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# Analysis of the discount rate for mining projects

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## Abstract

*The discount rate is one of the key planning parameters for defining and ranking mining projects. As miners, we assume that it is determined by a higher authority and take it as given. However, from the standpoint of a mining project, it warrants analysis. This paper discusses its definition and calculation, looking at the discount rates used in different sectors of the economy, including mining. In the case of mining, 100 projects were selected from the SEDAR database and discount rates were analysed by country-location, stage of development, size, the metals and minerals involved and project life. The average discount rate of the 100 projects was 7.18%, including 35 projects that used 5%. When these projects were excluded, the average rate was 8.36%. The discount rates used by a mining corporation over the last 50 years and an example of the effect of the discount rate on reserve determination for a block caving project are also shown and lower discount rates are recommended for long-life mining projects.*


## 1 Introduction

The discounted cash flow financial modelling methodology and the derived net present value (NPV) are widely used to evaluate and compare projects. The discount rate is applied to the project's future cash flows to calculate its NPV.

In the mining industry, the variables with the greatest impact on the NPV are mining reserves, metal prices and the discount rate (Smith 1995). It is the latter parameter that this paper discusses, looking at its components and the methodology for estimating project-specific discount rates.

The discount rate to be used for a project is usually set by an authority within the company or corporation, with little transparency as to how it is determined.

This paper is presented to support the use of lower discount rates (DR) for specific long-life projects.

## 2 Discount rate

### 2.1 What is the discount rate?

The discount rate (DR) is the annual percentage value used in discounted cash flow analysis to determine the net present value (NPV) of future cash flows. The NPV is calculated as shown in Equation (1):

$$\mathrm{NPV} = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} \tag{1}$$

Where:

| | | |
|---|---|---|
| NPV | = | net present value |
| N | = | final year of project |
| n | = | year, from initial year of investment to final year of production closedown |
| Cn | = | cash result in year n |
| r | = | discount rate |
| Σ | = | summation operator for all cash results of the project, from year 0 to year N |

In a discounted cash flow analysis, the sum (Σ) of all the project's future cash results ($C_n$), from the initial year of capital investment (0) through to the last closedown year (N), is discounted back to the present (year 0), using a rate of return (r). This rate of return (r) in Equation (1) is the discount rate.

## 2.2 How are future cash flows affected by different discount rates?

To show the effect of different discount rates, Table 1 indicates the present value of US$1,000 brought to the present from a selection of future years.

**Table 1 Present value of US$1,000 at different discount rates**

| From year | 0% | 2% | 3% | 4% | 5% | 6% | 7% | 8% | 9% | 10% | 12% | 15% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| 1 | 1,000 | 980 | 971 | 962 | 952 | 943 | 935 | 926 | 917 | 909 | 893 | 870 |
| 5 | 1,000 | 906 | 863 | 822 | 784 | 747 | 713 | 681 | 650 | 621 | 567 | 497 |
| 10 | 1,000 | 820 | 744 | 676 | 614 | 558 | 508 | 463 | 422 | 386 | 322 | 247 |
| 15 | 1,000 | 743 | 642 | 555 | 481 | 417 | 362 | 315 | 275 | 239 | 183 | 123 |
| 20 | 1,000 | 673 | 554 | 456 | 377 | 312 | 258 | 215 | 178 | 149 | 104 | 61 |
| 30 | 1,000 | 552 | 412 | 308 | 231 | 174 | 131 | 99 | 75 | 57 | 33 | 15 |
| 40 | 1,000 | 453 | 307 | 208 | 142 | 97 | 67 | 46 | 32 | 22 | 11 | 4 |
| 50 | 1,000 | 372 | 228 | 141 | 87 | 54 | 34 | 21 | 13 | 9 | 3 | 1 |

Obviously, at a DR of 0%, there is no time preference for money and US$1,000 in year 50 is worth US$1,000 today. On the other hand, at a DR of 15%, US$1,000 in year 50 is worth US$1 today. Similarly, for example, a present value of US$1,000, equivalent to US$372 today, occurs from year 50 at a 2% DR, from year 20 at a 5% DR and from year 7 at a 15% DR (shaded zone of Table 1).

## 2.3 How is the discount rate calculated?

The discount rate for evaluating mining projects performs the same function as for any other project. It takes into account the time value of money and project risk: the higher the perceived risk, the higher the discount rate.

Many authors have attempted to develop a procedure for estimating an appropriate discount rate for the evaluation of mining projects. In general, two methods are used.

### *2.3.1 Method 1*

The first calculates the company's cost of capital using the weighted average cost of capital (WACC) method, based on the capital asset pricing model (CAPM) in order to arrive at the cost of equity. There are other methods of calculating the cost of equity - for example, dividend yield plus the forecast growth rate, the CAPM including some additional risk, average historical returns, investors' required returns and the E/P ratio - but the CAPM is the most widely used.

The WACC can be considered as the minimum discount rate for any project of a certain company. It is calculated according to Equation (2), which essentially gives the weighted average of the cost of the company's own capital or equity (Ke) and the cost of debt (Kd):

$$WACC = \%Debt * Kd * (1\text{-}T) + \%Equity * Ke \quad (2)$$

Where:

| | | |
|---|---|---|
| %Debt | = | Percentage of project financed with debt |
| %Equity | = | Percentage of project financed with investor's own capital |
| Kd | = | Cost of debt |
| T | = | Tax rate |
| Ke | = | Cost of equity |

The basis of the CAPM method is that the return on a company's own stock can be related to the stock market as shown in Equation (3):

$$Re = Rf + R * ß \tag{3}$$

Where:

| | | |
|---|---|---|
| Re | = | expected return on the common stock |
| Rf | = | risk-free return (usually based on government bond rates) |
| R | = | risk premium of market returns above long-term risk-free rates |
| ß | = | beta factor for the common stock. |

The beta factor expresses the variability of the common stock with respect to the variability of the market. By definition, the beta of the market is 1.00.

As an example of the calculation of the expected return on common stock, Gilbertson (1981) used the CAPM method for important mining shares on the Johannesburg Stock Exchange, estimating ß through regression analysis. Equation (4) shows the cross-sectional regression of the expected return on many individual shares.

$$Re = 18.5\% + 6.8\% * ß \tag{4}$$

In this example, the risk-free rate was then a high 18.5%.

ß usually varies between 0.3 and 0.8.

### *2.3.2 Method 2*

The second method of estimating the discount rate for mining projects is to add up the discount rate components. The components used differ depending on the author. For example, Smith (1995) related the discount rate to the three components in Equation (5):

$$Re = Rf + Rp + Rc \tag{5}$$

Where:

| | | |
|---|---|---|
| Re | = | project-specific, constant-dollar, 100% equity discount rate |
| Rf | = | real risk-free long-term interest rate |
| Rp | = | risk portion of the project discount rate |
| Rc | = | risk increment for country risk |

This method is simple and is the one I favour. Rf and Rc are objective and obtainable and Rp can be benchmarked in the early stage of a project and estimated subsequently using Park's (2011) methodology.

## 2.4 Discount rate estimation in practice

The CAPM is the model most commonly used to estimate discount rates for projects, but is also subject to considerable criticism. In the valuation of mining projects, it has drawbacks as regards the use of the market-based beta. According to Lilford (2006), these drawbacks include:

- Betas indicate the volatility of a share price, not the specific asset of a listed company, such as a mineral property or specific mining operation;
- Betas of a specific listed entity vary with the market, not independently of the market;
- Betas vary over time so that the value of a project will also vary over time through a changing discount rate;
- Owing to the cyclical nature of mineral prices (supply and demand vary differently for each mineral), relative betas will also vary so that a perfect correlation is improbable.

Despite these debates, the CAPM continues to be the main method used, particularly by large companies, because it is supposedly the best method.

On other less frequently used models, Taheri (2009) noted the following:

- The problem with dividend growth models is the obvious uncertainty in the determination of anticipated future dividends from one period to the next. For mining projects, this uncertainty is exacerbated by the fact that many mining companies reinvest their distributable income into capital growth assets and, therefore, do not pay dividends at all or, at least, do not do so for long periods. A company's leverage will also influence whether it pays dividends or whether it uses free cash flow to reduce its debt profile to the desired level.
- The E/P model is obviously more suitable than the dividend valuation model for companies that pay low or no dividends. However, it has drawbacks related to the use of earnings per share (EPS) of which the most important is that earnings figures do not adequately reflect risk.

The limitations and shortfalls of all these methods oblige practitioners to use other methods to determine the company's cost of capital. As a last resort, the discount rate can be determined using a direct approach. The main difference is that the adjustments discussed above are not made.

Truong et al. (2008) looked at how discount rates for project evaluation were estimated in Australia. Their results are shown in Figure 1. The survey sample included 356 firms, of which 87 provided useful responses. One project may use one criterion or a number of combined criteria.

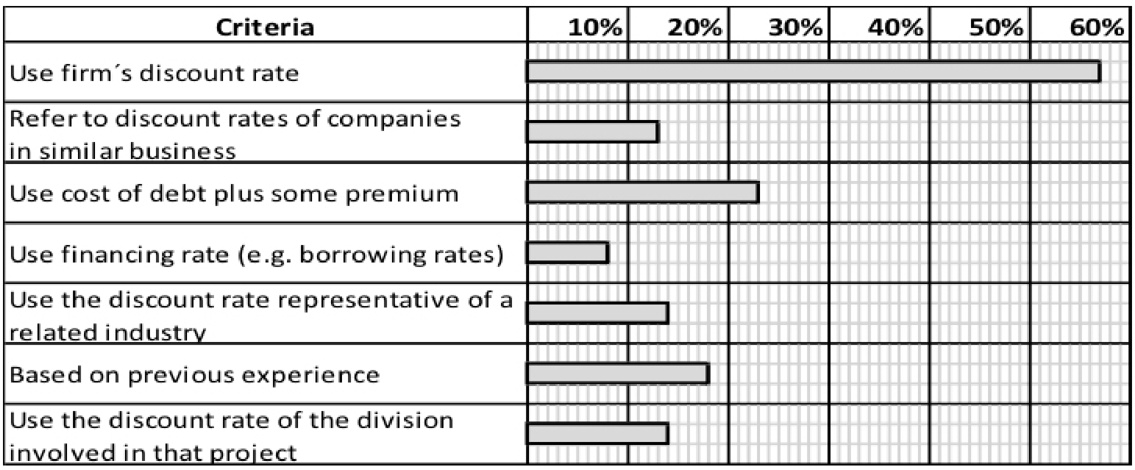



**Figure 1 Methods of estimating projects' discount rates in Australian mining firms (2007)**

# 3 Industry practice

In order to obtain an overview of discount rates in different sectors of the economy, information was compiled about the time value of money, risk-free rates and the DR in industries of different types.

## 3.1 Time value of money and risk-free rate

Out of the two main components of the DR, the time value of money is common to projects of all types while the risk component differs by sector.

The time value of money, which is usually assimilated to the return on government bills and bonds, is presented for 16 countries (Australia, Belgium, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK and US) and is summarised in Table 2 (Jordà 2017). Figure 2 shows the 10-year bond yield for the United States from 1987 to 2019.

**Table 2 Summary of real rates of return on bills and bonds of 16 countries, full sample, 1870-2015 (Jordà 2017)**

| | Full Sample | | Post-1950 | | Post-1980 | |
|---|---|---|---|---|---|---|
| | Bills | Bonds | Bills | Bonds | Bills | Bonds |
| Weighted average | 1.34% | 2.51% | 1.23% | 2.70% | 1.98% | 5.64% |
| Highest | 3.08% | 3.58% | 2.18% | 4.86% | 3.23% | 7.13% |
| Lowest | -0.47% | 1.41% | -0.65% | 1.21% | 0.33% | 3.35% |

In 1980-2015, the average bond yield was high (5.64%) but has dropped in the last five years when, as Figure 2 shows, it averaged 2.90% in the United States. Surprisingly, over the long term (1870-2015), the weighted average for all 16 countries was 2.51%, quite near the value for the last five years for the US and many other countries, despite the ups and downs, due to wars and catastrophes, that occurred over that long period.

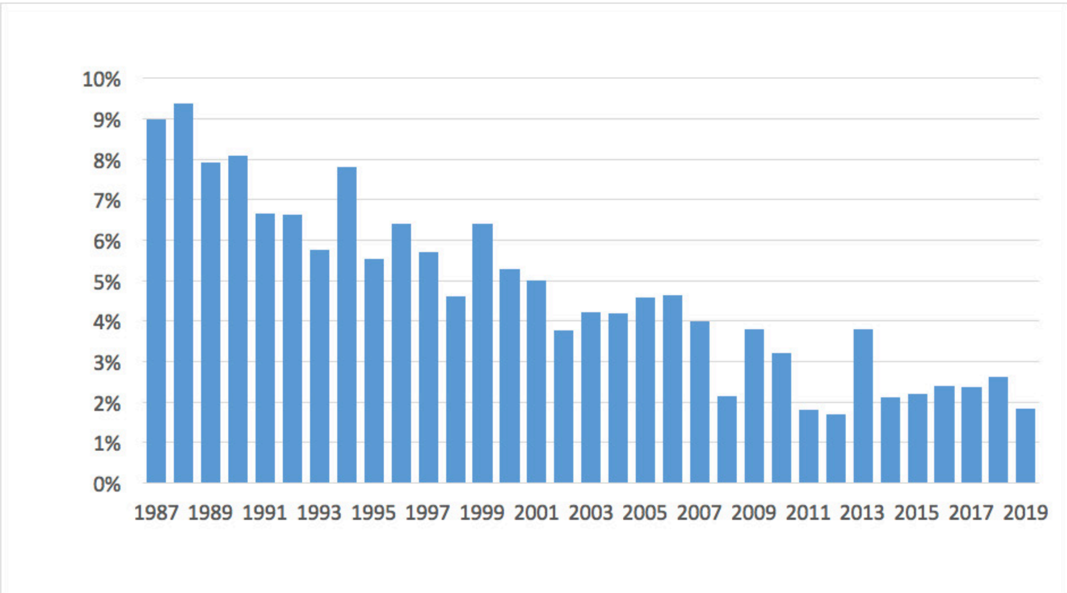



**Figure 2 Ten-year bond yields for US from 1987 to 2019 (Macrotrends 2020)**

A value of around 2% can be considered as the risk-free value of money today.

## 3.2 Discount rates used by different industries

Different types of economic activity have different risks and, hence, use different discount rates for their projects.

Discount rates were reviewed for the following non-mining sectors: equity or stocks, housing, biotech, renewable energy, traditional energy, transport infrastructure, forestry and social projects. A summary of the results is shown in Table 3, except forestry for which no results were found.

For the mining industry, 100 projects with NPV evaluations and their respective discount rates were taken from the System for Electronic Document Analysis and Retrieval (SEDAR) database, a filing system developed for the Canadian Securities Administrators.

**Table 3 Summary of discount rates for non-mining economic activities**

| | Stocks | Housing | Biotech | Renewable energy | Traditional energy | Transport infrastructure | Social |
|---|---|---|---|---|---|---|---|
| DR (%) | 9.08 | 5.50 | 13.50 | 6.45 | 5.50 | 7.00 | 3.50 to 3.00 |
| Years | 1980-2015 | 1980-2015 | PFS, 2010 | 2017 | 2015 | 2017 | UK, 0-75 yrs |

Details of the results for the different economic sectors and for the mining projects are presented below.

### *3.2.1 Equity and housing*

Table 4 shows the results for equity (or stocks) and housing projects (Jordà 2017) for the same 16 countries summarised in Table 2.

**Table 4 Summary of real rates of return on equity and housing for 16 countries, full sample 1870-2015 (Jordà 2017)**

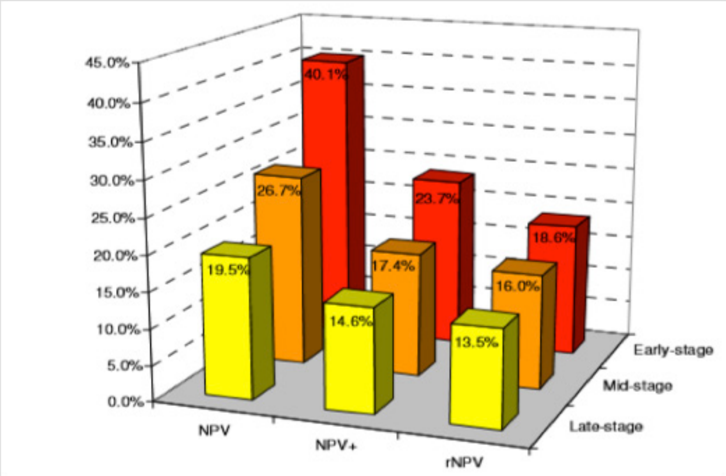
| | Last 145 years | | Last 65 years | | Last 35 years | |
|---|---|---|---|---|---|---|
| | Equity | Housing | Equity | Housing | Equity | Housing |
| Average | 7.12% | 6.72% | 8.19% | 6.40% | 9.08% | 5.50% |
| Highest | 10.03% | 9.58% | 12.89% | 11.18% | 15.87% | 9.82% |
| Lowest | 3.21% | 1.41% | 4.84% | 5.30% | 5.62% | 4.13% |

The average return on equity in these 16 countries in the last 35 years was 9.08%, above the 8% usually accepted for mining projects.

The average return on housing for the last 35 years was 5.50%, below the 8% usually accepted for mining projects.

### *3.2.2 Biotech*

The discount rates used in drug development projects were surveyed in 2010 by Villiger & Nielsen (2010). The survey had 243 respondents: US (43%), Europe (47%) and rest of the world (10%). It included the following groups: biotech (28%), consultants (24%), analysts (16%), pharma (12%), others (10%), investors (7%) and medtech (3%). Overall, the survey conveys a very reasonable picture of discount rates as used in discounted cash flow methods in the biotech sector.




Notes:

Earlier-stage companies are always more heavily discounted because they have more risks.

Evaluation methods are:

NPV = a discounted cash flow method without success rates, i.e. without risk adjustment

NPV+ = a discounted cash flow method which then multiplies the result by a probability

rNPV = a discounted cash flow method that risk-adjusts each cash flow with its specific probability

**Figure 3 Average discount rates used in biotech project evaluations**

In Figure 3, the rNPV has costed the success risk so the discount rates do not include the success risk and are lower: the total averages of 13.5% for advanced-stage projects (feasibility engineering), 16.0% for intermediate-stage projects (pre-feasibility engineering) and 18.6% for preliminary-stage projects (conceptual and scoping engineering) are significantly above the 8% commonly accepted for mining projects.

### *3.2.3 Renewable energy*

The discount rates for secondary market renewable energy mergers and acquisitions were surveyed in 2017 by Grant Thornton and the Clean Energy Pipeline Initiative (2018). The survey had a total of 35 respondents from Australia (3), Canada (4), France (4), Germany (3), Ireland (4), Italy (3), the Nordic countries (4), Spain (2), the UK (4) and the US (4) and included the following types of operation: offshore wind (7), onshore wind (10), solar (10) and hydro (8). The results are presented in Table 5. The projects for which responses were received represent a total investment of some US$7 billion.

**Table 5 Unlevered discount rates (%) used in the renewable energy market, mergers and acquisitions, 2017**

| Countries | Hydro | Solar | Onshore wind | Offshore Wind | Average |
|---|---|---|---|---|---|
| Australia | 8.50 | 6.75 | 7.50 | | 7.58 |
| Canada | 4.75 | 5.25 | 6.00 | 7.50 | 5.88 |
| France | 5.50 | 5.50 | 5.75 | 8.25 | 6.25 |
| Germany | | 4.25 | 5.00 | 6.25 | 5.17 |
| Ireland | 7.00 | 6.25 | 6.50 | 8.25 | 7.00 |
| Italy | 5.25 | 6.50 | 7.25 | | 6.33 |
| Nordic countries | 5.00 | 6.25 | 5.75 | 7.00 | 6.00 |
| Spain | | 7.00 | 7.25 | | 7.13 |
| UK | 6.50 | 6.00 | 6.75 | 7.75 | 6.75 |
| US | 5.75 | 6.70 | 6.70 | 7.50 | 6.66 |
| Average | 6.03 | 6.05 | 6.45 | 7.50 | 6.45 |

The values foe groups of projects showed some pattern with respect to risk, the highest being for offshore wind farms, followed by onshore wind farms and, with the lowest risk, hydro and solar operations.

The overall average of 6.45% is below the 8% commonly accepted for mining projects.

### *3.2.4 Traditional energy*

Khati (2015) studied the discount rate for traditional energy projects, mostly in North America. He found that investors in energy projects expect a rate of return from projects that compensates for the following: the minimum acceptable real return available in the market (risk-free interest rate), the risk of investing in the project, taxation and inflation. Nonetheless, the rate of return was calculated in real terms, thus ignoring inflation.

The return on equities (capital gains plus dividends) fluctuates in the stock market. Recently, this equity risk premium had been running at 5.75% in mature markets.

The level of risk in regulated energy utilities is lower than the average market risk. A stock's sensitivity to changes in the value of the market portfolio is known as beta. In a competitive market, the expected risk premium varies in direct proportion to beta. Using the CAPM: discount rate = real risk-free rate + market risk premium x beta.

If beta is assumed to have a value of 0.6 for an asset/project, the calculation of the discount rate is as follows:

DR = 0.7% (risk-free rate) + 5.75% (market risk premium) x 0.6 (which is ß) = 4.2%

This discount rate of 4.2% is substantially lower than the 8% commonly accepted for mining projects. However, it is worth noting that the 0.7% risk-free rate is considered low and, using the 2% risk-free rate indicated in Section 3.1, the discount rate for traditional energy projects would be 5.5%.

### *3.2.5 Transport infrastructure*

The discount rate for transport infrastructure projects in Australia was set at 7% in 1989 when the risk-free rate was 6.8% in real terms. In 2017, the discount rate for infrastructure projects remained at 7% but the risk-free rate had dropped to around 1%. Terril & Batrouney (2018) advocate periodic reviews and adjustments of rates for transport infrastructure projects in Australia in order to take account of variations in the risk-free rate, because "using an inappropriate discount rate is likely to distort the priority that is assigned to different projects, and so distort choices involving billions of dollars of public investment. We may end up building projects in the wrong order, or worse, building the wrong projects."

Even though the 7% discount rate fixed by the Australian authorities is now considered high for public transport projects, it is below the 8% commonly accepted for mining projects.

### *3.2.6 Social projects*

Discount rates for social projects receive special treatments in the United Kingdom, France, Norway and the United States.

For example, in the UK, it is based on the Ramsey formula ($\alpha = \delta + \gamma\mu$) and declines over time (Ni 2017). The first term ($\delta$ = 1.5%) is interpreted as a combination of pure time preference and the risk of catastrophe (under which the future effects would be eliminated or severely altered). The elasticity of the marginal utility of consumption ($\gamma$) is set at 1 and the economic growth rate ($\mu$) estimated as 2.0%, yielding a discount rate of 3.5% = 1.5% + 1*2.0%. For periods of more than 30 years, the UK guidance specifies a stepwise decreasing discount rate motivated by uncertainty as shown in Table 6 for up to 300 years (Ni 2017).

**Table 6 UK discount rate guidance table, green book appraisal and evaluation in central government**

| Period of years | 0-30 | 31-75 | 75-125 | 126-200 | 201-300 | 300+ |
|---|---|---|---|---|---|---|
| Discount rate | 3.5% | 3.0% | 2.5% | 2.0% | 1.5% | 1.0% |

### *3.2.7 Mining*

To analyse the discount rate for the mining industry, 100 projects with NPV evaluations and their respective discount rates were taken from the SEDAR database. These projects selected were filed between 2008 and 2020 and include a range of companies, project country-locations, project stages, project sizes, metals and minerals and project lives.

The distribution of projects according to the discount rates reported are shown in Figure 4.

The discount rates for the 100 projects by the year they were filed in SEDAR are shown in Figure 5.

The average discount rate for all the projects is 7.18%. The number of projects with a 5.00% DR is surprisingly high. When these projects are excluded, the average discount rate is 8.36%.

| | Number of projects | Discount rate (%) | |
|---|---|---|---|
| | 2 | 12 | |
| | 11 | 10 | |
| | 3 | >8 to <10 | |
| | 42 | 8 | |
| | 7 | >5 to <8 | |
| | 35 | 5 | |
| Total | 100 | 7.18 | Average |

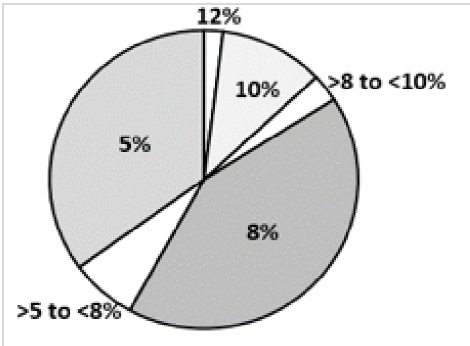



**Figure 4 Distribution of discount rates of 100 SEDAR-filed projects, 2008-2020**

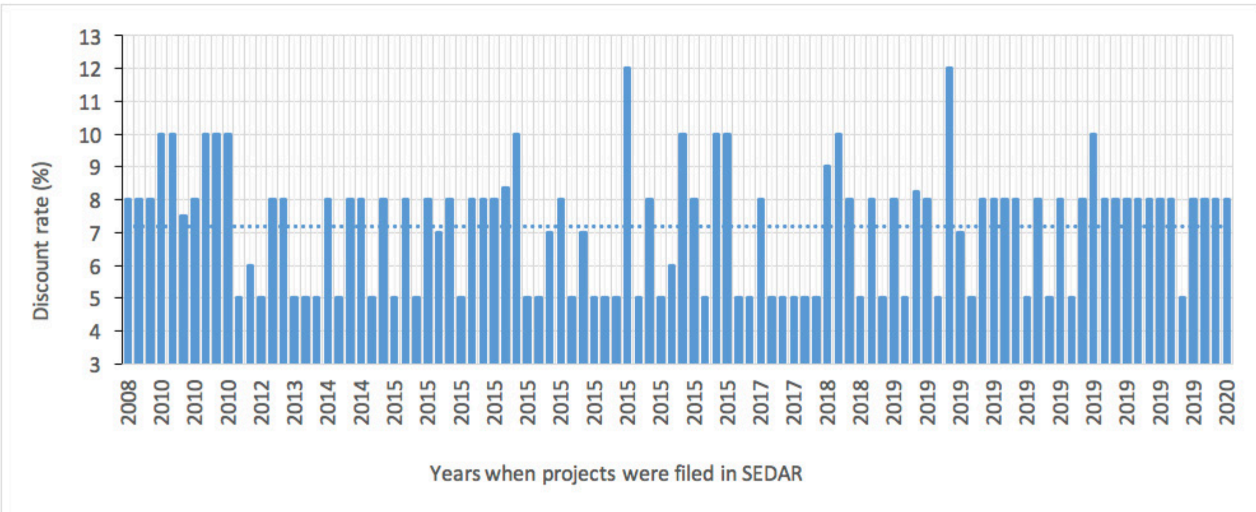



**Figure 5 Discount rates of 100 SEDAR-filed projects, 2008-2020**

The trend line for the DR is flat over the time span considered (2008-2020).

### 3.2.7.1 DR used for different countries

The discount rates used by projects in different countries are shown in Table 7.

Although the number of projects by country is small and non-representative, the countries have been arranged in ascending order of discount rate values in Table 7. Despite the comparison being non-valid, the percentage value of the country risk premium published by Damodaran (2020) is also shown as a reference. The comparison shows no correlation between the country risk premium and the discount rates used for different countries.

**Table 7 Discount rates by country for 100 SEDAR-filed projects, 2010-2020, and January 2020 values of country risk premiums (Damodaran 2020)**

| | Country | DR (%) | Projects | Country risk premium (%) | | Country | DR (%) | Projects | Country risk premium (%) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Argentina | 5.00 | 1 | 8.88 | 17 | Egypt | 8.00 | 1 | 5.43 |
| 2 | Guatemala | 5.00 | 1 | 2.46 | 18 | Kyrgyz Republic | 8.00 | 1 | 5.43 |
| 3 | Peru | 5.00 | 6 | 1.18 | 19 | Namibia | 8.00 | 1 | 2.96 |
| 4 | Serbia | 5.00 | 1 | 3.55 | 20 | Niger | 8.00 | 1 | 6.42 |
| 5 | Mexico | 5.63 | 8 | 1.18 | 21 | Romania | 8.00 | 2 | 2.17 |
| 6 | South Africa | 6.75 | 4 | 2.17 | 22 | Ukraine | 8.00 | 1 | 7.39 |
| 7 | Turkey | 7.00 | 4 | 4.44 | 23 | Australia | 8.08 | 3 | 0.00 |
| 8 | Canada | 7.03 | 29 | 0.00 | 24 | Zimbabwe | 8.36 | 1 | 11.83 |
| 9 | Brazil | 7.25 | 4 | 2.96 | 25 | Mali | 8.50 | 2 | 6.42 |
| 10 | Bulgaria | 7.50 | 1 | 1.88 | 26 | Ghana | 9.00 | 1 | 6.42 |
| 11 | Nicaragua | 7.50 | 2 | 5.43 | 27 | Czech Republic | 10.00 | 1 | 0.60 |
| 12 | United States | 7.50 | 14 | 0.00 | 28 | Côte D'Ivoire | 10.00 | 1 | 3.55 |
| 13 | Bolivia | 8.00 | 1 | 3.55 | 29 | Finland | 10.00 | 1 | 0.39 |
| 14 | Chile | 8.00 | 2 | 0.69 | 30 | Malawi | 10.00 | 1 | 6.42 |
| 15 | China | 8.00 | 1 | 0.69 | 31 | Papua New Guinea | 10.00 | 1 | 5.43 |
| 16 | DR Congo | 8,00 | 2 | 7.39 | Total weighted average | | 7.18 | 100 | 2.22 |

### 3.2.7.2 DR used for different project stages

The discount rates used for the different stages of projects are shown in Table 8. The distributions of discount rates for the scoping, pre-feasibility (PFS) and feasibility (FS) stages are shown in Figures 11, 12 and 13, respectively.

Scoping studies are also commonly referred to as Preliminary Economic Assessment (PEA) studies.

Among the 100 projects taken from SEDAR, there was only one detailed engineering study, which used an 8% discount rate.

Different authors have pointed out that discount rates should be higher for scoping studies, lower for projects with more engineering, and lowest for projects with detailed engineering. The SEDAR sample shows little correlation with this principle, except for PFS (7.80%) and FS (7.15%).

**Table 8 Discount rates for different stages in 100 SEDAR-filed projects, 2008-2020**

| Stage | Number of projects | Average DR |
|---|---|---|
| Scoping | 37 | 7.01 |
| PFS | 21 | 7.80 |
| FS | 41 | 7.15 |
| Detail | 1 | 8.00 |
| Total | 100 | 7.25 |

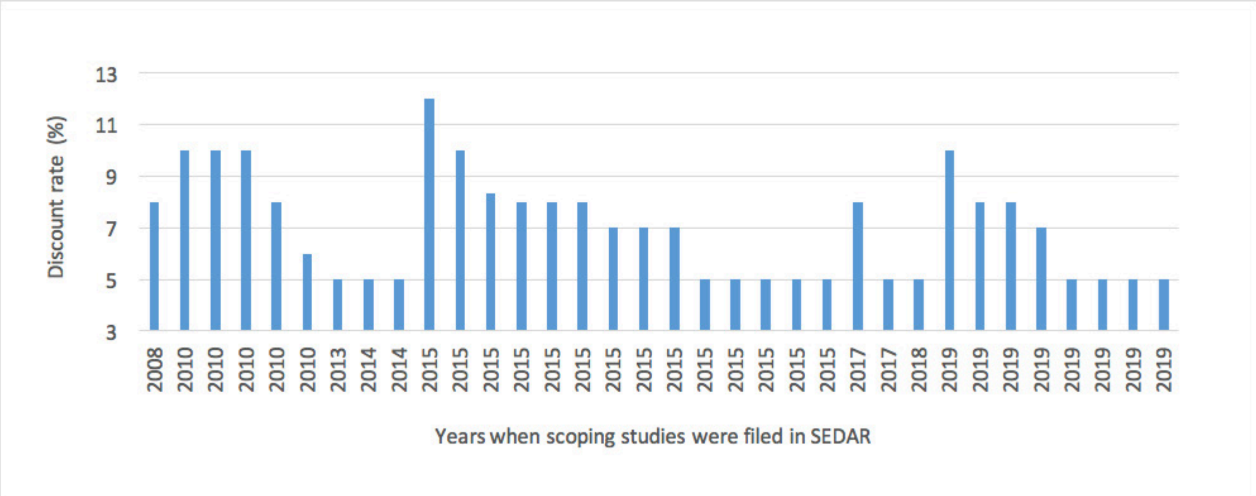



**Figure 6 Discount rates for <u>37 SCOPING</u> studies in 100 SEDAR-filed projects, 2008-2020**

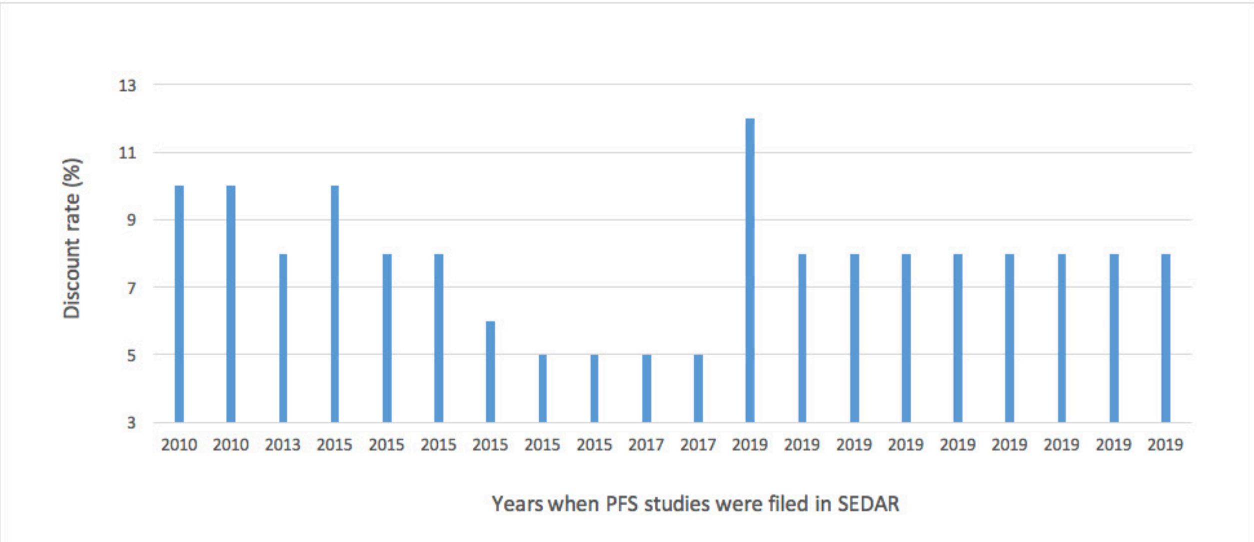



**Figure 7 Discount rates for <u>21 PFS</u> studies in 100 SEDAR-filed projects, 2008-2020**

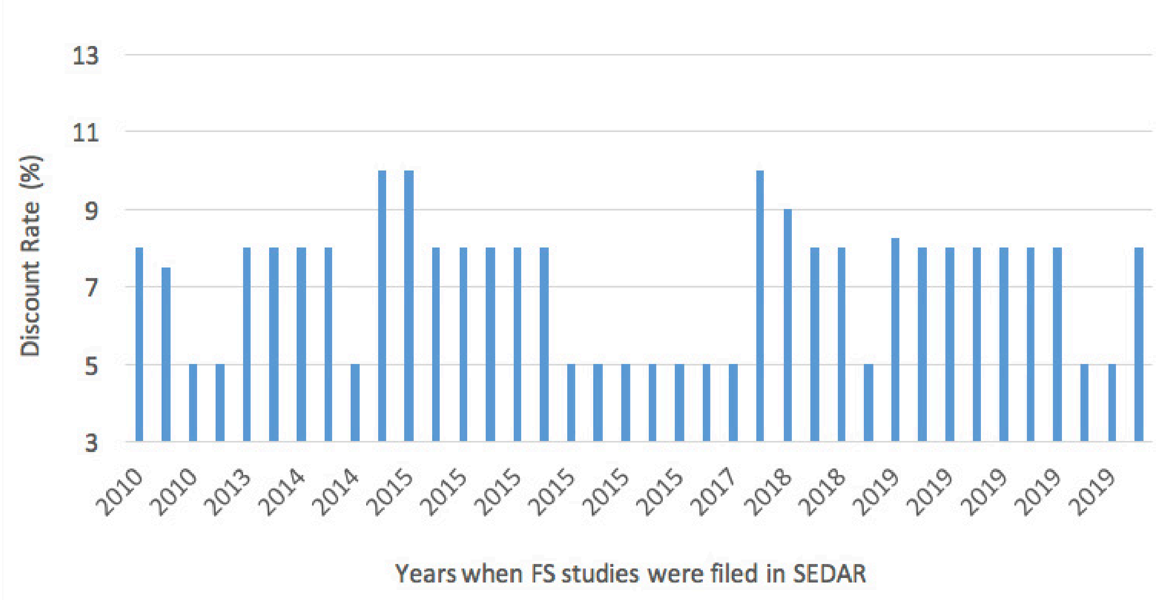



**Figure 8** **Discount rates for 41 FS studies in 100 SEDAR-filed projects, 2008-2020**

### *3.2.7.3 DR used for different project sizes*

The discount rates used for different sizes of project are shown in Table 9 where the rate of production in thousands of tons per day (ktpd) is used to represent size.

The trend line shows a slight increase in discount rates as project size increases. This is contrary to the principle stated by some authors.

**Table 9** **Discount rates for different project sizes in 100 SEDAR-filed projects, 2008-2020**

| ktpd | | Number of projects | DR | ktpd | | Number of projects | DR |
|---|---|---|---|---|---|---|---|
| min | max | | | Min | max | | |
| 140 | 150 | 1 | 8.00 | 60 | 70 | 0 | |
| 130 | 140 | 1 | 8.00 | 50 | 60 | 4 | 7.25 |
| 120 | 130 | 0 | | 40 | 50 | 0 | |
| 110 | 120 | 1 | 8.00 | 30 | 40 | 4 | 7.25 |
| 100 | 110 | 2 | 9.00 | 20 | 30 | 7 | 6.29 |
| 90 | 100 | 5 | 7.00 | 10 | 20 | 14 | 7.43 |
| 80 | 90 | 2 | 6.50 | 0 | 10 | 59 | 7.15 |
| 70 | 80 | 0 | | Average, total | | 100 | 7.18 |

### *3.2.7.4 DR used for different commodities*

The discount rates used by projects involving different commodities are shown in Table 10. In the case of polymetallic projects, the main metal is used. The lowest discount rates are for Ag and Au projects.

**Table 10 Discount rates for different commodities in 100 SEDAR-filed projects, 2008-2020**

| Metals and minerals | Number Of projects | DR | Metals and Minerals | Number of projects | DR |
|---|---|---|---|---|---|
| Ag | 13 | 5.85 | Zn | 2 | 8.00 |
| Au | 39 | 6.53 | U | 4 | 8.00 |
| Precious metals | 5 | 6.80 | Mo | 1 | 8.00 |
| Diamonds | 2 | 7.00 | Pb | 2 | 8.13 |
| Cu | 8 | 7.88 | Ni | 4 | 8.50 |
| Nb | 1 | 8.00 | Rare earths | 3 | 8.67 |
| Ti | 1 | 8.00 | Fertilizers | 8 | 8.75 |
| Fe | 3 | 8.00 | Mn | 1 | 10.00 |
| Li | 3 | 8.00 | Total, average | 100 | 7.18 |

### *3.2.7.5 DR used for different project lives*

The discount rates used for different project lives are shown in Table 11.

The trend line shows a slight increase in discount rates as project life increases. This is contrary to the principle stated by some authors.

Some mega-mining projects have very long lives as, for example, in the case of the Chuquicamata, Salvador, Andina and El Teniente mines of Codelco-Chile, BHP's Escondida mine, Rio Tinto's Oyu Tolgoi mine and Antofagasta Minerals' Los Pelambres mine. El Teniente has been operating since 1905 and there are plans to continue operations for over 50 more years. This 165-year project cannot reasonably be evaluated at the same discount rate as short-lived projects (Smith 2016).

**Table 11 Discount rates for different project lives in 100 SEDAR-filed projects, 2008-2020**

| Duration (yrs) | | Number of projects | DR | Duration (yrs) | | Number of projects | DR |
|---|---|---|---|---|---|---|---|
| min | max | | | min | max | | |
| 0 | 5 | 8 | 6.13 | 30 | 35 | 3 | 7.00 |
| 5 | 10 | 24 | 6.93 | 35 | 40 | 3 | 8.00 |
| 10 | 15 | 29 | 7.54 | 40 | 45 | 1 | 8.00 |
| 15 | 20 | 19 | 7.16 | 45 | 50 | 1 | 6.00 |
| 20 | 25 | 8 | 7.50 | | | | |
| 25 | 30 | 4 | 7.25 | Average, total | | 100 | 7.18 |

These long-life mega-projects, which are well defined technically, economically and risk-wise for a couple of decades and have ample time to solve future challenges, should use lower discount rates to make the future meaningful. Are these projects riskier than power generating projects that use a DR of around 6%?

### *3.2.7.6 DR used by CODELCO over the years*

The discount rate used by Codelco-Chile to evaluate its projects has dropped over the last 50 years. In the mid-1970s, it used a discount rate of 15% but, as country and project risks diminished, it was lowered to 12%, 10%, 8.5% and 8%, a value at which it has now stabilised for over ten years.

# 4 Effect of DR on reserve determination for a block caving project

In the mining sector, the DR not only affects the selection of projects, but also defines the amount of reserves.

Specifically, in the block cave mining method, the discount rate has a direct effect on the selection of the ore columns to be extracted. A high discount rate will result in the selection of fewer columns and a low discount rate in more columns, as shown in the example in Table 12. This analysis is especially valid for marginal benefit columns, which are usually on the fringe of the footprint areas (Vera et al. 2019).

**Table 12 Example of block caving column selection according to discount rate**

| *DF = Discount factor* | | | **Discount rate** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **0%** | | **4.0%** | | **6.0%** | | **8.0%** | | **10.0%** | |
| Extractio | Column | Extraction year | Extraction | | Discounted | | Discounted | | Discounted | | Discounted | |
| rate | height | | benefit | | extract. benefit | | extract. benefit | | extract. benefit | | extract. benefit | |
| m/year | m | | DF | MUS$ | DF | MUS$ | DF | MUS$ | DF | MUS$ | DF | MUS$ |
| | | | Extraction benefits | | | | | | | | | |
| 80 | 320 | 4 | *1.00* | 400,000 | *0.85* | 341,921 | *0.79* | 316,836 | *0.74* | 294,012 | *0.68* | 273,205 |
| | 240 | 3 | *1.00* | 300,000 | *0.89* | 266,700 | *0.84* | 251,884 | *0.79* | 238,150 | *0.75* | 225,394 |
| | 160 | 2 | *1.00* | 200,000 | *0.92* | 184,911 | *0.89* | 178,001 | *0.86* | 171,468 | *0.83* | 165,290 |
| | 80 | 1 | *1.00* | 100,000 | *0.96* | 96,154 | *0.94* | 94,341 | *0.93* | 92,592 | *0.91* | 90,909 |
| Total extraction benefits | | | 1,000,000 | | 889,686 | | 841,062 | | 796,222 | | 754,798 | |
| | | Year | Undercutting and preparation costs | | | | | | | | | |
| Undercutting cost | | 0 | *1.00* | 153,000 | *1.00* | 153,000 | *1.00* | 153,000 | *1.00* | 153,000 | *1.00* | 153,000 |
| Preparation cost | | -1 | *1.00* | 612,000 | *1.04* | 636,480 | *1.06* | 648,720 | *1.08* | 660,960 | *1.10* | 673,200 |
| Total UC & prep. cost | | | | 765,000 | | 789,480 | | 801,720 | 813,960 | | 826,200 | |
| NPV column | | | | 235,000 | | 100,206 | | 39,342 | | -17,738 | | -71,402 |
| Selection of column | | | | YES | | YES | | YES | | NO | | NO |

In this example, the column is not selected for extraction when the DR is 8% or higher and is selected when the DR is 6% or lower. Interpolating, the cut-off discount rate for this column is 7.33%. The column has a total tonnage of 220,000 t that could be included in or excluded from the reserves depending on the discount rate.

The discount rate will have a greater impact on the selection of extraction columns when the columns are relatively high, the extraction rate is slow and higher-grade mineralisation is in the upper part of the extraction column.

# 5 Impact of DR on mining projects

According to Lane's theory (1964), it is not convenient to put a tonne of ore through the processing plant with low benefit that will delay better future benefits. This is not true with a discount rate of zero but, as the discount rate increases, low benefit tonnes are discarded to make room for higher benefit tons. This has an important impact in all types of mining projects, independently of the exploitation method. This can be calculated on a case-by-case basis.

In the block caving method, this effect is additional to the one described in Section 4.

I suggest the use of a lower DR for reserve determination than the rate used for financial evaluation, especially in long-life projects. They may coincide, but not necessarily so.

# 6 Conclusions and recommendations

The discount rate for a mining project is the variable used not only to select projects, but also to define mine reserves, particularly in block cave mines.

There are methodologies to define the adequate discount rate for each mining project, all of which have their drawbacks. An Australian survey in 2007 showed that, in practice, rather than using the traditional CAPM methodology, companies tend to use the following direct methods in descending order: i) firm's discount rate; ii) cost of debt plus some premium; iii) previous experience; iv) a discount rate representative of a related industry; v) the discount rate of the division involved in the project; vi) the discount rates of companies in a similar line of business; and vii) the borrowing rate.

Usually, there is little transparency as to how companies establish the discount rate.

For corporations that must rank various projects, the use of an inappropriate discount rate is likely to distort the priority assigned to different projects and, therefore, distort choices involving billions of dollars of investment. The corporation may end up building projects in the wrong order or building the wrong projects.

Discount rates vary across different sectors of the economy. In the sectors examined here, they vary in the following descending order: biotech (18.6-13.9%), general equity (9.1%), mining (8.4-7.2%), transport infrastructure (7.0%), renewable energy (6.5%), traditional energy (6.2-5.5%), housing (5.5%) and social projects (7.0-3.5%).

The average discount rate for 100 mining projects filed between 2008 and 2020 in the SEDAR database was 7.18%. There was a surprisingly large number of projects (35) with a 5% discount rate. When these projects were excluded, the average discount rate was 8.36%. The highest discount rate, found in two projects, was 12%. The sample showed no time preference for the discount rates.

The sample included projects in 31 countries and there was absolutely no correlation with country risk tables.

The sample was well distributed in terms of the different stages of projects: 37 at the scoping stage, 21 at the PFS stage and 41 at the FS stage. There was also one detailed engineering project. According to the theory, earlier stage projects should use higher discount rates but this was not the case in this sample. The only good correlation was between PFS (7.80%) and FS (7.15%) projects.

The sample comprised projects of different sizes, from 140,000 to 300 t/d of mineral to the plant, albeit with a high concentration of projects below 20,000 t/d (73). The trend showed an increase in the discount rate from 7% to 8% from the smallest to the largest projects.

The sample comprised 17 different metals and minerals. The lowest average discount rates were for Ag (5.85%) and Au (6.53%).

The sample included projects with lives ranging from two to 50 years, with a high concentration of projects with a life of less than 20 years (72). The trend showed a slight increase in the discount rate from 7.0% to 7.3% from the shortest to the longest life.

Codelco-Chile has gradually reduced the discount rate it uses to evaluate projects, bringing it down from 15% in the mid-1970s to 8% for the last ten years.

The discount rate has an impact on reserve determination in all mining projects to maximise NPV (Lane 1988). The lower the discount rate the more reserves and vice versa.

Specifically, in block caving, the selection of extraction columns is also defined by the discount rate, with the number of columns selected dropping as the discount rate increases and increasing as the discount rate drops.

Based upon this analytical review of discount rates in a wide range of projects of different sizes and with different lives across the main economic sectors, it is recommended that lower discount rates be applied to mega-mining projects and that a further lowering of discount rates be considered over the course of long-life mega-mining projects.

The analysis also suggests that the mining sector should use a lower discount rate for reserve estimation than for financial evaluation, particularly in the case of long-life block cave projects.

I recommend using the methodology of adding up the discount rate risk components to determine the DR for specific projects (Method 2). This method is simple, direct and more objective than other methodologies.

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