

Investment Risk Evaluation of Siirt Madenköy Copper Mine in Turkey

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Abstract: Mining investments are high-risky investments due to mineral deposit uncertainties. Therefore, before any investment decision is given, an economic assessment should be performed and several risk situations must be taken into consideration. In this study, it was examined whether or not an investment made in a copper mine in Siirt, Turkey is economical by using Sensitivity Analysis and Monte Carlo Simulation. The aim of this study is to construct cash flows for this copper mine with an average grade of 2.35% Cu and 39.821.000 tons reserve throughout 25 years for two different situations. In the first case, it was assumed that the total investment amount will be covered by 100% equity, while in the second case the total investment amount was assumed to be 30% equity and 70% bank loan. In the Sensitivity Analysis, mineral processing and operating costs, the average grades and ore concentrate sale prices were evaluated over optimistic and pessimistic forecasts. Changes in the net present value and internal rate of return were examined without risk. Monte Carlo Simulation was run by using computer software program @Risk 6.0 and applied to investment criteria for this copper mine field. The analysis of the output modelling situations where decisions were made under uncertainty gave reliable results by quantifying the degree of risk for this mining project. Consequently, if the investment was provided with 100% equity, NPV was 136.369.150,7 \$ and IRR was 32% with a discount rate of 15%, probably as likely to harm the project was about 0,018. If the investment was provided with 30% equity, NPV was 111.742.245,4 \$, IRR was 28% with a discount rate of 15%, probably as likely to harm the project was about 0,05. In accordance with the results, the investment can be said to be a profitable project in both assumptions.

Keywords: Mining Investment, Uncertainty, Risk Analysis, Monte Carlo Simulation Method, Sensitivity Analysis, Investment Appraisal.

1. Introduction

The evaluation of a mining project is a long and complicated process from exploration to exploitation stages. Many decisions involve too many influential risk factors with different kinds of uncertainties since mining investments are potentially carrying high risks.

To evaluate mining project, it is necessary to make certain assumptions considering production rate range, reserve, characteristic of mineral deposit, capital cost, cash flow, mine life, return of capital, inflation, discount rate, unit sales price, operating cost per ton, operating methods and jeometallurgy.

Climatic conditions, environmental factors, ore dressing, market condition, productivity and rate of growth are essential to consider other parameters (Hartman and Mutmanky, 2002).

At the evaluation of the mine investment, there are a number of risks arising from some uncertainties. These uncertainties are classified as exploration uncertainties, economic uncertainties and engineering uncertainties (Dehghani and Ataepour, 2012). Economic uncertainties as future metal prices and operating costs are the most important factors affecting the value of the project. Exploration uncertainties occur during the resource

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evaluation stages such as geologic uncertainty, data collection, modelling, classification and reporting of the deposit (Dehghani and Ataee-pour, 2012). Engineering uncertainties include determination of bench heights, control of grade, minimum production width, choice of production process, dilution factor, geotechnical and hydrological factors, recovery factors and metallurgical recovery (Hartman and Mutmanský, 2002).

Risk analysis is the compulsory factor for all stages of mine feasibility studies, planning and production (Simonsen and Perry, 1999). To evaluate the risk of a considered mining risk, firstly economic model must be generated. Determining the economic value of a project is based on several investment approaches and cash flows such as net present value, payback period, internal rate of return and accounting rate. After calculating these values, risk analysis methods such as Sensitivity Analysis and Monte Carlo simulation are generally used to investigate the changes and measure the risk (Wei et al., 2011; Pincock Consulting Service, 2012).

Literature on Sensitivity Analysis was limited in the past. Morley et al. (1999) proposed a financial model of a project significant effort was expended on capital and operating cost estimation, commodity price forecasts, and choice of discount rates while uncertainty in the primary input, the reserve, was overlooked. Iloiu and Csiringa (2009) was based on IRR and NPV criteria. They presented the purpose of sensitivity analysis and the steps that must be followed in order to perform a sensitivity analysis as well as a numeric example. Sabour and Wood (2009) proposed the economy of a gold mine over cash flow model. Aryafar et al. (2011) estimated the capital costs and present value of revenue and costs and then assessed the operating costs by considering total production at Basalt-Andesite Mine in Persian.

Literature on Monte Carlo Simulation is more than literature on Sensitivity Analysis. Kreuzer et al. (2008) showed that how the potential mining project formation was formed, how the expected average value was computed and net present value's possible distribution. As discussed by Bastante et al. (2008) suggested a simple method for introducing price and cost increases into the risk analysis via the Monte Carlo method and show how geological, technical and economic uncertainty could be integrated in risk analysis. Sabour and Dimitrakopoulos (2011) conducted a survey by the open pit mine design that combines the flexibility of

operating with uncertainty in the selection of a method. Oraee et al. (2011) pointed out the project on the basis of several economic variables. These economic variables have been estimated under the conditions of uncertainty. The net present value was obtained under these uncertainties. As described in Wei et al. (2011) proposed that the Monte Carlo simulation was performed in computer and applied to an iron ore mine investment. Based on the simulating results, this project's investment was analyzed.

In this study, the importance of estimation of NPV of orebody with risk and without risk was underlined. This study summarizes the preliminary results of a research project supported by Teaching Staff Training Program (OYP). A copper mine was investigated through Sensitivity Analysis and Monte Carlo simulation and the difference was compared in terms of economic under risk and without risk situations. Cash flow was constructed by two assumptions, 100% equity and 30% equity and 70% bank loan. The investment was evaluated with Sensitivity Analysis and Monte Carlo Simulation Analysis. In accordance with the results, the investment can be said to be a profitable project in both assumptions.

2. Material and Method

2.1. Description of the Project Site

Project site is located near the village of Madenköy, 40 km north-east of the town of Siirt. Resource estimation and classification results were obtained and calculated for three domains. Three orebody were created for the Madenköy deposit. Domain 1, the largest orebody, is located in the eastern part of the study area with a volume calculated by almost 10 million m³. Domain 2, the small orebody above orebody 3, is located in the eastern part of the study area with a volume calculated by around 120.000 m³. Domain 3, the other small orebody below orebody 2, is located in the south-west of the area with a volume calculated by around 500.000 m³ (Figure 1).

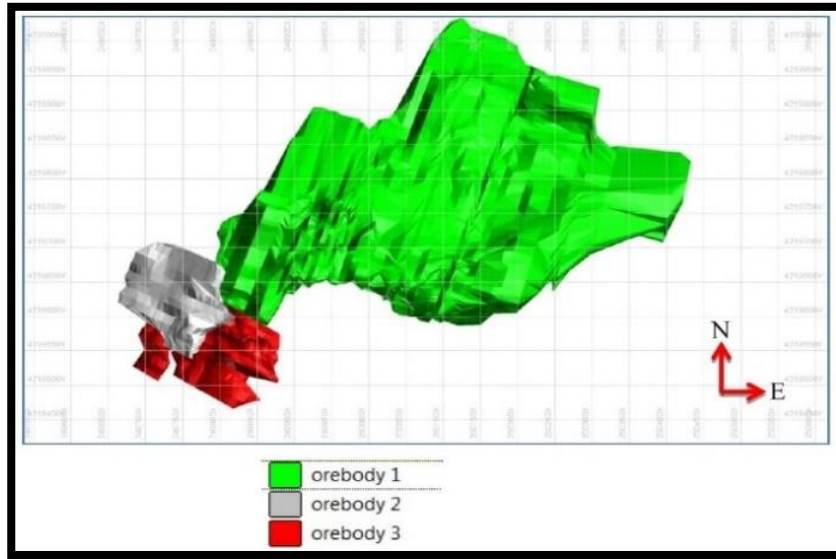


Figure 1. Plan view of the Park Electric wireframes (Park Electric Technical Report)

2.2. Operating Method

Park Elektrik Üretim Madencilik Sanayi ve Ticaret A.Ş has turned underground mining to open pit mining method in Madenköy. It was tried in 2 shifts of 8 hours per day and 300 days per year. According to Park Electric technical report, copper reserves on the mine's total measured, indicated and inferred

are 39.821.000 tonnes. In this study, the evaluation was made out of copper reserves of 37.572.183 tonnes by considering measured and indicated reserves (Table 1). It was of an average grade of 20% copper concentrate. Concentrate recovery of 90%, the average ore grade was calculated as 2.40% Cu and concentration ratio was calculated 9,46 ton ore/ ton concentrate.

Table 1. Resource Estimation and Classification

Resource Category	Tonnes(t)	Cu(%)	SG(t/m ³)
Measured + Indicated	37.572.183	2,35	4,05
Total Resources	39.821.000	2,40	

1.500.000 tonnes of ore was operated and returned to about 160.000 tonnes of concentrate at plant per year from mine.

2.3. Equipment Selection

It was planned to product 1.500.000 tonnes ore per year. Ore production and overburden were done with 5 m³ capacity excavators and 40 tonnes capacity trucks. Average density of stripping material was 2,5 ton/m³, average density of ore was 4,05 ton/m³.

2.3.1. Selection of drilling machine

Considered in the design of drilling and blasting, hole diameters, slice thickness and the distance between holes were selected as 6 inches (15,24 cm), 5 m and 5 m respectively. It has been decided to

select 6 drilling machines and 5 of them were for overburden and the other one was for ore production.

2.3.2 Selection of excavator and truck

The excavated overburden material was conveyed to the dump site in approximately 2,5 km distance. The produced ore was transferred to 2 km away. According to the amount of overburden and production, the number of required trucks and excavators was calculated as 9 excavators and 45 trucks for overburden, 1 excavator and 5 trucks for ore production.

2.4. Costs Analysis

Total Investment Expenditures for 5 m³ excavators and 40 tonnes trucks were shown in Table 2.

Investigation project costs of 65.502 \$, land arrangement expenses of 78.603 \$, communication systems of 131.004 \$, fuel oil storage and drainage systems of 131.004 \$ was expected.

Table 2. Total Investment Costs

	Value (TL)	Value (\$)
Studies Project Costs	150.000	65.502
Land Regulation Costs	180.000	78.603
Mineral Processing Machinery Equipment Expense	4.995.000	2.181.223
Overburden Machinery Equipment Expense	39.625.000	17.303.493
Fuel Tank-Drainage Systems	300.000	131.004
Communication Systems	300.000	131.004
Foundation Expense	450.000	196.506
Unexpected Expenses (%4)	1.840.000	803.493
General Expenses (%2)	953.800	416.506
Physical Growth (%2)	975.876	426.147
Total Fixed Investment (TL)	49.769.676	21.733.483

2.5. Operating Cost

As a result of the data, for 5m³ excavator and 40 tonnes truck, stripping cost was 4,93 \$/m³, ore production costs was 3,53 \$/m³ (Table 3).

Table 3. Total Operating Costs

Expenses	Overburden (TL/m ³)	Ore (TL/ton)
Drilling	0.7903	0.1951
Blasting	1.7165	0.4238
Loading	1.5333	0.7667
Transport	5.1633	4.4200
Repair and Maintenance	0.1769	0.1130
Personel Expenses	0.7568	1.4040
Spare Part	0.1397	0.0943
General Expenses (%2)	0.2055	0.1483
Unexpected Expenses (%2)	0.2096	0.1513
Depreciation	0.5885	0.3735
TOTAL (TL)	11.28	8.09
TOTAL (\$)	4.93	3.53

2.6. Cash Flow

Cash flow was formed as a result of cost calculations. In the case of investment with 100% equity investment, NPV was 136.369.150,7 \$ with a reduction rate of 15% and IRR was 32% (Table

4). When the project was invested with 30% equity +70% bank loan, NPV was calculated as 111.742.245,4 \$, and IRR was 28% (Table 5). In both cases, the project investment was paid back about 2 years.

Table 4 Annual Cash Flow (100% equity investment)

Year	Annual Cash Flow(\$)	Year	Annual Cash Flow(\$)	Year	Annual Cash Flow(\$)	Year	Annual Cash Flow(\$)
0	-73.342.107	7	53.329.655	14	53.329.655	21	42.524.415
1	-36.943.231	8	53.329.655	15	53.184.677	22	53.184.677
2	14.191.524	9	53.329.655	16	47.258.040	23	53.329.655
3	53.329.655	10	53.329.655	17	53.329.655	24	53.329.655
4	53.329.655	11	38.157.603	18	53.329.655	25	76.665.791
5	53.329.655	12	53.329.655	19	53.329.655		
6	47.258.040	13	53.329.655	20	53.329.655		

Table 5 Annual Cash Flow (30% equity investment + 70% bank loan)

Year	Annual Cash Flow(\$)	Year	Annual Cash Flow(\$)	Year	Annual Cash Flow(\$)	Year	Annual Cash Flow(\$)
0	-73.342.107	7	48.038.429	14	53.329.655	21	42.524.415
1	-42.216.879	8	48.262.606	15	53.184.677	22	53.184.677
2	10.499.971	9	48.776.740	16	47.258.040	23	53.329.655
3	46.561.808	10	49.145.895	17	53.329.655	24	53.329.655
4	46.930.963	11	34.342.998	18	53.329.655	25	76.665.791
5	47.300.119	12	49.884.206	19	53.329.655		
6	41.597.658	13	53.329.655	20	53.329.655		

2.7. Sensitivity Analysis

In this research, in the sensitivity analysis, mineral processing and operating costs, the average grade and ore concentrate sale prices were evaluated $\pm\%$ changes over optimistic and pessimistic forecasts with Excel, changes in the net present value and internal rate of return were examined.

In the case of 100% equity investment, in cases where price fell below 30%, NPV fell to negative

values. If the grade was down around 36%, the project NPV value was to be negative. It was observed that the cost of operating and mineral processing projects did not have much impact on NPV.

Similarly, when results of price and grade showed a 20%-30% decline, IRR fell below the target of 20% (Figure 3 and Figure 4).

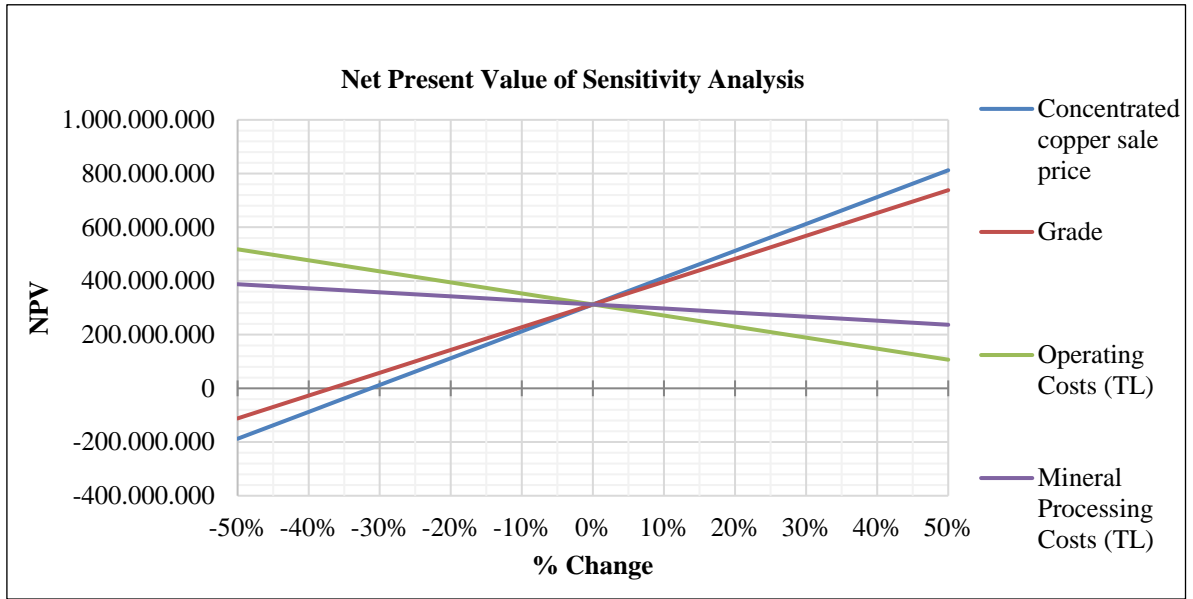


Figure 3. Effects of change on NPV

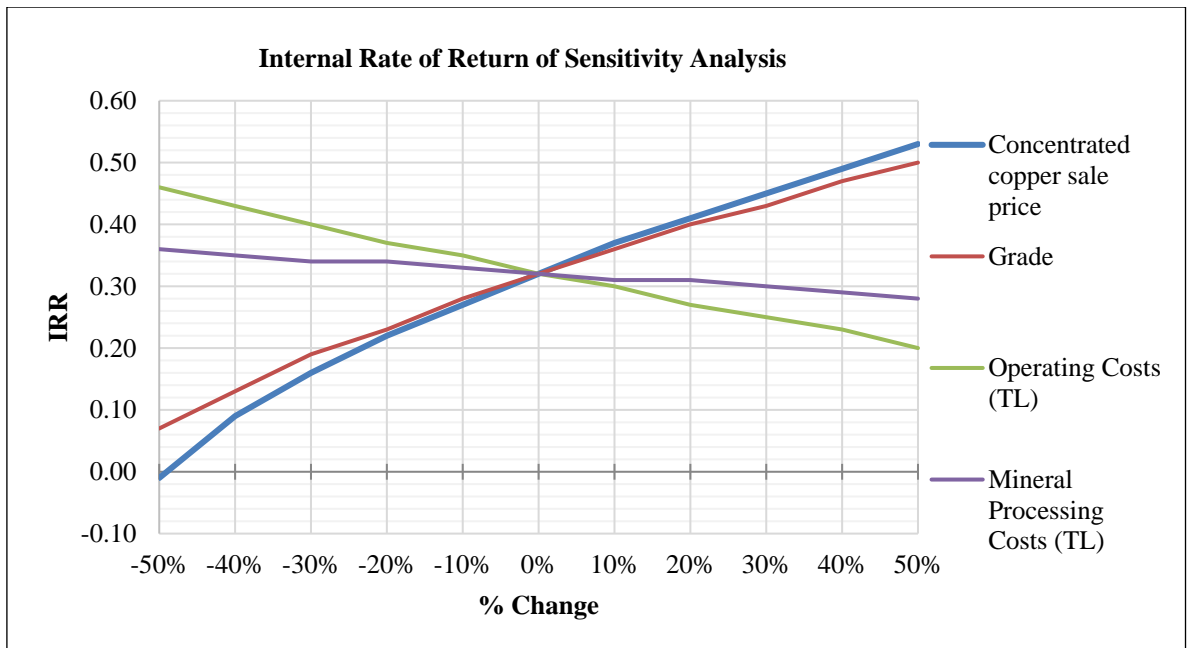


Figure 4. Effects of change on IRR

In the case of 30% equity investment, in cases where price fell below 25%, NPV fell to negative values. If the grade was down around 30%, the project NPV value was to be negative. It was observed that the cost of operating and mineral processing projects did not have much impact on NPV.

Similarly, when results of price and grade showed a 20%-30% decline, IRR fell below the target of 20%. It is shown as below (Figure 5 and Figure 6).

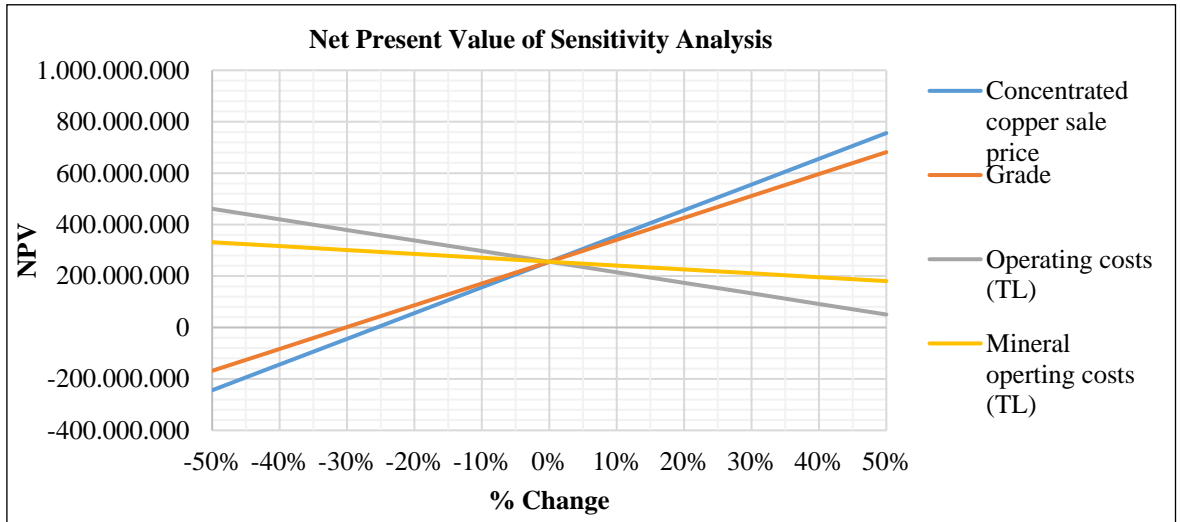


Figure 5. Effects of change on NPV

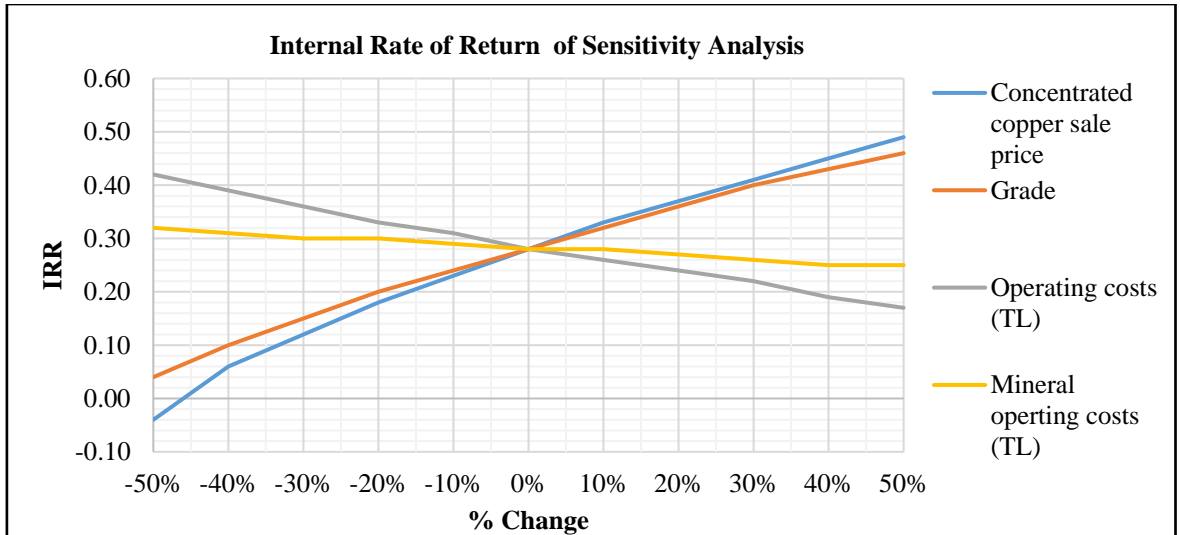


Figure 6. Effects of change on IRR

2.8. Probability Analysis - Monte Carlo Simulation

Monte Carlo simulation is one of the powerful and commonly used techniques for risk analysis. When the net cash flow was prepared by considering risks and uncertainties, NPV and IRR were calculated by performing 100,000 iterations in @RISK software programme. Concentrated ore sales price, average grade, overburden and operating costs, mineral

processing costs and initial investments were considered as risky situations.

Some probability distributions were defined to evaluate the uncertainties in this study. These uncertainties were;

Mine operating costs and overburden costs outcome differed in scale parameters, the mean and standard deviation. Thus, the distribution was normal (Figure 7).

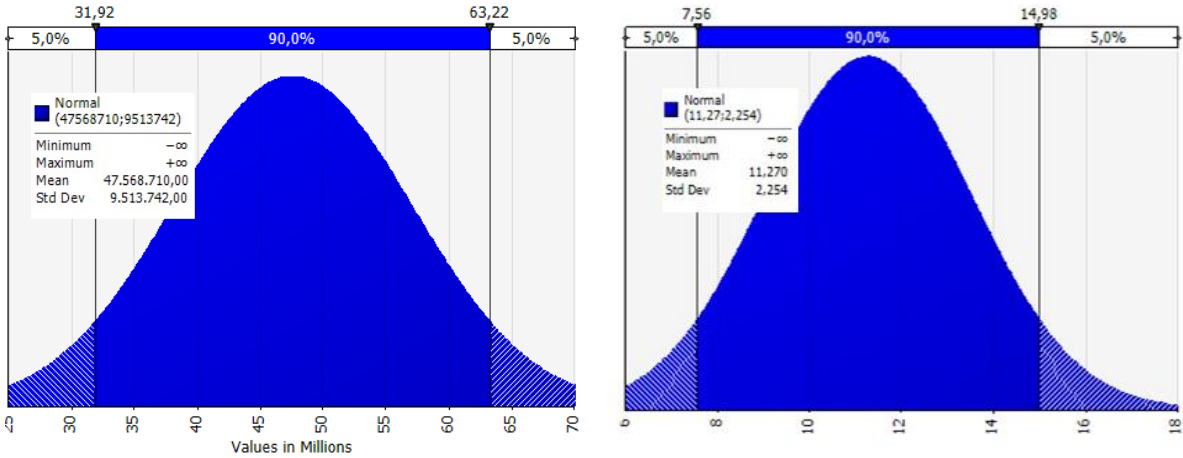


Figure 7. Distribution of operating costs: Normal(47.568.710, 9.513.742), and Distribution of the overburden costs: Normal (11.27,2.254).

Mineral processing costs outcomes were similar as operating costs, so the distribution was normal, and the average grade outcome was the constant average rate, so the distribution was exponential (Figure 8).

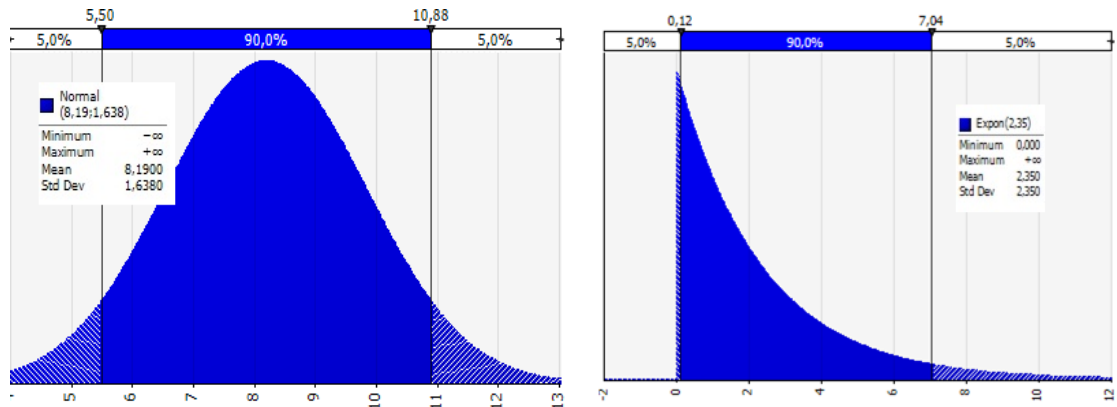


Figure 8. Distribution of the ore costs: Normal(8.19,1.638), and Distribution of average grade: Expon(2,35).

Total initial investment outcome was based on knowledge of minimum, maximum and most likely, so the distribution was triangular, and concentrated ore sales price outcomes were equally probable, so the distribution were uniform (Figure 9) .

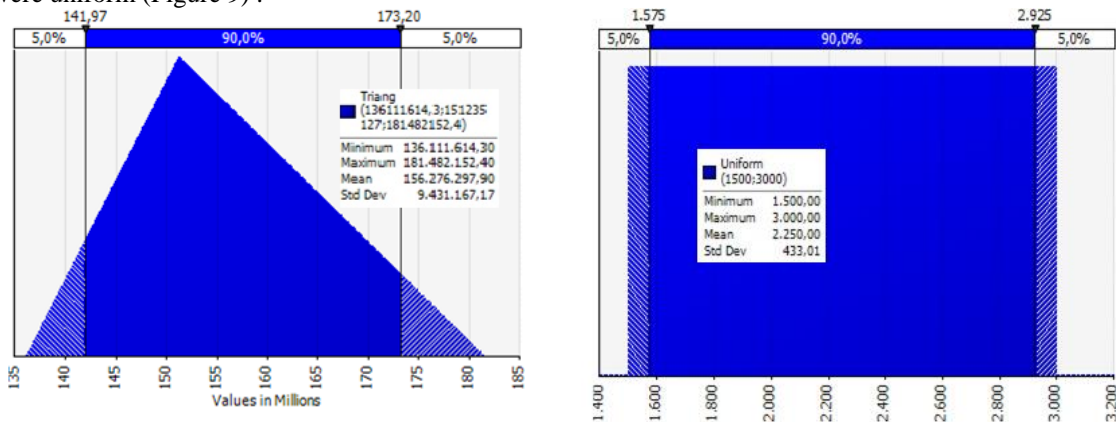


Figure 9. Distribution of Total initial investment: Triang(129.392.708, 143.769.676, 172.523.611), and Distribution of Concentrated ore sales price: Uniform (1500-3000)

By using these probability distributions, risk simulation studies on net cash flow were made. If the investment was provided with a 100% equity, NPV was as 481.068.929,76 TL, IRR was 36% average(Figure 10 and Figure 11).

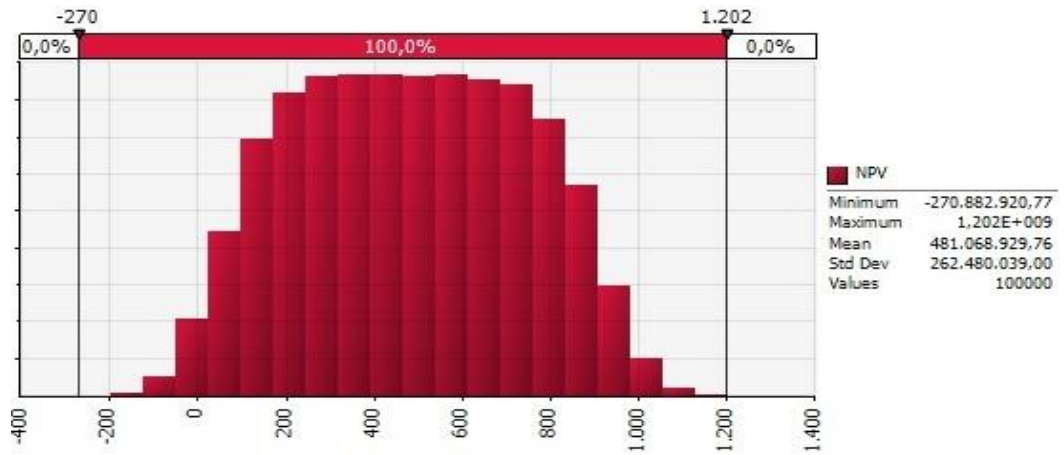


Figure 10. Probability distribution of NPV

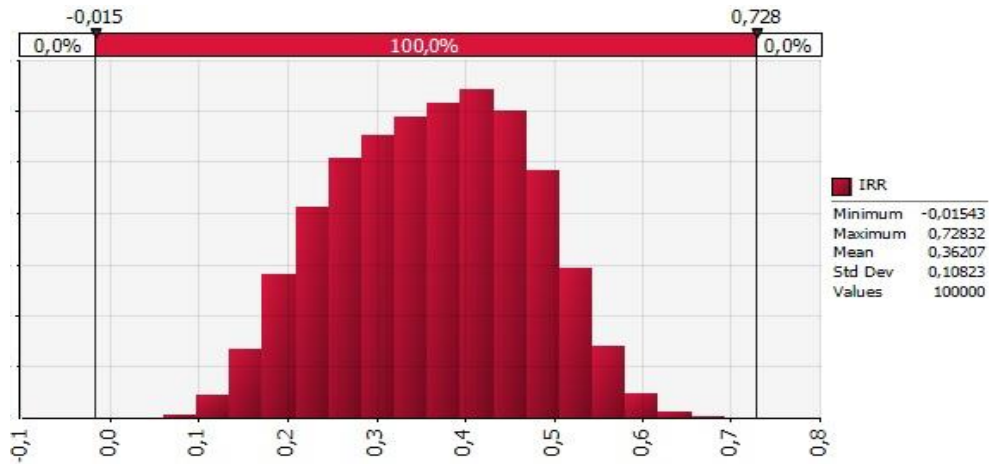


Figure 11. Probability distribution of IRR

By using these probability distributions, risk simulation studies on net cash flow were made. If the investment was provided with a 30% equity, NPV was as 414.052.307,84 TL, IRR was 32% average (Figure 12 and Figure 13).

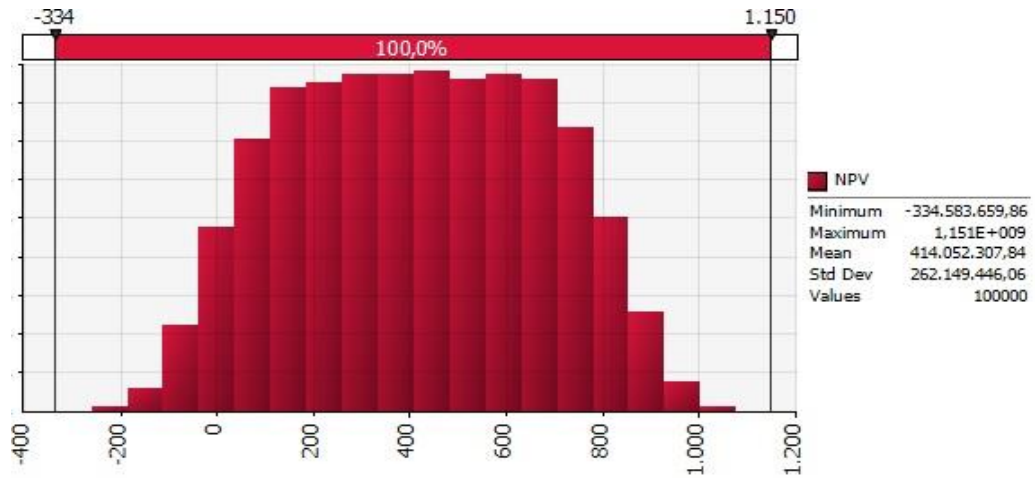


Figure 12. Probability distribution of NPV

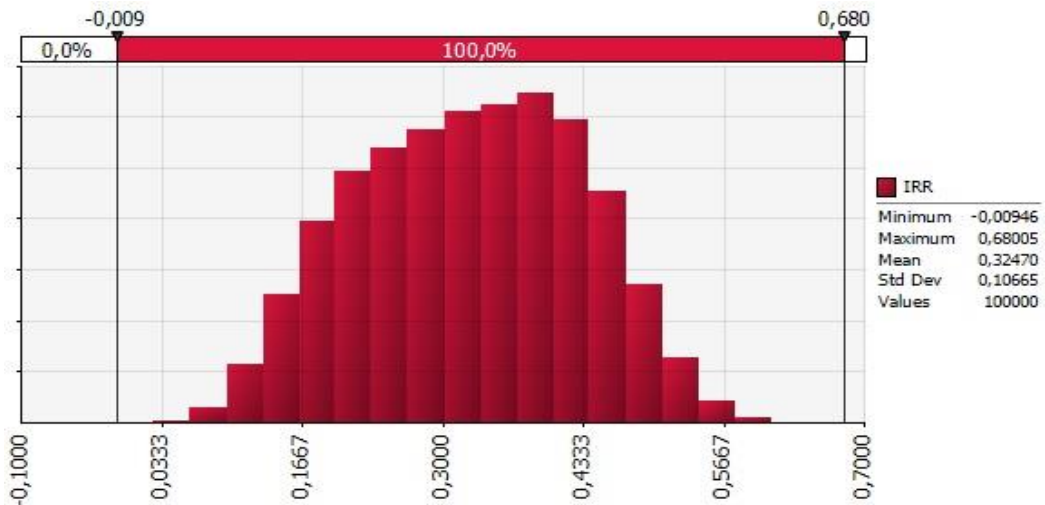


Figure 13. Probability distribution of IRR

3. Results

Considering all data, total initial investment of 62.781.518 \$, overburden cost of 4.93 \$/m³, ore cost of 3.53 \$/tonnes and concentrate cost of 131 \$/tonnes were calculated. Firstly, the net cash flow has been established by ignoring the uncertainty and risk. In this case, if the investment was provided with 100% equity, NPV was 136.369.150,7 \$ and IRR was 32% with a discount rate of 15%. If the investment was provided with 30% equity, NPV was 111.742.245,4 \$, IRR was 28% with a discount rate of 15%.

When the net cash flow was formed, the net present value and the internal rate of return were taken into consideration without risk. Uncertainties such as concentrated ore sales price, grade, costs of operating and mineral processing were taken into account over optimistic and pessimistic predictions with ± % changes. In case the price fell below 25-30%, NPV fell into negative. If grade fell below 30-35%, NPV would be negative. It was observed that the cost of operating and mineral processing projects did not have much impact on NPV. If sales price and grade fell below 20-30%, IRR would reach the lower value than the target rate.

Simulation results in the case of 100% equity investment;

- Average net present value was about 210 million \$, internal rate of return was 36%.
- Net present value was higher than probability of 0,90 from 56.33 million \$; probability of 0,50 from 210 million \$.
- The probability of NPV any higher chance than net present value with risk-free was 0,69.
- A little probable as 0,018 of net present value took negative project.
- Internal rate of return was high probably of 0,90 from 21,5%; probably of 0,50 from 36,6%;
- Internal rate of return was high probably of 0,927 from 20%;
- Internal rate of return likely to be lower than selected rate of 15% was 0,018.

Simulation results in the case of 30% equity investment;

- Average net present value was about 181 million \$, internal rate of return was 32%.
- Net present value was higher than probability of 0,90 from 27 million \$; probability of 0,50 from 181 million \$.
- The probability of NPV any higher chance than net present value with risk-free was 0,686.
- A little probable as 0,05 of net present value took negative project.
- Internal rate of return was high probably of 0,90 from 17,9%; probably of 0,50 from 32,9%;
- Internal rate of return was high probably of 0,856 from 20%;
- Internal rate of return likely to be lower than selected rate of 15% was 0,05.

4. Discussion

Assessing the all simulations if the investment was provided with 100% equity, probably as likely to harm the project was about 0,018. In accordance with the above results, the investment can be said to be a profitable investments of all kinds. In the other case, assessing the all simulations if the investment was provided with 30% equity, probably as likely to harm the project was about 0,05. In accordance with the above results, the other investment alternative can be said to be a profitable investments of all kinds. NPV and IRR values resulting from the simulation have been found to be consistent with the net present value and internal rate of return of cash flow in evaluation of risk-free. Consequently, the overall mining investment in economic evaluation techniques was assessed and risk parameters were calculated. While the risk analysis was carried out,

sensitivity analysis and Monte Carlo simulation can be selected as risk analysis. Uncertainties that are selected during the sensitivity analysis of the parameters are not understood how they affect each other, because it is considered separately. But Monte Carlo simulation is done if the uncertainties are taken into consideration at the same time. Monte Carlo simulation of the investment risk assessment is carried out as a result of the probability distribution.

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