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Research Article

Economic Evaluation and Risk Analysis of the Bisha Volcanogenic Massive Sulphide Mining Project

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Abstract

Bisha Mining Share Company (BMSC), Eritrea, is a subsidiary of Nevsun Resources of Canada. BMSC completed exploration work in the year 2005, which discovered Volcanogenic Massive Sulphide (VMS) deposit containing commercial quantities of gold, silver, copper and zinc at Bisha. An optimal open pit has been designed for the exploitation of the deposit using MineSight and Surpac software under the given geotechnical and economic parameters. The total tonnage from the optimised pit was 90 161 903t at a stripping ratio of 3.4. A Life of Mine (LOM) schedule carried out in Minesched predicted a mine life of 10 years and defined the transitional periods for the exploitation of gold, silver, copper and zinc deposits. The objective of this paper is to determine the economic viability of the project with its associated risk under the Mining and Mineral Laws of Eritrea. With a capital structure of 100% equity, a discounted cash flow analysis was conducted which resulted in a Net Present Value (NPV) of US$344 553 000 @10% discount rate and an Internal Rate of Return (IRR) of 29.9% which suggest the project to be economically viable. Sensitivity analysis conducted revealed that, the project will continue to be economically viable until the revenue decreases beyond 28.5%. Risk analysis using Monte Carlo simulation indicated a risk of failure of 18%. It is recommended that other financing sources such as long-term loans be exploited to further improve the economics and reduce the financial burden on the investors.

Keywords: Mineral project evaluation; Risk analysis; Cash flow analysis; Sensitivity analysis; Monte carlosimulation

Introduction

Mineral projects have a number of characteristics or features which make them somewhat unique from other investment opportunities. Gentry & O'Neil [1] agree that the investment environment associated with the mining industry is unique when compared with the environment encountered by typical manufacturing industries and explain further that some of these characteristics include capital intensity, long preproduction periods, high risks and the fact that minerals are non-renewable resource.

Torries [2] defines mineral project evaluation as the process of identifying the economic feasibility of a mineral project that requires a capital investment and making the investment decision. De la Vergne [3] defines mineral economic evaluation as rational continuous process whereby final decisions on alternate choices, either of a different mining project or changes in parameters, such as production rates and methods are made. Tschabrun [4] is of the view that mineral economic evaluation is the method used to determine the economic viability of a mineral project and it is the primary measure of alternative investment opportunities. Eshun & Mireku [5] define mineral project evaluation as the economic analysis by which investment decisions are made with respect to mining projects.

From the given definitions, mineral economic evaluation can be defined as a pragmatic approach whereby a mineral investment is thoroughly examined using the project's economic parameters such as revenue, capital cost, operating cost, taxes and allowances in a discounted cash flow analysis to determine the viability of the project.

Risk analysis in mineral project evaluation allows a thoughtful consideration of both anticipated problems and unexpected occurrences. Consequently, any evaluation of a project's robustness must take into account its various risk areas and the potential for adverse interaction of those risks on the project. According to Rozman [6], the resources business like so many others is all about risk management. Seymour [7] argues that the key objective of a mining company is to maximize shareholder contribution within acceptable risks. Sayers et al. [8] define risk as a combination of the chance of a particular event, with the impact that the event would

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cause if it occurs. Hence risk analysis of a mineral project involves the investigation of the possible effect of changes in the economic parameters on the viability of the mineral project.

Bisha Mining Share Company (BMSC), Eritrea, is a subsidiary of Nevsun Resources of Canada. BMSC completed exploration work in the year 2005, which discovered Volcanogenic Massive Sulphide deposit containing commercial quantities of gold, silver, copper and zinc at Bisha. Net Smelter Returns values were modelled using a script developed in Surpac. The deposit was optimised and an open pit was designed using Mine Sight software under the given geotechnical and economic parameters with a marginal tonnage deviation of 3%. A Life of Mine (LOM) schedule carried out in Minesched predicted a mine life of 10 years and defined the transitional periods for the exploitation of gold, copper and zinc deposits [9]. The objective of this paper is to determine the economic viability of the project with its associated risk under the Mining and Mineral Laws of Eritrea.

Materials and Methods

Data was obtained from BSMC and MS Excel software was used in the data analysis. Detailed method of estimation was employed in the capital cost, operating cost and revenue estimation. Discounted cash flow analysis was used to evaluate the economic viability of the project while sensitivity analysis was conducted to assess the level of independent changes in the economic parameters that the project could absorb and still be economically viable. Finally, risk analysis using Monte Carlo simulation was conducted to investigate the effect of simultaneous changes in the economic parameters on the viability of the project to estimate the probability of failure of the project.

Capital cost estimation

Basis of estimation: The following served as the basis in the estimation of the capital cost:

a. Capital cost estimates were based on price quotations from international and local suppliers and contractors.

b. Medium to long term capital expenditure comprised mainly of mining fleet replacement, process plant expansion and sustaining capital associated with tailings dam lifts and progressive community resettlement works.

c. Cost contingency allowance of 15% was applied to take care of uncertain elements within the project scope and to reduce the risk of cost overrun.

d. Table 1 presents the exchange rates used in converting the input pricing sourced in currencies other than US dollars for the capital cost estimates.

Table 1: Currency exchange rate.

Currency		Exchange Rate to USD
Australia Dollar	AUD	0.75
United States of America	USD	1
Euro	Euro	1.09
Canadian Dollar	CAD	0.75
Swiss Franc	CHF	1
British Pound	GBP	1.52
South African Rand	ZAR	0.07
Ghanaian Cedis	GHS	0.26
Eritrean Nakfa	NKFA	0.06

Capital cost estimates

The bulk of the capital expenditure is incurred in the project's construction period and this is associated with the purchasing of the mine equipment, processing plant installation and infrastructural development. Table 2 presents the summary of the project's capital cost estimates. This has been grouped into three categories with the following codes:

Table 2: Capital cost summary.

CCE	Description	Amount (US $000's)
CCE 1	**Direct Capital Cost**	
1	Mining	44 882
2	Processing	167 597
3	Infrastructure and site works	22 657
	Subtotal	**235 136**
CCE 2	**Indirect Capital Cost**	
1	Acquisition & exploration	25 000
2	Eia and environmental permit	9 500
3	Engineering and consultancy	6 400
4	Compensation and resettlement	12 820
5	General and adm mobile equipment	3 350
6	Commissioning	80
7	Sustaining capital	120 000
8	Mine development capital	15 000
	Subtotal	**192 150**
CCE 3	**Allowance**	
	Contingency (15 %)	64 093
	Subtotal	**64 093**
	Grand Total	**491 379**

a. CCE 1 Direct Capital Cost;

b. CCE 2 Indirect Capital Cost; and

c. CCE 3 Allowances.

Each of the categories under the direct capital cost has been expanded into specific costs under appropriate headings. These are presented in Table 3-5.

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Table 3: Detailed mining capital cost.

MCC	Description	Qty	Unit Price ($'000)	Amt ($'000)
MCC 1	**Mobile equipment**			
1.1	ROC L8 drill	3	795	2 385
1.2	Pantera 1500 drill	1	450	450
1.3	Terex RH40 excavator	3	1 580	4 740
1.4	CAT 990H loader	1	1 345	1 345
1.5	CAT 966H loader	1	1 821	1 821
1.6	20,000 Litre water truck	1	45	45
1.7	Cat d10t dozer	2	1 740	3 480
1.8	Cat d8 dozer	1	1 040	1 040
1.9	Cat 16 grader	3	600	1 800
1.1	CAT 775 truck	12	985	11 820
1.11	CAT 775 Water truck	1	579	579
1.12	$2m^3$ Backhoe	1	90	90
1.13	Cs 683 compactor	1	185	185
1.14	Explosive truck	1	140	140
1.15	Cat 365 CL $2.4m^3$	1	530	530
1.16	Tyre handler, 966^{TH}	1	475	475
1.17	Low loader	1	1 500	1 500
1.18	Mine utility vehicle	20	65	1 300
1.19	33-Seater mini bus	2	65	130
	Subtotal			**33 855**
MCC 2	**Miscellaneous capital items**			
2.1	Light plant	5	80	400
2.2	Stadium lights	5	100	500
2.3	Mining software	1	612	612
2.4	Survey equipment	1	540	540
	Subtotal			**2 052**
MCC 3	Dewatering equipment and installation			
3.1	Pit dewatering ring bores	6	400	2 400
3.2	In-pit pumps	5	100	500
3.3	Standpipes/transfer	2	200	400
	Subtotal			**3 300**
MCC 4	**Mining facilities**			
4.1	Mining adm building			950
4.2	Mine workshop			1 600
4.3	Wash down facility			471
4.4	Mine rescue			104
4.5	Fuel storage facility			1 000
4.6	Mine services facility			400
	Subtotal			**4 525**
MCC 5	**Explosives infrastructure**			
5.1	Explosives magazine and ANFO mixing plant			1 150

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	Subtotal	**1 150**
	Grand total	**44 882**

Table 4: Detailed processing capital cost.

PCC	Description	Amount ($'000)
PCC 1	**Processing plant**	
1.1	Complete plant includes the following plus delivery: Sag and Ball grinding mill, Cyanide leach/Carbon-in-leach (CIL) circuit, cyanide destruction circuit, refinery to be produced dore bullion, tailings thickener, tailings discharge system and necessary regent, water and air systems	125 000
	Subtotal	**125 000**
PCC 2	**Additional equipment for supergene**	
2.1	Flotation cells, for copper roughing and cleaning duties, regrind mills for rougher concentrate, copper concentrate thickener, and pressure filters, copper concentrate load out building, copper floatation reagent systems, floatation air blowers, and pressure filter air compressors	1 224
	Subtotal	**1 224**
PCC 3	**Additional equipment for zinc**	
3.1	Flotation cells, for zinc roughing and cleaning duties, regrind mills for rougher concentrate, zinc concentrate thickener, and pressure filters, zinc concentrate load out building, copper floatation reagent systems, floatation air blowers, and pressure filter air compressors	1 224
	Subtotal	**1 224**
PCC 4	**Plant infrastructure**	
4.1	Plant buildings	843
4.2	Laboratory complex	555
4.3	Tailings dam	4 509
	Subtotal	**5 907**
PCC 5	**Reagents & plant services**	
5.1	Reagents	8550
5.2	Water services	1646
5.3	Process control system	2035
5.4	Compressed air services	1495
5.5	Electrical services	3244
5.6	Fuels	325
5.7	Initial spares and 1-month consumables	1260
5.8	Instrumentation and automation	1800
	Subtotal	**20 355**
PCC 6	**Port logistics and rotainer**	
6.1	Port logistics	593
6.2	Rotainer based transport	5 509
6.3	Port storage facility	2 025
	Subtotal	**8 127**
PCC 7	**Process plant mobile fleet**	
7.1	Crane-200T (1)	1 879
7.2	Boom-20T (1)	90
7.3	Hdpe welding unit (1)	114

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7.4	Mobile welding machines (1)	25
7.5	Cat 990h loader (2)	2 690
7.6	Bobcats (1)	78
7.7	Forklifts (2)	70
7.8	Cs 683 compactor (1)	150
7.9	4x4 Toyota Pick-up (4)	204
7.1	Dual cab4wd land cruiser (6)	330
7.11	33-seater buses (2)	130
	Subtotal	**5 760**
	Grand total	**167 597**

Table 5: Detailed infrastructural capital cost.

ICC	Description	Amount (US $000's)
ICC 1	**Infrastructure and site works**	
1.1	Site development	2593
1.2	Environmental unit	618
1.3	Utilities & services	513
1.4	Power generation and reticulation	1874
1.5	Adm and management offices	1250
1.6	Warehouse and spares store	1456
1.7	Maintenance workshop	2250
1.8	Construction camp	155
1.9	Permanent camp complex	8750
1.1	Fire service	240
1.11	It hardware/software	1255
1.12	Communication services	903
1.13	Site security	800
	Total	**22 657**

Operating cost estimation

Basis of estimation: The cost estimate for the mining operation is based on owner mining. Equipment operation and maintenance will be carried out by the parent company. The operating cost estimates for mining and processing were assembled from quotations given to 'peer' companies within the African Region and from current NI 43-101 technical reports [10]. Additional prices were sourced from suppliers of ancillary equipment, explosives and blasting services. All costs are presented on yearly basis in the year in which they are incurred and they are based on working regime of 2shifts/day, 9.8hr/shift for 360 days/year. The estimated average equipment operating hours is 4 862.

Most of the skilled labour will be expatriates for the first five years of the project life and all the unskilled labour will be Eritreans. All cost estimates will be based on the base mining schedule. The project operating cost estimate includes all recurring costs for payroll, service camp operations, contractors, maintenance parts and supplies, reagents, consumables, supplies, freight, personnel transportation, etc. to operate all facilities expensed in the tax year in which they occur. These estimates have been developed from first principles and grouped into categories. Each category has been expanded into specific costs under appropriate headings to provide detail cost estimates.

The categories include:

A. OCE 1 Mining;

B. OCE 2 Processing and

C. OCE 3 General and Administration.

Table 6: Project total operating cost summary.

OCE	Description	Amount ($'000)
OCE 1	**Mining operating expenditure**	
1.1	Drilling	14 095
1.2	Blasting	44 922
1.3	Excavator operation	13 456
1.4	Dump truck operating	30 448
1.5	Mine auxiliary equipment	51 598
1.6	Mine labour	114 685
1.7	Miscellaneous	26 921
	Subtotal	**296 125**
OCE 2	**Processing plant operating cost**	

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1.1	Consumables	211 497
1.2	Mobile equipment	6 180
1.3	Electric power	114 702
1.4	Off site administration	15 921
1.5	Process & maintenance labour	105 260
1.6	Miscellaneous	45 356
	Subtotal	**498 916**
OCE 3	**General and administrative**	
1.1	Head office charges	1 440
1.2	Office administration - site	2 210
1.3	Insurances	13 140
1.4	Financial	1 410
1.5	Fees and taxes	6 750
1.6	Consultants	3 340
1.7	Personnel affairs	7 690
1.8	Contracts	26 700
1.9	General maintenance	14 730
1.1	Mobile equipment	3 840
1.11	Admin labour	57 432
1.12	Miscellaneous	13 869
	Subtotal	**152 551**
	Grand total	**947 592**

Table 7: Project yearly operating cost summary.

Cost Centre	TOTAL	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Mining operating cost	**296 125**	38 229	38 187	33 833	32 451	30 349	31 238	30 745	28 051	20 173	12 869
Processing operating cost	**498 916**	54 416	61 425	49 897	52 182	47 203	46 646	50 714	50 490	50 830	35 113
General and Adm Cost	**152 551**	15 564	15 564	15 564	15 564	15 564	15 564	15 564	15 564	15 564	12 475
Total (US $000)	**947 592**	108 207	115 174	99 293	100 194	93 114	93 446	97 022	94 103	86 566	60 457

The estimated total operating cost for mining, processing and G&A are US $296M, US $498M, 152M respectively. Table 6 presents the summary of the project total operating cost whilst Table 7 gives the yearly operating cost summary.

Mining operating cost details

The mining operating cost estimation includes:

A. All requirements for drilling, blasting, loading, hauling and dumping of ore to the crusher or ROM pad and waste to either the waste dump or dump for tailings dam wall construction purposes;

B. All auxiliary operations such as haul road construction and drainage maintenance;

C. All mining technical services including survey and geotechnical activities;

D. The open pit production geology, resource modelling and grade control functions;

E. All Mining department management, supervision, operating and maintenance manpower requirements up to and including the Mining Manager;

F. All equipment operating costs and consumables such as repairs, tyres, tracks, lubricants, fuel, wear parts, explosives and major overhauls are based on vendor supplied information, and industrial experience. The summary is presented in Table 8.

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Table 8: Mining operating cost summary.

Cost Centre	LOM	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Total material (t'000)	**92 976**	**13 885**	**14 651**	**10 929**	**10 457**	**9 568**	**9 112**	**9 047**	**8 319**	**4 782**	**2 226**
Drilling	14 095	2 807	2 829	1 574	1 275	1 025	1 178	1 188	1 246	708	265
Blasting	44 922	8 092	8 130	5 468	4 564	3 481	4 211	4 245	3 889	2 065	777
Excavator	13 456	1 539	1 539	1 539	1 539	1 448	1 448	1 448	1 267	1 086	603
Dump Truck	30 448	4 029	3 930	3 889	3 836	3 402	3 709	3 217	2 588	1 275	573
Auxiliary	51 598	5 479	5 479	5 479	5 479	5 426	5 275	5 275	5 275	4 572	3 859
Labour	114 685	12 808	12 808	12 808	12 808	12 808	12 577	12 577	11 236	8 633	5 622
Miscellaneous	26 921	3 475	3 472	3 076	2 950	2 759	2 840	2 795	2 550	1 834	1 170
Total (US$ 000)	**296 125**	**38 229**	**38 187**	**33 833**	**32 451**	**30 349**	**31 238**	**30 745**	**28 051**	**20 173**	**12 869**
(US$/t)	**3.28**	**2.75**	**2.61**	**3.1**	**3.1**	**3.17**	**3.43**	**3.4**	**3.37**	**4.22**	**5.78**

Process plant operating cost

The processing operating cost consists of reagents and consumables, plant maintenance parts, fuel and lubricants, general administration, offsite administration expenses, electric power, plant services and labour. The summary of the processing cost is presented in Table 9.

Table 9: Summary of process plant operating cost.

Cost Centre	LOM	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Total material (t'000)	**21 228**	**2 000**	**2 348**	**2 133**	**2 330**	**2 156**	**2 101**	**2 056**	**2 038**	**2 066**	**2 000**
Reagent & Cons.	211 497	25 000	31 111	20 793	22 721	18 326	17 860	21 593	21 402	21 691	11 000
Mobile Equip.	6 180	618	618	618	618	618	618	618	618	618	618
Electric Power	114 702	11 825	11 825	11 825	11 825	11 825	11 825	11 825	11 825	11 825	8 277
Port Utilities	15 921	1 500	1 761	1 599	1 748	1 617	1 576	1 542	1 529	1 549	1 500
Labour	105 260	10 526	10 526	10 526	10 526	10 526	10 526	10 526	10 526	10 526	10 526
Miscellaneous	45 356	4 947	5 584	4 536	4 744	4 291	4 241	4 610	4 590	4 621	3 192
Total (US$ 000)	**498 916**	**54 416**	**61 425**	**49 897**	**52 182**	**47 203**	**46 646**	**50 714**	**50 490**	**50 830**	**35 113**
(US$/t)	**23.77**	**27.21**	**26.16**	**23.4**	**22.39**	**21.89**	**22.2**	**24.66**	**24.77**	**24.61**	**17.56**

General and administration (G&A) cost

General and administration cost were assembled from local and international contractors, agents, suppliers, and mining companies in operation. Major cost centres include: general maintenance, financial, insurance, contracts, and administration labour costs. It also includes fees and taxes, travel and accommodation, consultant and operating vehicle costs for the day to day running of the project. Table 10 shows the summary of the G&A cost.

Table 10: General and administration cost summary.

Cost Centre	LOM	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Total material (t'000)	**21 228**	**2 000**	**2 348**	**2 133**	**2 330**	**2 156**	**2 101**	**2 056**	**2 038**	**2 066**	**2 000**
Head office charges	1 440	144	144	144	144	144	144	144	144	144	144
Office adm-site	2 210	221	221	221	221	221	221	221	221	221	221
Insurances	13 140	1 314	1 314	1 314	1 314	1 314	1 314	1 314	1 314	1 314	1 314
Financial	1 410	141	141	141	141	141	141	141	141	141	141
Fees and taxes	6 750	675	675	675	675	675	675	675	675	675	675
Consultants	3 340	334	334	334	334	334	334	334	334	334	334
Personnel Affairs	7 690	769	769	769	769	769	769	769	769	769	769
Contracts	26 700	2 670	2 670	2 670	2 670	2 670	2 670	2 670	2 670	2 670	2 670
General Maintenance	14 730	1 473	1 473	1 473	1 473	1 473	1 473	1 473	1 473	1 473	1 473

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Mobile Equipment	3 840	384	384	384	384	384	384	384	384	384	384
Admin Labour	57 432	6 024	6 024	6 024	6 024	6 024	6 024	6 024	6 024	6 024	3 216
Miscellaneous (10%)	13 869	1 415	1 415	1 415	1 415	1 415	1 415	1 415	1 415	1 415	1 134
Total (US $000)	**152 551**	**15 564**	**15 564**	**15 564**	**15 564**	**15 564**	**15 564**	**15 564**	**15 564**	**15 564**	**12 475**
(US$/t)	**7.22**	**7.78**	**6.63**	**7.30**	**6.68**	**7.22**	**7.41**	**7.57**	**7.64**	**7.53**	**6.24**

Revenue estimation

One of the advantages of NSR is quick revenue estimation. The total revenue was estimated using NSR values and the annual ore tonnages. The total revenue is US $2 615 801 000. Table 11 presents the summary of the revenue estimation on annual basis for the LOM.

Table 11: Revenue estimation.

Cost Centre	LOM	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Total Ore (t)			2 000	2 348	2 133	2 330	2 156	2 101	2 056	2 038	2 066	2 000
Au (t'000)	3 958		2 000	1 945	12	0.238						
NSR	196		162	231	176	59						
Rev (US$000)	774 220		323 486	448 527	2 193	14						
Sup-Cu (t'000)	5 540			291	2 006	1 990	1 173	39	32	9		
NSR	213			265	253	201	154	173	241	228		
Rev (US$000)	1 180 859			77 109	506 945	399 739	180 386	6 811	7 796	2 073		
Pr-Cu (t'000)	6 009			111	91	259	405	1 235	846	837	852	1 371
NSR	58			36	36	36	76	39	46	61	67	76
Rev (US$000)	346 447			3 956	3 243	9 204	30 822	47 987	38 587	51 289	57 020	104 339
Pr-Zn (t'000)	5 721				23	81	578	826	1 178	1 193	1 213	629
NSR	55				36	36	36	43	56	62	62	62
Rev (US$000)	314 275				826	2 865	20 588	35 505	66 348	74 415	74 719	39 009
Total Rev (US$ 000)	**261 5801**		**323 486**	**529 592**	**513 207**	**411 822**	**231 796**	**90 303**	**112 731**	**127 777**	**131 739**	**143 348**

Discounted cash flow analysis

The discounted cash flow method was used to evaluate the economic viability of the mineral project because of its simplicity and wider acceptability. The following general parameters were used in the cash flow analysis considering the Mining and Mineral laws of Eritrea:

a. A 5% royalty is payable, for precious metals, on the net smelter return;

b. A 3.5% royalty is payable, for base metals, on the net smelter return;

c. An income tax rate of 38% was applied over the life-of-mine;

d. Capital Allowance (Straight Line Depreciation) for 4 years and

e. A reinvestment allowance of 5%.

Risk analysis

Gentry & O'Neil [1] outlines three approaches that are essentially employed in handling risk using the Discounted Cash Flow (DCF) computations which are technical or conservative approach, sensitivity analysis, and risk analysis by simulation. This paper employed sensitivity analysis and risk analysis using Monte Carlo simulation to assess the risk associated with the Bisha Volcanogenic Massive Sulphide Mining Project.

Sensitivity analysis

Sensitivity analysis of a mineral project refers to the investigation of the effect of changes in the project's economic parameters such as revenue, capital cost and operating cost on the economic viability of the project. Sensitivity analysis is required because the project's economic parameters such as the revenue, capital cost and operating cost, which are used in the economic evaluation of the

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project, are all only estimates. Now, every estimated value has some degree of error associated with it and therefore may not be the real value. Again, by the time a mining project is being commissioned, all estimated values of the economic parameters may have changed.

Sorentino & Barnett [11] therefore, describe sensitivity analysis as the process of examining the impact of errors. The approach is to vary one of the economic parameters while keeping the others constant and calculating the NPV and IRR consequent to the changes. A graph of the NPV and IRR against the changes in the economic parameter will give the effect of the change in the parameter on the viability of the project. The main purpose is to identify those variables that have the most significant impact on the viability of the project.

However, sensitivity analysis by itself cannot and will not measure the uncertainties of an investment alternative; it provides no estimate of the probability that the contemplated change will really occur. Furthermore, it is mostly desirable to know the cumulative effect on viability of simultaneous variations in all or several of the variables. This combined effect is not shown in sensitivity analysis but rather in risk analysis using the Monte Carlo simulation method (among others).

Risk analysis by monte carlo simulation method

Barish & Kaplan [12] assert that simulation is the use of a model which takes account of those essentials of reality which are significant to the decision-making objective. Indeed, Sturgal & Harrison [13] point out that a simulation model should accurately and quickly represent a real-life situation. Shamblin & Stevens [14] affirm that simulation is a powerful tool that is particularly useful in analyzing systems which are too complex for mathematical analysis.

It is the process of assessing the simultaneous effect that the input variables have on the viability of the project. Since there are many risk elements to consider and because the interaction requires complex calculations, the only practical method available is to perform the cash flow calculations on a computer. The approach is to quantify the variability of the input variables, sample the distributions in a random manner, calculate the cash flows for each set of input data, repeat the procedure many times, and display the result as a probability distribution of expected Internal Rate of Return (IRR) and Net Present Values (NPV).

Results and Discussion

Project discounted cash flow analysis

Table 12 shows the details of the cash flow analysis reported to the nearest 1000. The Net Present Value (NPV) @10% discount rate for the project is US $344 553 000 and Internal Rate of Return (IRR) of the project is estimated to be 29.9%. As the NPV of US $344 553 000 is greater than zero and IRR of 29.9% is greater than the discount rate of 10%, the Bisha project is evaluated to be economically viable.

Table 12: Cash flow analysis of the bisha VMS project.

Equity Capital=100% Loan Capital=0% Total Capital Investment Working Capital Total Operating Cost (LOM)	=US $491 380 =US $0 =US $491 380 =US $108 207 =US $947 592		Royalty Precious Metal Royalty Base Metal Project Life Discount Rate Percentage equity		=5% =3.5% =10yrs =10% =100%		(Cash Flow Computed in $'000)				
	0	1	2	3	4	5	6	7	8	9	10
Gross Rev (Total NSR)		323 486	529 592	513 207	411 822	231 796	90 303	112 731	127 777	131 739	143 348
Less:											
Royalty (Precious Metal)		16 174	22 426	110	1						
Royalty (Base Metal)			2 837	17 885	14 413	8 113	3 161	3 946	4 472	4 611	5 017
Operating Cost		108 209	115 176	99 294	100 197	93 116	93 448	97 023	94 105	86 567	60 457
Net Revenue (Rn)		199 105	389 155	399 919	297 214	130 569	-6 304	11 763	29 202	40 562	77 874
Less:											
Reinvestment Allowance		16 174	26 480	25 660	20 591	11 590	4 515	5 637	6 389	6 587	7 167

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Depreciation		122 845	122 845	122 845	122 845						
Interest											
Loss Carry Forward								4 515			
Taxable Income *(Ti)*		60 084	239 828	247 413	153 775	118 977	- 10 821	1 610	22 811	33 974	70 707
Tax, T=(38% Of Ti)		22 832	91 135	94 017	58 434	45 211		612	8 668	12 910	26 869
Net Income		37 252	148694	153396	95 340	73766	-10 821	998	14 143	21 064	43 838
Reinvestment Allowance		16 174	26 480	25 660	20 591	11 590	4 515	5 637	6 389	6 587	7 167
Depreciation		122845	122845	122845	122845						
Loss Carry Forward								4515			
Working Capital (Last Yr Only)											108207
Less											
Working Capital (First Yr Only)		108 207									
Equity Capital	491 380										
Loan Repayment											
Cash Flow (Cf)	**-491 380**	**68 065**	**298 018**	**301 901**	**238 777**	**85 356**	**- 6 306**	**11 150**	**20 532**	**27 651**	**159 212**
Npv @ 10%=	**344 553**										
Irr=	**29.9%**										

Project sensitivity analysis

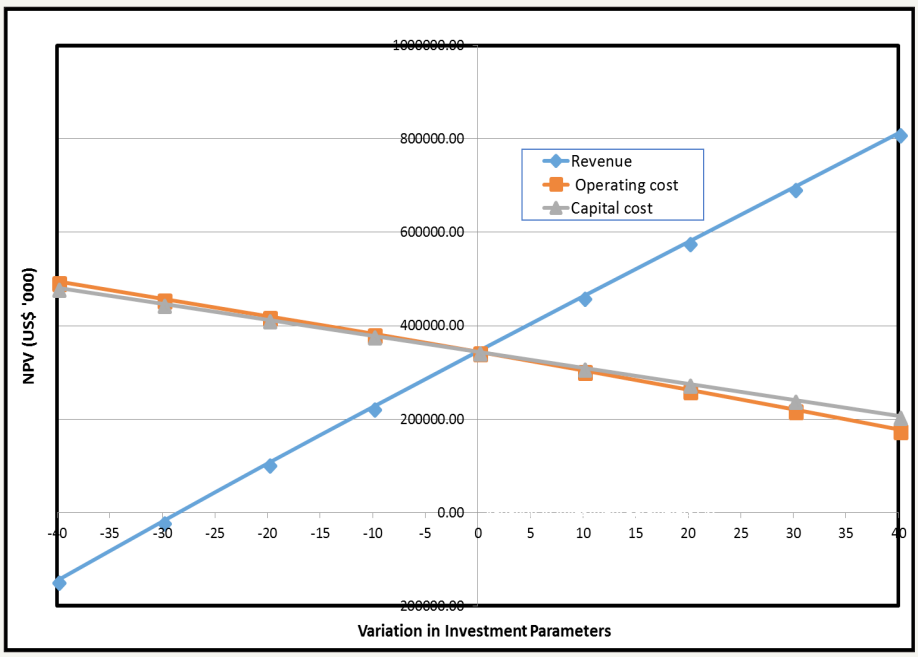

Figure 1: Variation of economic parameters with NPV.

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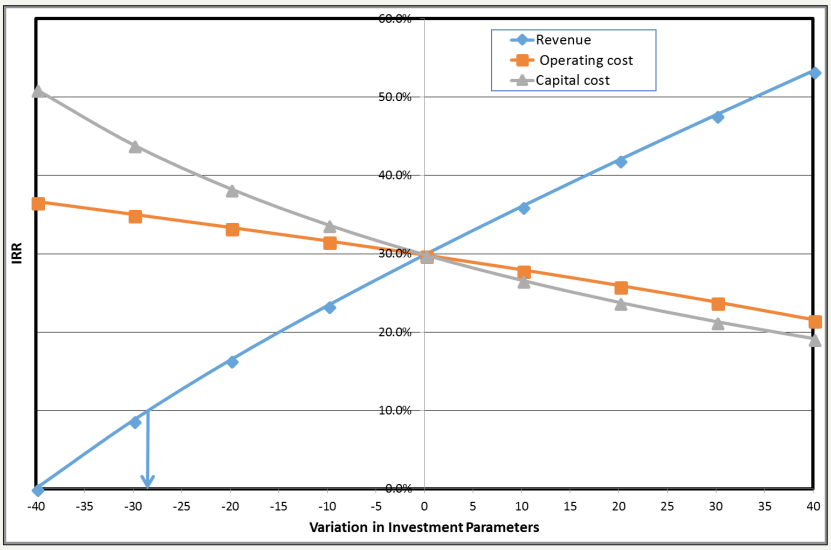

Figure 2: Variation of economic parameters with IRR.

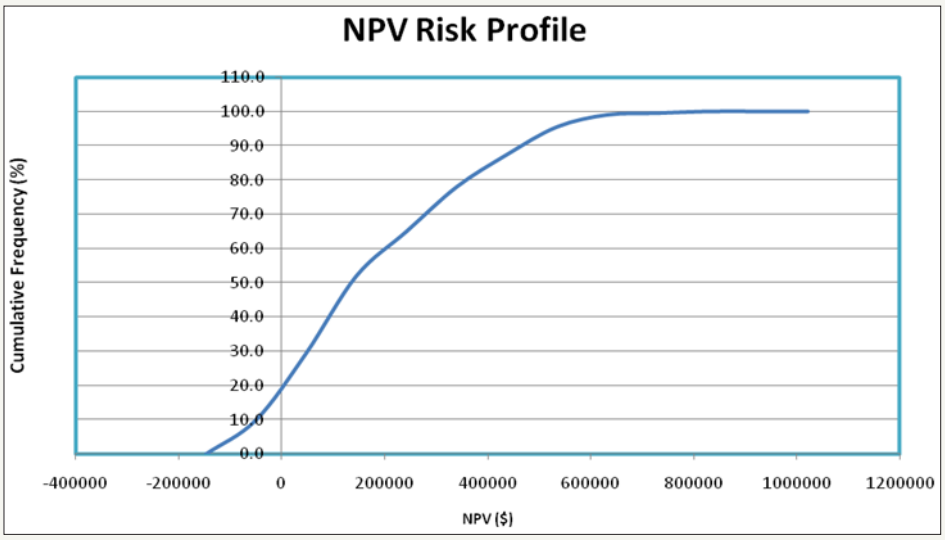

Figure 3: Risk profiles of NPV.

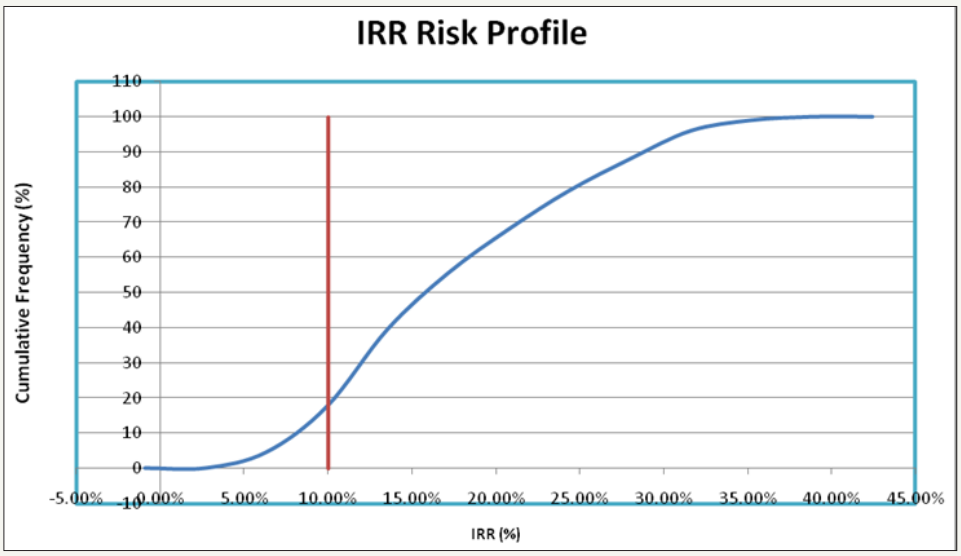

Figure 4: Risk profiles of IRR.

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Results of the sensitivity analysis are presented graphically in Figure 1 & 2. The project will cease to be economically viable should the revenue decrease below 28.5%. The project will still remain viable after 40% increment in both the capital and operating costs.

Project risk analysis using monte carlo simulation

Figure 3 & 4 presents the risk profiles from the risk analysis of the Bisha VMS Project. From the risk analysis the project is associated with a risk of failure of 18%.

Conclusion and Recommendations

Conclusion

The economic viability of the Bisha VMS deposit has been analysed under robust and careful technical conditions considering the Mining and Mineral Laws of Eritrea. NSR values were modelled as in most cases of poly metallic deposits and a script was developed in Surpac to calculate these values to facilitate the preparation of economic model for the evaluation of the deposit.

A total capital of US $491 380 000 will be required for the project. The estimated Mine operating cost for the total life of mine is US $947 592 000 and an estimated total revenue of US $2 615 801 000 has been projected. Using a capital structure of 100% equity a cash flow analysis has been conducted which resulted in a Net Present Value of US $344 553 000 @10% discount rate and an Internal Rate of Return of 29.9%. The project is considered economically viable owing to the fact that the NPV is positive and the IRR is greater than the minimum rate of return.

The robustness of the projects financial performance has been tested with simple sensitivity analysis which reveals that the project is sensitive to variations in the project revenue and less sensitive to the capital and operating costs. The project will continue to be viable economically until the revenue is decreased by 28.5%. Risk analysis using more rigorous Monte Carlo simulation indicated a risk of failure of 18%.

Recommendations

The following recommendations have been made:

a. Extensions to the Primary massive sulphide mineralisation, including the Primary Zn Domain, should be tested with further drilling. This may have the effect of increasing the mineable reserve and extend the project life.

b. The financial structure can be analysed critically considering other sources of financing such as loan to further improve the projects NPV.

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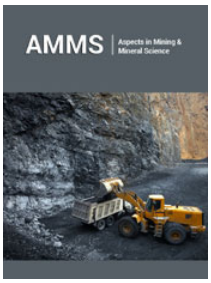

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