decided that if further concentration of the tin tailings have to be done, the coarser size above 595 microns (which accounts for about 60% by weight) should be screened off as less Sn, Nb_2O_5 and Ta_2O_5, can be noticed from Table 1. Then, the screened fraction (-595 micron) should be further concentrated by gravity concentrators. However, for better efficiency of gravity separation, it is decided that this undersized fraction should be further screened (using 250 micron screen) into two different size fractions. Then, these two size fractions would be concentrated by two different gravity concentrators due to the coarser size fraction by gravity method behaves differently from the finer size fraction. After that, the heavy fraction from gravity separation would be further treated by high-tension and magnetic separators respectively to obtain concentrates of each valuable mineral.

Table 1. Grade and distribution of the valuable elements (Sn, Nb_2O_5 and Ta_2O_5) in each drilling hole fraction of the Jig tailings.

Hole	Depth(m)	%Sn	%Nb_2O_5	%Ta_2O_5	Hole	Depth(m)	%Sn	%Nb_2O_5	%Ta_2O_5
1	10	0.064	0.10	0.007	8	14.5	0.090	0.002	0.003
2	16	0.046	0.002	0.001	9	13	0.069	0.001	0.003
3	19	0.026	0.006	0.004	10	9	0.077	0.001	0.004
4	22	0.012	0.002	0.002	11	10	0.069	0.001	0.004
5	25	0.001	0.002	0.001	12	12	0.092	0.002	0.004
6	20	0.008	0.001	0.001	13	13	0.122	0.002	0.004
7	15	0.138	0.002	0.004					

4. Separation of the Jig Tailings to Obtain Valuable Mineral Concentrates

Jig tailings have been screened using 595 micron and 200 micron screen to obtain three size fractions namely +595 micron, -595+200 micron, and -200 micron fractions. The +500 micron fraction which contains very few Sn and should be discarded as waste. The -500+200 micron and -200 micron fractions are then processed by gravity separators using Spiral Concentrator with Shaking Table (corse sand) and Spiral Concentrator with Shaking Table (fine sand), respectively. The heavy concentrates obtained from each separation are then dried before feeding to high-tension separators and then Mclean magnetic separators. The grades and distribution of Sn of each separated fraction can be shown according to Fig. 9.

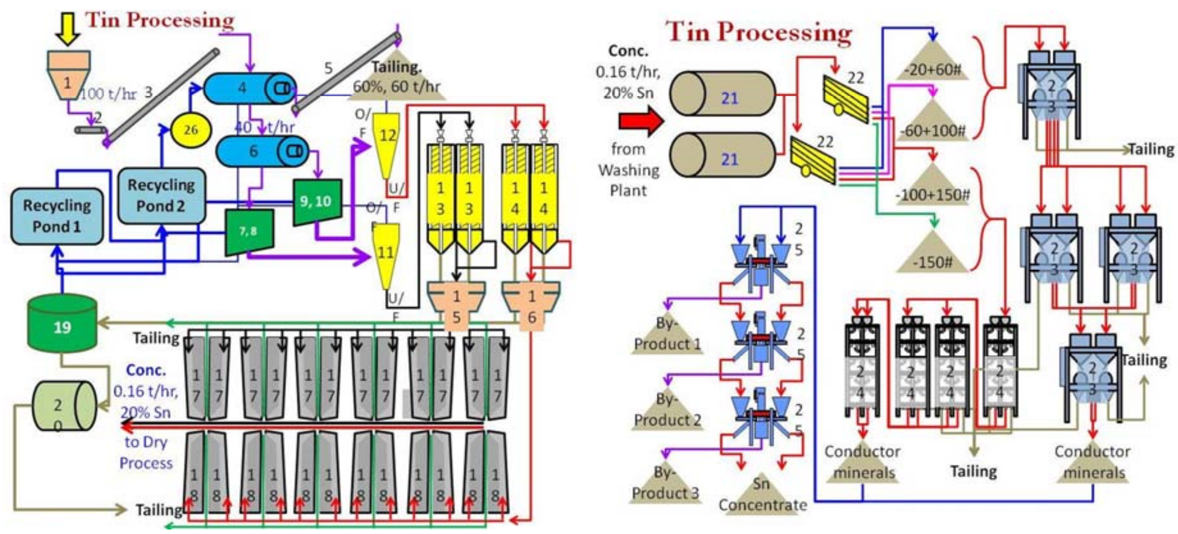

Fig. 9. Wet and dry dressing of the tailing dump.

5. Discounted cash flow

The discounted cash flow methods are widely accepted and used in the industry for all types of investment, which it gives a confident to investor because of the investing need to spend a lot of money. It is necessary to calculate the Internal Rate of Return (IRR), Net Present Value (NPV), Payback period, and discount rate [11,12], which are the most important parameters for financial analysis.

From the financial analysis of this project, the IRR was 38%, the NPV was 286,053,112 baht, and the payback period equal to 2.29 year. The data for calculation of the discounted cash flow of this project is listed in Tables 2, 3, and 4.

Table 2. Parameter for financial analysis.

No.	Parameter	Value	Unit
1	Tin reserve	17,611,402.00	ton
2	Tin grade (Sn)	0.05	percent
3	Tin price	407,000.00	baht/ton
4	Tin royalty	30,062.50	baht/ton
5	Diesel price	30	baht/liter
6	Electricity	4	baht/unit
7	Discount rate	13	percent
8	Feed rate	300	ton/hour
9	Recovery	75	percent

Table 3. Investment for financial analysis.

No.	Detail	Price	Unit
1	License	100,000,000.00	baht
2	Construction	42,240,000.00	baht
3	Machine and Equipment of dressing	75,800,000.00	baht
4	Vehicles 4 cars	4,400,000.00	baht
5	Construction of mine site	4,000,000.00	baht
6	Machine and Equipment of mine site	25,200,000.00	baht
7	Capital Expenditure	108,540,000.00	baht
	Total	360,180,000.00	baht

Table 4. Cash flow of the project.

Year	0	1	2	3	4	5	6	7	8
Capex (Baht/ton)	360,180,000								
Working Capital	10,000,000								
Total Investment	370,180,000								
Price of Tin (Baht/Ton)	407,000	407,000	407,000	407,000	407,000	407,000	407,000	407,000	407,000
Tin production per year (ton/year)	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
Revenue of Tin (Baht/year)		447,700,163	447,700,163	447,700,163	447,700,163	447,700,163	447,700,163	447,700,163	447,700,163
Gross Revenue		447,700,163	447,700,163	447,700,163	447,700,163	447,700,163	447,700,163	447,700,163	447,700,163
Royalty of Tin	30,063	33,068,762	33,068,762	33,068,762	33,068,762	33,068,762	33,068,762	33,068,762	33,068,762
Sale and Marketing	10%	44,770,016	44,770,016	44,770,016	44,770,016	44,770,016	44,770,016	44,770,016	44,770,016
Sale Expense		77,838,778	77,838,778	77,838,778	77,838,778	77,838,778	77,838,778	77,838,778	77,838,778
Total Revenue		369,861,384	369,861,384	369,861,384	369,861,384	369,861,384	369,861,384	369,861,384	369,861,384
Depreciation		13,292,000	13,292,000	13,292,000	13,292,000	12,412,000	12,412,000	12,412,000	60,356,000
Year	0	1	2	3	4	5	6	7	8
Operating Expense		140,319,819	148,681,784	157,745,074	168,183,436	180,142,944	193,851,257	209,563,521	227,572,740
Income before Tax		216,249,566	207,887,601	198,824,310	188,385,948	177,306,440	163,598,127	147,885,863	81,932,644
Tax 30%	30%	64,874,870	62,366,280	59,647,293	56,515,784	53,191,932	49,079,438	44,365,759	24,579,793
Income after tax		151,374,696	145,521,321	139,177,017	131,870,164	124,114,508	114,518,689	103,520,104	57,352,851
Net Cash flow	(370,180,000)	164,666,696	158,813,321	152,469,017	145,162,164	136,526,508	126,930,689	115,932,104	117,708,851

6. Conclusion

This pre-feasibility study to including reserve estimation by using the information from the Department of Primary Industries and Mine, mine design and planning, financial model the minable reserve is 17,611,402 metric tons of tin ore was estimated and with production of 2,201,405 metric tons per year to processing plant of tin product 1,100 metric tons per year. The result of the financial model analysis showed that the project had the Internal Rate of Return (IRR) of 38% and its Net Present Value (NPV) was 286,053,112 baht, so the mine life is 8 years.

This project is financially viable at this level of the study. However, more data can be collected to increase the level of confident of this study.

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