INVESTIGATION OF FACTORS INFLUENCING THE DETERMINATION OF DISCOUNT RATE AND THE APPLICATION OF QUANTITATIVE METHODS FOR DISCOUNT RATE USING RISK FACTORS IN THE MINERALS INDUSTRY

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Abstract

For the evaluation of mineral development projects, it is imperative to consider the risks involved in mineral exploration and development. The discount rate has a tremendous effect on the economic evaluation of mineral projects. Even when all other factors used as inputs for calculating the NPV (Net Present Value) are equal, the project under consideration may be accepted or rejected depending upon the discount rate, and the fluctuation of the NPV from positive to negative. A major problem in determining the appropriate discount rate is that it effectively depends more on subjective perception of the degree of risk or other past experience factors than on a systematic approach. Determining a realistic discount rate for a given project is therefore the most difficult and important aspect of cash-flow analysis. It should be determined with the full consideration of technical, economic and political conditions surrounding the specific project undergoing economic evaluation. Thus, the main aim of this research is to determine the discount rate by using aforementioned risk factors which influence the choice of the final discount rate used on any chosen mineral project.

Key Words:

Discount Rate, Risk Factors, Economic Evaluation

1 Introduction

An investment decision on a mining project is usually made after economic evaluation which is common in every business application.

When evaluating investment opportunities, one should consider the risks associated with mineral exploration and development. These are commonly classified as technical, economic, and political risks, and are accounted for in the investment decision by applying an appropriate discount rate. There is no doubt that the determination of the discount rate to be implemented for a given project is the most difficult aspect of cash-flow analysis. In practice, however, the discount rate is still subjective and dependent on corporate or other experience factors. This is usually determined by top management and then handed down to the departments responsible for the immediate evaluation of projects.

This study will address the technical, economic and political risk factors which might influence the determination of the discount rate, with particular reference to the role and impact thereof on the economic evaluation. This study will also pinpoint the procedure of determining discount rate by using aforementioned factors.

2   Mine Evaluation Procedure

Mining investments are largely different from investments in other sectors because the targets of mining investments are minerals that are hidden beneath the ground. However, mining evaluation is similar to other sectors since a mine is evaluated on the present value of possible generation of cash flows associated with certain time and risks by incorporating certain interest rates that are appropriate for such investment.

In order to evaluate a mine, reserves need to be calculated to estimate how much mineral is buried underground, then decide the on the production capacity based on certain mining methods that suit the ore body. Finally, estimation on the possible revenue generated by selling the produced mineral product has to be made. Therefore, when evaluating mines, the information on the mineral property needs to be collected and analyzed first before calculating possible cash flows, and then a certain discounted rate needs to be chosen to calculate the net present value of the mine based on the investor's evaluation standard.

Purpose of mine evaluation is to a) sell a property b) obtain a loan from the bank c) assess necessary amount of capital investment required and e) evaluate the value of the assets. There are many other purposes for evaluating a mine and there can be significant differences in the outcome depending on who is evaluating the subject. For an example, manipulation of information data may be possible in order to maximize the value if the owner of a mine was conducting the evaluation. Conservatively minimizing the value may be favorable to minimize the risk of loss if lending institutions such as banks conduct the evaluation.

Therefore, it is important to visit the actual site to ascertain the reliability and correctness of data collected for the evaluation of the project.

Mine evaluation procedures can be divided into three modules of reserve evaluation, optimization decision and feasibility study.

Reserve evaluation module includes steps from collecting drilling samples to reserve calculation. Optimization decision module consists of selecting appropriate mining techniques suitable for a specific ore type while calculating mine life and optimum level of production. Feasibility study module includes an economical analysis of a proposed funding plan along with financial analysis for the cash flow projection as well as thorough review of risks that may affect the project such as politics and environmental issues. However, these modules may not necessarily occur in chronological order as they can be carried out separately and concurrently.

3   Factors Influencing the Determination of Discount Rate

The magnitude of uncertainties in a mine development project is even larger than in most other manufacturing industries. On the basis of some samples and geologic maps, a decision must be reached about development of a mine, its capacity in terms of rate and level of output, a processing plant, and a smelter/refinery complex.

Uncertainty can arise in the estimates of reserves and their average metallic content, in the expected demand and prices for the mineral, and in any other aspects of operation.

Future revenues and costs associated with mineral development are not known with certainty because the factors that determine these revenues and costs are impossible to know with certainty at the time of investment.

During initial exploration, for example, many outcomes are possible, ranging from no indication of commercial mineralization to geologic evidence that eventually leads to a producing mine. During the development of a deposit, initial ore reserve estimates may have to be revised, thus altering estimates of future production and revenues. During production, mineral prices may be higher or lower than predicted at the time of investment, leading to higher or lower revenues than anticipated.

These factors can be grouped into three categories of mineral-development risk according to the cause of the risk: Technical risks, Economic risks, Political risks (W.R.Gocht, 1988a)

3.1   Technical Risks

The technical risks are divided into the following three sub categories: Reserve risk, Completion risk, Production risk.

3.1.1   Reserve Risk

Reserve risk, determined both by nature (the distribution of minerals in the earth's crust) and the quality of ore-reserve estimates, reflects the possibility that actual reserves will differ from initial estimates. A complete understanding of the geology of the deposit is imperative to estimate accurately the distribution, grade and tonnage contained in reserve estimates.

3.1.2   Completion Risk

Completion risk reflects the possibility that a mineral-development project will not make it into production as anticipated because of cost overruns, construction delays, or engineering or design flaws.

3.1.3 Production risk

Production risk reflects the possibility that production will not proceed as expected, either because of problems with equipment or extraction processes, or because of poor management. Technical risks are at least partially under the control of the organizations active in mineral development

3.2 Economic Risks

The economic risks are divided into the following three sub categories:
Price risk, Demand risk, Foreign - Exchange risk

3.2.1 Price risk

Price risk is the variability of possible future mineral prices. Mineral prices are normally determined by the economic law of supply and demand. Mineral prices, together with production levels, determine revenues from mining. Thus, to the extent that actual future prices differ from the prices expected at the time of the cash-flow analysis, actual revenues and profits will differ from those expected.

3.2.2 Demand risk

Demand risk is the variability of future demand for minerals. General economic conditions directly impact on the fluctuation in demand. To the extent that actual and expected mineral demands differ, actual mine production and revenue are affected.

3.2.3 Foreign - Exchange Risk

Foreign-Exchange rate risk is the natural consequence of international operations in a world where relative currency value move up and down. Rates of foreign exchange significantly influence the revenues of firms operating outside their home country, and the revenues of firms selling products that are priced in terms of foreign currencies, as well as the costs of firms importing equipment from outside the country of operation.

3.3 Political Risks

The political risks are determined by the action of governments and reflect the possibility that unforeseen government actions will affect the profitability of an investment. Potential actions include nationalization and changes in regulations concerning, for example, the environment, taxation, currency convertibility. These political risks are divided into the following four sub categories:
Currency convertibility, Environment, Tax, Nationalization

3.3.1 Currency Convertibility

Currency convertibility affects guaranteed freedom of capital transfer.

3.3.2 Environment

Environmental regulations affect the economic viability of mineral projects in three different ways (W.R.Gocht, 1988b).
Firstly, they often increase the costs of mining and mineral processing by requiring,

for example, scrubbers on smelter smokestacks that reduce the amount of sulfur dioxide emitted into the air, plastic liner at the base of tailings ponds that minimize the release of toxic heavy metals into adjoining ground and surface water.

Secondly, environmental regulations often increase the time spent on non mining activities, such as conducting environmental baseline studies, compiling environmental impact statements, and applying for mining permits and waiting for their approval which often associated with delays.

Thirdly, regulations often increase the risks associated with an investment in mining because of the discretionary authority that some regulations vest in government agencies to halt development or mining even after significant expenditures have been made.

3.3.3 Tax
Tax risk affects operating costs and reduces the profitability of mineral projects by the amount of taxes paid. Tax incentives such as tax concession for a limited period, special allowance, debt balance carried forward can be disadvantageously changed by government.

3.3.4 Nationalization
In mineral producing countries, nationalization is pursued to acquire control over foreign mining companies operating in the country, and sometimes leading to complete ownership.

4. Proposed Quantitative Methodology for Discount Rate
From the review of factors influencing the determination of discount rate carried out, it is concluded that the quantitative methodology for discount rate should be a process of identifying potential risk, analyzing risk to determine those that have the greatest impact on mineral development, and determining the discount rate. It is therefore imperative to find a methodology whereby all mining risks, together with their probability and impact, and an understanding of the combined effect of all risks attached to the cash flow and the rate of return. Thus a methodology for calculating risk scores is required. Existing knowledge proposed by Kim Heldman (2005) should therefore be used optimally to determine discount rate.

It is proposed that the quantitative methodology for discount is a process consisting of the following steps:
- Identifying risks
- Developing Rating Scales
- Determining risk values
- Calculating Risk Scores
- Determining discount rate

These steps will be discussed briefly in the following sections.

4.1 Identifying Risks

The first step in the determination of discount rate is identifying all the potential risks that might crop out in the mineral development project. The identification of risk and attitudes towards it are very important in the life of a mine. The following risks should be considered:

- Technical risk- reserve, completion, production
- Economical risk –price, demand, foreign exchange
- Political risk – currency conversion, environment, tax, nationalization
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4.2 Developing Rating Scales

A risk scale assigns High-Medium-Low values for both probability and impact. Most risks will impact cost, revenue, time or scope to a minimum. Thus, scales for each of these constraints can be devised as shown in Table I.

Table I: Risk Scales Assigned by High-Medium-Low Values

Constraint	Risk	Low	Medium	High
Cost	Environmental Tax	Less than 5% increase	6-10% increase	Greater than 10% increase
Revenues	Price Foreign exchange	Less than 5% decrease	6-10% decrease	Greater than 10% decrease
Time	Completion	Less than 5% increase	6-20% increase	Greater than 20% increase
Scope	Reserve Production Demand Currency convertibility Nationalization	Insignificant change	Change to major Deliverable	Change to critical path task

4.3 Determining Risk Values

The second way of creating a risk scale is to assign numeric values to both probability and impact so that an overall risk score can be calculated.

Risk is associated with events in the future and, therefore, to try to measure risk objectively is very difficult. To surmount this difficulty one needs to use the quantitative risk analysis method.

The quantitative risk analysis method assigns not only High-Medium-Low values but also assigns numeric values to both probability and impact, so that an overall risk score can be calculated.

Cardinal scale values are numbers expressed between 0 and 1.0. Probability is usually expressed as a cardinal value.

Tables II and III show description and definition of typical risk values for the High-Medium-Low categories.

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Table II: Probability Scales with Risk Values

Score	Description	Definition
High 0.8	Critical	Will occur frequently, has occurred on the past projects, and the present conditions exist for it to recur
Medium 0.5	Significant	Will occur sometimes, has happened a minimal number of times on past projects, and present conditions are somewhat likely for it to recur
Low 0.1	Negligible	Will not likely occur, has never occurred on past project, and present conditions do not exist for it to recur

Table III: Risk Impact Scales with Risk Values

Score	Description	Definition
High 0.8	Critical	A consequence that will cause loss, cause severe interruptions to the profit or project
Medium 0.5	Significant	A consequence that may cause loss, may cause annoying interruptions to the profit or project
Low 0.1	Negligible	A consequence that may cause minimal loss, cause minimal interruptions to the profit or project

4.4   Calculating Risk Scores

The risk, the probability, and the impact can be listed into a table as individual components. Table IV shows the calculation of risk scores for each category.

The total risk score is calculated by multiplying the probability by the impact. Using the reserve risk, for example, this risk has a low probability of occurring but a medium impact. Therefore, the risk score is calculated by multiplying 0.1 by 0.5 for a final value, also known as an expected value, of 0.05.

Total risk scores are calculated by summing up each risk score and converting to a risk premium.

4.5   Determining the Discount Rate

The rate of discount can be regarded in two ways. In the first case, if a company raises funds from external sources, the discount rate is regarded as **the cost of the capital.** It is the percentage rate of return that the firm must generate to compensate those outside investors, who supply funds to the company rather than to invest their money in another company or activity.

Secondly, if a company uses internal funds, the discount rate is regarded as **the opportunity cost**. This opportunity cost, therefore, is the rate of return the company could earn in the best use of its money.

Each project will have its own degree of risk, and so its own discount rate. The greater the risk, the higher the discount rate should be, raising the discount rate reduces the NPV of a set of cash flows.

Determining the risk-adjusted discount rate is the most difficult aspect of cash-flow analysis where it is important to determine discount rate by the systematic method.

5.   The risk premium

A risk-adjusted discount rate may be developed by using a risk-free rate of return, plus a subjectively determined risk premium, which is expected to compensate the investor for the extra risk involved. In practice the selection of a risk-free rate of return is relatively simple. In the majority of cases, the yield on government bonds, under non-inflationary conditions, is adopted as the risk-free rate of return (Whitney, 1979).

The real problem relates to the selection of the risk premium which must be sufficient to compensate for the additional risks associated with the investment at hand. The risk premium is the premium which is required by the average investor to invest in a risky project. The risk premium is entirely dependent on the risks influencing the mineral development project; which are the result of analysis of:

- The macroeconomic circumstances
- The industry trends
- The project's strong points and weak points and key economic and financial variables
- All other information that significantly affects future cash flows of the project.

When determining an appropriate risk premium, all risks affecting the discount rate should be considered. This, however, is an extensive exercise and will encompass a greater number of risks which makes the determination very difficult to work through and use. Furthermore, there are significant difficulties in structuring an involved analysis with many factors, for the obvious reason that it is complex and multi-faceted. In order to facilitate the determination, they are usually focused on a definite number of key risks such as technical, economical and political risks.

To determine risk premium, an expected value (the sum of all possible values for the risk) as calculated in the previous section has to be converted to an overall value and risk premium.

An expected value can be divided into five levels based on the total risk scores, for example, if all ten risk factors have low risk score for both probability and impact, it would be an expected value of 0.00 - 0.10, and if five risks have high risk score and the others medium, it would be 4.46 - 6.40.

An overall value and risk premium can be determined as shown in Table V.

Table V: Risk Premium Determination

Expected Value	Value	Risk Premium
4.46-6.40	High-High	20.0%
2.51-4.45	High	16.0%
1.51-2.50	Medium	12.0%
0.11-1.50	Low	9.0%
0.00-0.10	Low-Low	6.0%

The determination of risk premium is incumbent on the impact of the factor and the potential possibility of it affecting success in the mineral development project.

6. The risk-adjusted discount rate

Put simply but rather crudely, we can represent a risk-adjusted discount rate as follows:

Risk-Adjusted Discount Rate = Risk-free rate of return + Risk premium

- The risk-free rate of return – for mineral development projects, it is advisable to use a 10-year bond that yields 1.2 percent
- The risk premium – use 6~20 per cent as the generally accepted range.
- The application of these numbers to the risk-adjusted discount rate formula yields the following risk-adjusted discount rate for mineral development projects.

Risk-Adjusted Discount Rate = Risk-free rate of return + Risk premium
= 1.2% + 6~20% = 7.2~21.2%

Thus, the risk-adjusted discount rate required by mining companies should ideally range between **7.2 and 21.2 percent.**

7. Case study

This Case Study is based on developing a nickel mine in Madagascar called the Ambatovy Project. This study gives an example of the risks that were considered in selecting a discount rate such as exploration, reserve calculation, construction phase, the operation and the sales associated with the product. Discount rate for the Ambatovy project was selected by using the quantitative methodology explained in previous section to assess the economic viability of the project.

7.1 Introduction

Located in Madagascar, the Ambatovy is a world-class, large tonnage nickel project that is positioned to become the world's biggest lateritic nickel mine by 2013. Ambatovy is a

long-life lateritic nickel project with annual design capacity of 60,000 tons of nickel and 5,600 tons of cobalt. The mine life is currently projected to be 27 years. The Ambatovy mine site is located 80 kilometers east of Antananarivo (the capital of Madagascar) near the city of Moramanga. It is within a few kilometers of the main road and rail system connecting Antananarivo and the main port city of Toamasina on the

east coast. The project will consist of an open-pit mining operation and an ore preparation plant at the mine site. The slurried laterite ore will then be delivered via pipeline to a process plant and refinery located directly south of the port of Toamasina.

Development plan

Mineral reserves

- 125 million tonnes @ 1.04% Ni, 0.10% Co (0.8% nickel cutoff)
- Additional 39.4 million inferred tonnes @ 0.69% Ni, 0.064% Co
- Potential to increase reserves with additional drilling

Mining method

- 4 separate open pits
- Mine limonite and low magnesium saprolite "LMS" after stripping overburden of 3m from the surface
- Mine ore delivered by truck to ore preparation plant
- Ore then conveyed to scrubber where water is added to slurry the ore
- Slurry thickened and delivered to pipeline

Transportation of ore

- Ore transformed into a slurry from at the Ore Preparation Plant is transported through the pipeline buried 1.5m below the surface to the processing plant
- Pipeline is 220km long and 600mm in diameter
- Single pump station at mine site is installed to transport the slurry ore while using the gravity as a dragging force since the elevation difference is about 1,000m

Processing and refinery

- Project to utilize only proven metallurgical processes, all process unit operations found elsewhere operating on a commercial scale
- High Pressure Acid Leaching technique is used to produce nickel briquette and cobalt.
- This process is separated into two parts where pressure leach is applied to produce mixed sulphides and the stage where the mixed sulphides are smelted and refined.

Capex

- Capital Expenditure (Capex): U$2,500 millions

Operating Expenditure (Opex)

- Average Opex during 27 yrs of mine life: Ni- 1.99U$/lb (with credit, 0.97U$/lb)
- 10 year average Opex after ramp-up period:Ni- 1.75U$/lb (with Credit, 0.77U$/lb)

7.2 Determining the Rating Scales for Ambatovy Project

The potential risks associated with the project are: Technical risk (reserve, completion and production risk), Economic risk (price, demand and foreign-exchange risk and Political risk (currency convertibility, environment, tax and nationalization)

Effects of possible technical, economical and political risks on the project's schedule, budget, resources, deliverables, costs and quality were evaluated using the High-Medium-Low rating scales.

The effects of potential risks on cost, revenue, time or scope were also evaluated using High-Medium-Low rating scale.

Probability and impact scales of the Ambatovy Project are shown in Table VI.

Table VI: Rating Scales of Ambatovy Project

Category	Risk	Probability	Impact	Remarks
Technical Risk	Reserve	Low	Low	Drilled: 1,282holes, 54,888M
	Completion	Medium	Medium	Period of construction: 36months
	Production	Low	Medium	Utilizing globally proven technology
Economic Risk	Price	Medium	High	Changes in the price range is large
	Demand	Low	Medium	Shortage of supply
	Foreign Exchange	Low	Medium	Stable currency market forecasted
Political Risk	Currency Convertibility	Low	Medium	Low Currency Convertibility risk due to specialized law
	Environment	Low	High	EA approved by the government
	Tax	Low	Medium	Tax incentives due to specialized law
	Nationalization	Low	High	Low risk for nationalization

7.3   Determining Risk Values for Ambatovy Project

Numeric values need to be applied in the probability and impact explained in the previous section in order to calculate the risk score of the Project. However, this process is very hard to carry out especially for calculating a value that represents a possible risk in the future.

Therefore, the quantitative risk analysis method as previously explained is used to decide the risk value of between 0 and 1.0 for the probability and impact.

7.2   Calculating Risk Scores for Ambatovy Project

As explained before the risk, the probability, and the impact can be listed in a table as individual components. The Risk score was calculated by multiplying the probability of the risk by the impact as shown in Table VII.

Table VII: Calculation of Risk Score of Ambatovy Project

Category	Risk	Probability	Impact	Risk Score
Technical Risk	Reserve	Low -0.1	Low-0.1	$0.1 \times 0.1 = 0.01$
	Completion	Medium-0.5	Medium-0.5	$0.5 \times 0.5 = 0.25$
	Production	Medium-0.5	Medium-0.5	$0.5 \times 0.5 = 0.25$
Economic Risk	Price	Medium-0.5	High-0.8	$0.5 \times 0.8 = 0.40$
	Demand	Low-0.1	Medium-0.5	$0.1 \times 0.5 = 0.05$
	Foreign Exchange	Medium-0.5	Medium-0.5	$0.5 \times 0.5 = 0.25$
Political Risk	Currency Convertibility	Low-0.1	Medium-0.5	$0.1 \times 0.5 = 0.05$
	Environment	Low-0.1	Medium-0.5	$0.1 \times 0.5 = 0.05$
	Tax	Low-0.1	Medium-0.5	$0.1 \times 0.5 = 0.05$
	Nationalization	Low-0.1	High-0.8	$0.1 \times 0.8 = 0.08$
Total				**1.44**

Total risk scores are 1.44 which is calculated by summing up each risk score.

7.5   Determining the Discount Rate for Ambatovy Project

7.5.1   The risk premium

To determine risk premium, an expected value (risk score) as calculated in the previous section has to be converted to an overall value and risk premium.

An overall value and risk premium for Ambatovy Project was determined as shown in Table VIII.

Table VII: Expected Value and Risk Premium for Ambatovy Project

Expected Value	Value	Risk Premium
4.46 - 6.40	High-High	20.0%
2.51 - 4.45	High	16.0%
1.51 - 2.50	Medium	12.0%
0.11 - 1.50	Low	9.0%
0.00 - 0.10	Low-Low	6.0%

Risk premium calculated in accordance with the table above is 9.0% since the risk score of the Project calculated is 1.44.

7.5.2   The risk-adjusted discount rate

From the above extrapolation the risk-adjusted discount rate can be determined from the risk-adjusted discount rate formula as follows:

Risk-Adjusted Discount Rate = Risk-free rate of return + Risk premium

- **The risk-free rate of return** – *a 10-year bond that yields 1.2 percent*
- **The risk premium** – *9.0%*

Thus, the risk-adjusted discount rate required for Ambatovy Project is **10.2 percent.**

8.   Conclusions

- It is concluded that the quantitative methodology for discount rate should be a process of identifying the factors influencing mineral development projects. Therefore, a methodology is required whereby the key factors crucial for success of the mineral development projects are used as a fundamental base.

These key factors can be grouped into three categories of mineral-development risk according to the cause of the risk as follows:

- Technical risk: reserve, completion, production
- Economic risk: price, demand, foreign exchange
- Political risk: currency convertibility, environment, tax, nationalization

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A procedure for identifying the key factors relevant to discount rate is then required. In this way, existing knowledge should be used in an optimal way to determine discount rate. Hence the quantitative methodology for discount rate is a process considering the following steps:

- Identifying risks
- Developing rating scales
- Developing risk values
- Calculating risk scores
- Determining the discount rate

Put simply but rather crudely, we can represent a risk-adjusted discount in the following formular:

Risk-Adjusted Discount Rate = Risk-free rate of return + Risk premium

The risk-free rate of return: for mineral development projects, it is advisable use a 10-year bond that yields 1.2 percent

The risk premium : use 6~20 percent as determined by the researcher

Thus, the risk-adjusted discount rate required by mining companies ranges between **7.2 and 21.2 percent.**

It is obvious that the risk-adjusted discount rate approach is useful to the decision-maker in that it produces decision tool in the form of a risk-adjusted rate of return. The inherent disadvantage of this approach is the selection of the risk premium which is subjective and hence the reliability of the method is often suspect.

The risk-adjusted discount rate is not the end-all and be-all criterion for the decision to invest in a mineral development project under consideration, although it is generally one of the motivating factors considered by the firm's management.

The attitude of investors to risk taking is entirely subjective and very difficult to express in quantitative terms. Investors who are not particularly averse to risk, tend to choose the low level of discount rate, whereas the more cautious and risk-averse investors will usually tend to select the medium level of discount rate. The decidedly risk-averse investors will usually opt for a high level of discount rate.

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