Methods of Financial Modelling

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Abstract

Dynamic and static financial models are mathematical modeling tools. Evaluating the risk of a financial investment is essential for investors. Financial modelling methods are used to conduct investment analysis supporting mining engineers and investors in decision making. In this paper different financial modelling methods are discussed. A case study example of a financial evaluation of two different investment possibilities in copper mines is presented to elaborate an example of these financial modelling methods.

1. Introduction

The evaluation of risks is essential before investment decisions are made. Financial risks can be assessed by creating financial models. These financial models should be justified with a sensitivity analysis. Especially in the mining industry other risks have to be considered additionally. These risks might include changing and variable geology, environmental and social aspects, H&S standards and other risks, related to the country in which the mine is located. This paper introduces different financial modelling methods and demonstrates their application with a case study example. Within this case study the financial aspects of two copper mines are evaluated in a detailed dynamic cash flow model. A risk assessment supports the conclusions drawn from this dynamic cash flow model. Finally, other influencing factors are considered together with the results of a sensitivity analysis of the dynamic cash flow model to justify the final investment decision.

2. Financial Modelling

Static financial modelling tools are used to predict the profit of an investment. The future value of the initial investment and of the capital and operating costs is not considered in static financial models. To calculate the profit in a static cash flow model CAPEX and OPEX are summed up and subsidized from the mine revenue.

Dynamic financial modelling tools are also used to predict the profit of an investment. The initial investment and the capital and operating costs are discounted by a discounting factor to calculate the future value of the invested money. The calculation of the Net Present Value (NPV) and the Internal Rate of Return (IRR) are methods to create discounted cash flow models. Especially to evaluate high-risk investments a risk-adjusted discounting rate is useful. In the mining industry the country risk for a mining project is a good example for a reason to use a risk-adjusted discounting rate. The country risk can be assumed from different data sources and varies between 10 - 25 %.

Financial models like cash flow models are based on assumptions and conflicting results are likely to occur from different interpretations.

3. Case Study – Financial evaluation of two Copper Mines

The financial analysis of two Copper Mines presented in this paper was done in 2018 during the European Mining Course (EMC). The objective of this Case Study was to perform a detailed financial analysis of Mine A and Mine B and to give an investment recommendation.

The cumulative Net Present Value (NPV) in year 2035 is $1.343.720.259 for Mine A and $846.754.890 for Mine B according to the cash flow model (see Appendix) that was developed in this case study. The cumulative NPV for Mine B is only lower due to a Brownfield investment in year 2030. McKinsey & Company confirmed in 2018 during the presentation of this case study the assumption that the Brownfield investment in the underground infrastructure of Mine B extends the mine life of Mine B significantly beyond 2035. Therefore is the cumulative NPV in year 2035 not a reliable profitability indicator for the investor. Mine B in Zambia has a higher EBIT per ton refined copper measured in [$/ton] then Mine A in Chile, as shown in Figure 1.

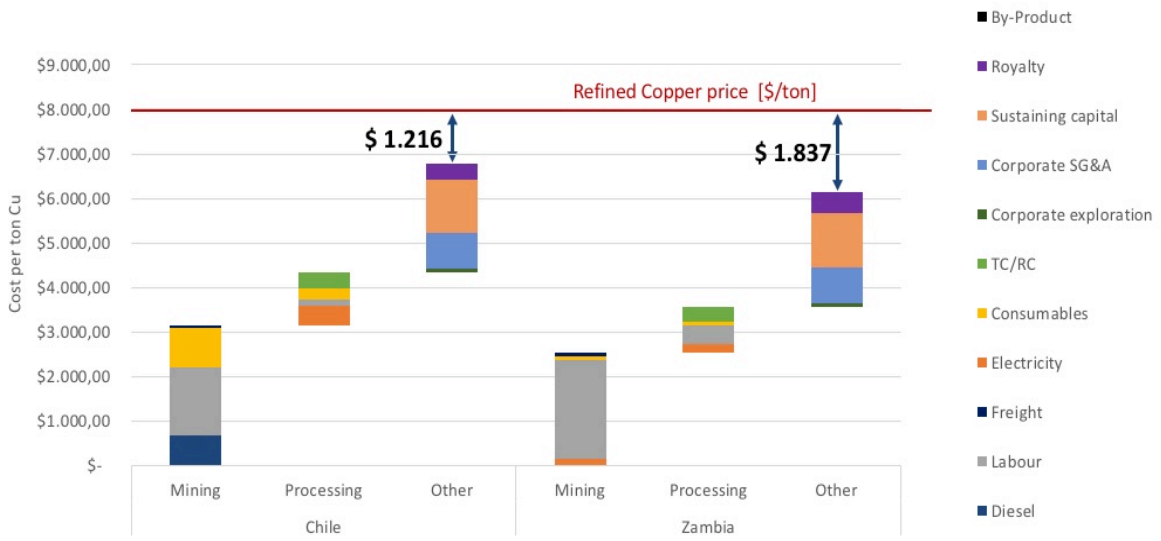

Figure 1: Diagram demonstrating the EBIT of Mine A (Chile) and Mine B (Zambia)

For the risk assessment of the financial analysis other factors were considered. These rated factors are listed in Table 1. To evaluate the geopolitical risk of the potential investments in these two copper mines a development trend was assumed from data out of different sources (e.g. data from Institutions like the World Bank). A positive development of the geopolitical and social risks was assumed for Zambia. A negative development of the geopolitical and social risks was assumed for Chile.

Factors	Chile	Zambia
Water Supply	-	o
Environmental Impact	- -	+
Availability of qualified workforce	+ +	o
Availability of supplies (maschinery parts, etc.)	+ +	o
Simplicity to obtain social licence to operate	+	-
Political stability	o	-
Risk of labour disputes	o	- -
Health and Safety Standards	o	- -
By-products		++

Table 1: Other influencing factors considered during the risk assessment of the financial analysis

Within the sensitivity analysis of the financial analysis mainly the operating costs and the copper price were considered as volatile variables. The variables considered the most important within the operating costs are diesel, electricity, labour and consumable costs.

After applying these evaluated variables on the financial model of the Zambian Mine B, the potential investment in Mine B was considered less sensitive. The geopolitical risk in Zambia was considered less important; than the other influencing factors (for example the foreign exchange risk) and the results of the sensitivity analysis. The high amount of cobalt as a by-product in Mine B was also considered an advantage regarding the cobalt demand outlook in 2018. The final investment recommendation in this case study was to invest into Mine B in Zambia.

In summary, the evaluated results of the case study and the comments from McKinsey & Company showed in 2018 that sometimes a perceived high-risk investment (e.g. the Zambia Mine) can be regarded as a low-risk investment after a validity check is done by a certain group of persons with a certain mindset.

4. Conclusion

A variety of financial modelling methods exist to predict the profitability of an investment. A financial analysis consists at least of a detailed cash flow model, a risk assessment and a sensitivity analysis of the cash flow model which must be included. Discounted cash flow models are created by calculating the NPV or the IRR. These discounted cash flow models take the time value of money into account. Especially in the mining industry risk-adjusted discounting rates are used to increase the validity of the financial assessment of a potential investment.

The case study presented in this paper demonstrates the steps that are done during a financial analysis of two potential investments and outlines how the decision making process is influenced by assumptions.

5. References

Fahl, Korte, Meyer, Monteith (2018) – Presentation: Case Study for McKinsey & Company. RWTH Aachen University, 27. April, 2018.

6. Appendix

	Given Information	
	Mine A	Mine B
Country	Chile	Zambia
Start-up	2008	1931
Mining method	Open pit	Underground
Type of deposit	Porphyry	Stratiform
Production	~130 kt of refined copper	~100 kt of refined copper
Geological Factors		
Strip Ratio	~3.5	Not applicable (10% waste dilution)
Mill head grade	~0.5% Cu	~1.8% Cu
Mining Method	Open pit truck and shovel	Underground stoping
Other		
Beneficiation Route	Heap leach	Flotation
Metallurgical Recovery	~73%	~93%
By- products	None	Cobalt (2 million USD per annum fixed)
Discharge point	On-site SxEw	Smelter

Given Information		Mine A	Mine B	Unit
Mining	Diesel	0,8	0,03	L/t(rock)
	Electricity	0	0,03	MWh/t(rock)
	Labour	55000	650	t(rock)/FTE
	Consumables	$ 0,70	$ 1,20	$/t(rock)
Processing	Electricity	3,5	3	MWh/t(Cu)
	Labour	500	55	t(Cu)/FTE
	Consumables	$ 250,00	$ 90,00	$/t(Cu)
Other costs	Corporate exploration	1%	1%	of revenue
	Corporate SG&A	10%	10%	
	Sustaining capital	15%	15%	
	Corporate tax rate	22%	22%	
	Discount rate	6,3%	6,3%	
Geologial Factors	Strip ratio	3,5	0,1	t(waste)/t(ore)
	Mill head grade	0,5%	1,8%	
Others	Metallurgical Recovery	73%	93%	
	By-products	$ -	$ 2.000.000,00	$/a
Country Factors	Electricity price	125	70	$/MWh
	Diesel price	0,68	1,7	$/L
	Wages	69000	22000	$/FTE
	Royality	9%	6%	
Global costs	Flat copper price	8000	8000	$/t(Cu)
	TC/RC	350	350	$/t(Cu)
	Freight	80	80	$/t(Cu)
Production	refined copper	130000	100000	t(Cu)/a

Figure 2: Information for both Mines used in the Case Study (Fahl & Meyer, 2018)

Production	Mine A	Mine B	Unit
refined copper	130000	100000	t(Cu)/a
Ore	35616438,36	5973715,651	t(ore)/a
Rock	160273972,6	6571087,216	t(rock)/a

Consumption		Mine A	Mine B	Unit
Mining	Diesel	128219178,1	197132,6165	L/a
	Electricity	0	197132,6165	MWh/a
	Labour	2914,072229	10109,36495	FTE/a
Processing	Electricity	455000	300000	MWh/a
	Labour	260	1818,181818	FTE/a

Costs & Incomes		Mine A	Mine B	Unit
Mining	Diesel	$ -87.189.041,10	$ -335.125,45	$/a
	Electricity	$ -	$ -13.799.283,15	$/a
	Labour	$ -201.070.983,81	$ -222.406.028,86	$/a
	Consumables	$ -112.191.780,82	$ -7.885.304,66	$/a
Processing	Electricity	$ -56.875.000,00	$ -21.000.000,00	$/a
	Labour	$ -17.940.000,00	$ -40.000.000,00	$/a
	Consumables	$ -32.500.000,00	$ -9.000.000,00	$/a
Other Costs	Corporate exploration	$ -10.400.000,00	$ -8.020.000,00	$/a
	Corporate SG&A	$ -104.000.000,00	$ -80.200.000,00	$/a
	Sustaining capital	$ -156.000.000,00	$ -120.300.000,00	$/a
Global Costs	TC/RC	$ -45.500.000,00	$ -35.000.000,00	$/a
	Freight	$ -10.400.000,00	$ -8.000.000,00	$/a
Opex (without Royality)		$ -834.066.805,73	$ -565.945.742,12	$/a
Revenues	Copper	$ 1.040.000.000,00	$ 800.000.000,00	$/a
	By-Products	$ -	$ 2.000.000,00	$/a
	Total	**$ 1.040.000.000,00**	**$ 802.000.000,00**	$/a
Operating profit (without Royality)		$ 205.933.194,27	$ 234.054.257,88	$/a
Royality		$ -47.900.987,48	$ -48.120.000,00	$/a
Opex		**$ -881.967.793,21**	**$ -614.065.742,12**	**$/a**
Gross income		$ 158.032.206,79	$ 187.934.257,88	$/a
EBIT		$ 1.215,63	$ 1.879,34	$/t

Figure 3: Detailed Cost Calculations for both Mines (Meyer, 2018)

Discount rate	6,3%

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Revenues	$ -	$ 1.040.000.000,00	$ 1.040.000.000,00	$ 1.040.000.000,00	$ 1.040.000.000,00	$ 1.040.000.000,00	$ 1.040.000.000,00	$ 1.040.000.000,00	$ 1.040.000.000,00	$ 1.040.000.000,00
Opex	$ -	$ -881.967.793,21	$ -881.967.793,21	$ -881.967.793,21	$ -881.967.793,21	$ -881.967.793,21	$ -881.967.793,21	$ -881.967.793,21	$ -881.967.793,21	$ -881.967.793,21
= Gross income	$ -	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79
Depreciation	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
= Net incom before Tax	$ -	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79
Tax	$ -	$ -34.767.085,49	$ -34.767.085,49	$ -34.767.085,49	$ -34.767.085,49	$ -34.767.085,49	$ -34.767.085,49	$ -34.767.085,49	$ -34.767.085,49	$ -34.767.085,49
= Profit after Tax	$ -	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29
Capex	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
= Cash Flow	$ -	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29
Cumulative cash flow	$ -	$ 123.265.121,29	$ 246.530.242,59	$ 369.795.363,88	$ 493.060.485,18	$ 616.325.606,47	$ 739.590.727,76	$ 862.855.849,06	$ 986.120.970,35	$ 1.109.386.091,65
Discount factor	1	0,940733772	0,88498003	0,832530602	0,783189654	0,736772958	0,693107204	0,652029355	0,613386035	0,577032958
NPV	$ -	$ 115.959.662,55	$ 109.087.170,79	$ 102.621.985,69	$ 96.539.967,73	$ 90.818.408,02	$ 85.435.943,58	$ 80.372.477,49	$ 75.609.103,95	$ 71.128.037,58
Cumulative NPV	$ -	$ 115.959.662,55	$ 225.046.833,35	$ 327.668.819,04	$ 424.208.786,77	$ 515.027.194,79	$ 600.463.138,37	$ 680.835.615,86	$ 756.444.719,81	$ 827.572.757,39

Cumulative NPV Total	$ 1.343.720.258,67

2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
$ 1.040.000.000,00	$ 1.040.000.000,00	$ 1.040.000.000,00	$ 1.040.000.000,00	$ 1.040.000.000,00	$ 1.040.000.000,00	$ 1.040.000.000,00	$ 1.040.000.000,00	$ 1.040.000.000,00	$ 1.040.000.000,00
$ -881.967.793,21	$ -881.967.793,21	$ -881.967.793,21	$ -881.967.793,21	$ -881.967.793,21	$ -881.967.793,21	$ -881.967.793,21	$ -881.967.793,21	$ -881.967.793,21	$ -881.967.793,21
$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79
$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79	$ 158.032.206,79
$ -34.767.085,49	$ -34.767.085,49	$ -34.767.085,49	$ -34.767.085,49	$ -34.767.085,49	$ -34.767.085,49	$ -34.767.085,49	$ -34.767.085,49	$ -34.767.085,49	$ -34.767.085,49
$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29
$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29	$ 123.265.121,29
$ 1.232.651.212,94	$ 1.355.916.334,23	$ 1.479.181.455,53	$ 1.602.446.576,82	$ 1.725.711.698,11	$ 1.848.976.819,41	$ 1.972.241.940,70	$ 2.095.507.062,00	$ 2.218.772.183,29	$ 2.342.037.304,58
0,542834391	0,510662645	0,480397596	0,451926243	0,425142279	0,3999457	0,376242427	0,353943958	0,332967035	0,313233335
$ 66.912.547,11	$ 62.946.892,86	$ 59.216.267,98	$ 55.706.743,16	$ 52.405.214,64	$ 49.299.355,26	$ 46.377.568,44	$ 43.628.944,91	$ 41.043.221,93	$ 38.610.745,00
$ 894.485.304,50	$ 957.432.197,36	$ 1.016.648.465,33	$ 1.072.355.208,49	$ 1.124.760.423,13	$ 1.174.059.778,39	$ 1.220.437.346,83	$ 1.264.066.291,74	$ 1.305.109.513,68	$ 1.343.720.258,67

Figure 4: Detailed Cash Flow Model Chilean Mine A (Meyer, 2018)

Discount rate	6,3%

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Revenues	$ -	$ 802.000.000,00	$ 802.000.000,00	$ 802.000.000,00	$ 802.000.000,00	$ 802.000.000,00	$ 802.000.000,00	$ 802.000.000,00	$ 802.000.000,00	$ 802.000.000,00
Opex	$ -	$ -614.065.742,12	$ -614.065.742,12	$ -614.065.742,12	$ -614.065.742,12	$ -614.065.742,12	$ -614.065.742,12	$ -614.065.742,12	$ -614.065.742,12	$ -614.065.742,12
= Gross income	$ -	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88
Depreciation	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
= Net incom before Tax	$ -	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88
Tax	$ -	$ -41.345.536,73	$ -41.345.536,73	$ -41.345.536,73	$ -41.345.536,73	$ -41.345.536,73	$ -41.345.536,73	$ -41.345.536,73	$ -41.345.536,73	$ -41.345.536,73
= Profit after Tax	$ -	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15
Capex	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
= Cash Flow	$ -	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15
Cumulative cash flow	$ -	$ 146.588.721,15	$ 293.177.442,29	$ 439.766.163,44	$ 586.354.884,59	$ 732.943.605,73	$ 879.532.326,88	$ 1.026.121.048,03	$ 1.172.709.769,18	$ 1.319.298.490,32
Discount factor	1	0,940733772	0,88498003	0,832530602	0,783189654	0,736772958	0,693107204	0,652029355	0,613386035	0,577032958
NPV	$ -	$ 137.900.960,63	$ 129.728.090,90	$ 122.039.596,33	$ 114.806.769,83	$ 108.002.605,67	$ 101.601.698,66	$ 95.580.149,26	$ 89.915.474,37	$ 84.586.523,40
Cumulative NPV	$ -	$ 137.900.960,63	$ 267.629.051,53	$ 389.668.647,86	$ 504.475.417,69	$ 612.478.023,37	$ 714.079.722,03	$ 809.659.871,28	$ 899.575.345,65	$ 984.161.869,05

Cumulative NPV Total	$ 846.754.890,07

2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
$ 802.000.000,00	$ 802.000.000,00	$ 802.000.000,00	$ 802.000.000,00	$ 802.000.000,00	$ 802.000.000,00	$ 802.000.000,00	$ 802.000.000,00	$ 802.000.000,00	$ 802.000.000,00
$ -614.065.742,12	$ -614.065.742,12	$ -614.065.742,12	$ -614.065.742,12	$ -614.065.742,12	$ -614.065.742,12	$ -614.065.742,12	$ -614.065.742,12	$ -614.065.742,12	$ -614.065.742,12
$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88
$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ -478.732.408,79	$ -478.732.408,79	$ -478.732.408,79	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88
$ -41.345.536,73	$ -41.345.536,73	$ -41.345.536,73	$ -41.345.536,73	$ -	$ -	$ -	$ -41.345.536,73	$ -41.345.536,73	$ -41.345.536,73
$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15	$ 187.934.257,88	$ 187.934.257,88	$ 187.934.257,88	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15
$ -	$ -	$ -	$ -	$ -666.666.666,67	$ -666.666.666,67	$ -666.666.666,67	$ -	$ -	$ -
$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15	$ -478.732.408,79	$ -478.732.408,79	$ -478.732.408,79	$ 146.588.721,15	$ 146.588.721,15	$ 146.588.721,15
$ 1.465.887.211,47	$ 1.612.475.932,62	$ 1.759.064.653,76	$ 1.905.653.374,91	$ 1.426.920.966,12	$ 948.188.557,34	$ 469.456.148,55	$ 616.044.869,70	$ 762.633.590,85	$ 909.222.311,99
0,542834391	0,510662645	0,480397596	0,451926243	0,425142279	0,3999457	0,376242427	0,353943958	0,332967035	0,313233335
$ 79.573.399,24	$ 74.857.384,05	$ 70.420.869,28	$ 66.247.290,01	$ -203.529.387,49	$ -191.466.968,48	$ -180.119.443,53	$ 51.884.192,16	$ 48.809.211,82	$ 45.916.473,96
$ 1.063.735.268,29	$ 1.138.592.652,34	$ 1.209.013.521,63	$ 1.275.260.811,64	$ 1.071.731.424,15	$ 880.264.455,67	$ 700.145.012,14	$ 752.029.204,30	$ 800.838.416,12	$ 846.754.890,07

Figure 5: Detailed Cash Flow Model Zambian Mine B (Meyer, 2018)