Monte Carlo risk assessment for Indeep mining operation

Declan Stockdale

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Executive Summary

Due to the high costs of operating a gold mine, a risk analysis has been performed to inform the decision-making process for the first five years of the mine operation. A risk analysis using a Monte Carlo simulation of 10,000 simulations has been used to identify factors and decisions that will result in the project failing or succeeding. As long-term viability is favored over riskier more profitable strategies, this report focuses on factors and decisions with a higher probability of survival rather than being highly profitable.

The key finding of the report are as follows:

- If the mine is not profitable within the first year, there is over 92% of the project failing within 5 years.
- There is a negligible difference between winning the legal challenge in the first year and never challenging it. Due to the risks involved of losing the challenge, its recommended to delay indefinitely.
- The probability to find the additional claim is largest in the first year at almost 50%. Each subsequent year the chance drops due to limited funds for additional search teams.
- The average number of additional teams used is 3.6.

Assumptions

Monte Carlo (MC) simulations assume that the supplied minimum, most likely and maximum distribution values are valid for the extent of the project (appendix table 1,2). Various emerging economic or technological factors may impact these values and would alter the simulation results.

The MC results rely on all values created from the distributions being known at the very start of the year. These include the mine operating costs, mine output, legal fees, and gold price. Realistically, these values wouldn't be known initially and may fluctuate throughout the year which is not taken into account for this simulation.

Business Decisions

There are numerous business decisions that have been hard coded to mitigate poor outcomes from occurring during the operating of the mine(s) and are as follows.

1. The decision to resolve the legal dispute at the start of the year is 50/50 and the legal fees must be paid regardless of the result.
2. The mine will only operate if its profitable to do so (32% expenses is accounted for). If it isn't profitable to operate, there will be no income and no operating costs for that year.
3. In the case that the legal dispute is lost, the number of additional teams is set to the maximum that can be afforded. This is to maximize the chances of finding the new claim which can then potentially generate revenue.

Results

The simulation was run 10,00 times to estimate probabilities of events occurring. Initial results can be viewed in figure 1. The large spike is due to a large number of simulations having less than $1 million after the 5-year period.

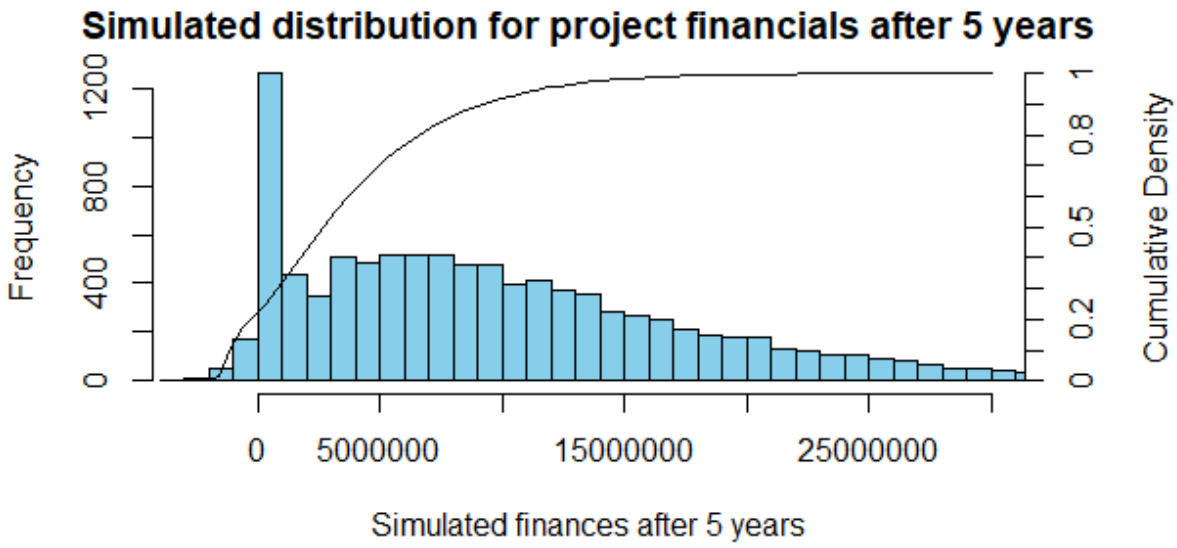

Figure 1. Histogram and cumulative probability distribution for 10,000 simulations. Finances are in $ AUD

There a 2.3% chance of finishing with $0 or less and a 20% chance of finishing with less that the starting funds of $2.2 million resulting in an 80% chance of the project failing to generate money after 5 years. Table 1 below goes into the probabilities of earning at least a certain amount after 5 years

Probability %	Minimum potential earnings after 5 years (million $AUD)
80	2.24
70	4.46
60	6.40
50	8.36
40	10.54
30	13.11
20	16.52
10	22.10

Table 1. Probability of minimum potential earning after 5 years

What defines a successful project

A successful project is defined by 3 characteristics. The first is that it hasn't gone bankrupt. The second is that at least one mine is operational going into the 6th year. The final characteristic is that the project at the end of year 5 has more funds that the initial starting value of $2.2 M. Using these metrics, the percentage of projects that fail increases up to 22.5%. This is likely due to the additional simulations fail the second characteristic test.

The result in table 2 show various ranges for potential profits. The median successful mine has $10.8 M at the end of 5 years with only a 10% chance to earn more than $ 22.1 M.

Min ($ AUD)	Q1 ($ AUD)	Median ($ AUD)	Q3 ($ AUD)	Max ($ AUD)	Mean ($ AUD)
2,200,00	6,670,000	10,800,000	16,700,000	65,300,000	12,800,000

Table 2. Summary statistics for successful mines

Impact of initial mine output

One of the key indicators of mine success is the initial mine output in year 1. This values are calculated at the start of the year and is used to calcualte if the mine is profitable. The result in table 3 clearly show mines that have a lower initial output are more likely to fail compared to successful mines. This is due to a higher proability fo the mine not being profitable. This can also be observed in figures 2,3. Cumulative probabilites can be found in appendix table 3.

	Min (ounces)	Q1 (ounces)	Median (ounces)	Q3 (ounces)	Max (ounces)	Mean (ounces)
Successful	215	810	1027	1250	1782	1033
Failed	109	403	642	962	1752	705

Table 3 Comparison of statistics for successful and failed mines

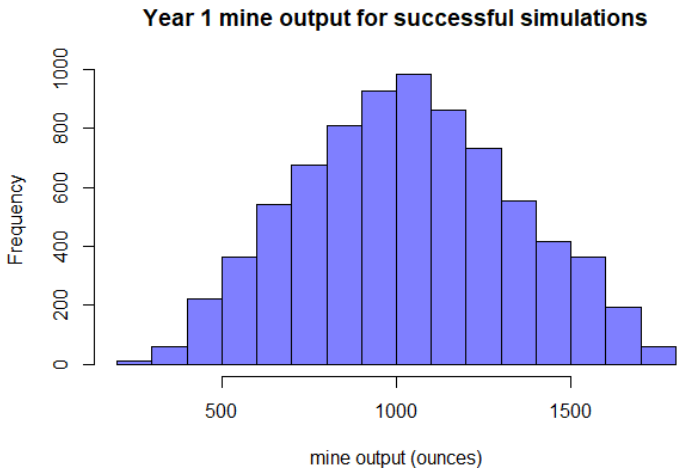

Figure 3. Mine output in year 1 for successful mines

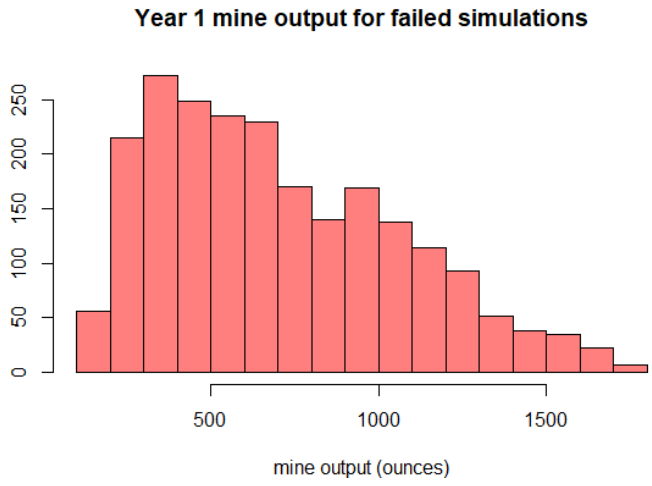

Figure 2. Mine output in year 1 for failed mines

From figure 3, it can be observed that failed mines that have a higher initial output compared to the average successful mines initial output can still fail. Of these mines, 99.6% lost the legal challenge with over 50% losing in the first year and another 30% losing in the second year. Additionally, 85% never found the additional mine.

Impact of unprofitable mine

The probability of a mine being successful depends on whether it's profitable. Table 4 details the number of years a mine was unprofitable separated into all simulations, successful and failed projects. The highest chance of success occurs when the mine is always profitable.

	Number of years mine wasn't profitable					
	0	1	2	3	4	5
All (%)	81.3	9.4	4.5	2.4	1.2	0.7
Success (%)	89.8	8.1	1.7	0.25	0.003	0
Failed (%)	51.6	12.8	14.2	10.0	5.3	3.0

Table 4. Years that various simulations were not profitable.

If the mine isn't profitable in the first year, the likelihood of success is 8.1% falling to 1.7% if it's also not profitable in year 2. This is due to the initial mine output rarely achieving a high enough value to make the mine profitable.

Impact of legal dispute

Table 5 below details the effect of challenging within the first year and never challenging. The key finding is that there is very little difference overall between the two outcomes financially. This would indicate that it's safer to delay the case indefinitely, even if it incurs additional costs however it seems the income generated from the mine outweighs this burden for the majority of simulations.

	Min ($ AUD)	Q1 ($ AUD)	Median ($ AUD)	Q3 ($ AUD)	Max ($ AUD)	Mean ($ AUD)
Resolved year 1	-70,000	3,660,000	8,560,000	14,700,000	59,100,000	10,300,000
Never resolved	-2,950,000	4,100,000	8,000,000	15,300,000	61,900,00	10,800,000

Table 5. Various statistics associated with either challenging in first year (win or loss)

If the legal challenge was to be challenged, the optimal time would be the first year. This is because the mine is still operational, and the generated funds can be used to hire additional teams to search for the new mine. From table 6, the highest chance of a successful project occurs if the loss is in the first year falling dramatically for each subsequent year.

Year lost legal case	1	2	3	4	5	Not lost
% Of successful mines	16.8	8.1	3.6	2.0	0.8	n/a
% Of failed mines	56.9	29.0	6.3	3.49	4.1	0.22

Table 6. Probabilities of a mine being successful depending on when the legal challenge was lost

Impact of finding additional claim

The additional mine claim is most likely to be found the first year (42%) or never (23%) using table 7. This is likely due to the availability of initial funds available for additional search teams, which drops dramatically if the mine is not found immediately. The average number of additional teams deployed is 3.6 regardless of finding the mine.

Finding the additional mine has two benefits The first is two mines are potentially operational and profitable. The second is that no additional funds are spent searching for the mine.

Probability of finding the new claim						
	1	2	3	4	5	Not found
All %	42.2	10.6	10.3	10.4	3.9	22.7
Success	49.6	12.0	12.3	11.7	2.4	11.9
Fail	16.4	5.5	3.6	5.6	9.0	59.9

Table 7. Probabilities of finding new claim

Decision making process of simulation throughout years

The logic behind the decision processes in the simulation is described below. The code that will accompany this report has also been commented to ensure readability.

Year 1

1. Generate initial values for legal fees, mine output, and how many teams to use for new claim search from the distributions in the appendix (appendix table 1,2).
2. There is a 50% chance of challenging the legal decision. If this occurs the chance of winning is 50%. Legal fees are paid before challenging.
3. Calculate the maximum number of teams that can be afforded and randomly choose a value in this range. Each team has a 15% chance of discovery.
4. Determine if income from mine exceeds operating costs, if true, then mine isn't operating that year
5. Find expenses and income generated and calculate funds at the end of the year

Following years

6. Check if legal dispute is resolved from the previous year, if won or lost, there are no legal fees for this current year. If lost, the original mine will no longer be able to generate income. If unresolved, repeat process from (2)
7. Check if mine was found in previous year. Its output is the same as the original mine. If mine unfound, then repeat (3). Check (4) to determine if mine(s) operate this year.
8. If ownership of the original mine has been lost and new claim hasn't been found, set teams in (3) to maximum.
9. Repeat (5)

Conclusion

A Monte Carlo simulation has been used to model 10,000 simulations of a mine operating for a 5-year period. Various starting initial conditions and decisions have been explored to determine the best course of action to ensure long term viability of the mine. The most important factor was found to be the initial mine output as it's a key factor in whether the mine is profitable. It was found that the financial impact of delaying the legal challenge was negligible but the consequences of losing at any point resulted > 65% chance of failure. The chances of discovering the additional mine are highest in the first year and drop off substantially. If the mine is not immediately discovered, its recommended to cease searching for it while funds are low.

Appendix

Appendix Table 1. Values used for the distributions used in the Monte Carlo simulation. A triangular distribution was used to generate random values within the values given.

	Minimum	Most likely	Maximum
Gold price change (AUD) - compared to previous year	-250	200	500
Mine output (ounces)	100	1,000	1,800
Change in mine output (%) - compared to previous year	85	130	170
Mine operating costs (AUD)	500,000	750,000	1,000,000
Legal challenge (AUD)	500,000	750,000	1,000,000

Appendix Table 1. Values for distributions.

Appendix Table 2. Fixed values used for Monte Carlo simulations. All values were supplied except for 'chance of challenging legal' which was decided by the author. It's unknown what effects altering this value would have on the recommendations given in this report. It should be minimal as the recommendation is to delay rather than challenge.

	Fixed values
Start gold price (AUD)	1,800
Starting funds (AUD)	2,200,000
Chance of discovery (%)	15
Chance of challenging legal (%)	50
Chance of winning legal (%)	50

Appendix Table 2. Fixed values

Appendix Table 3. This table describes the cumulative distribution probabilities of having at least a given initial mine output for both successful and failed project. It should be read as : there is a 90% probability of a successful mine having a minimum initial mine output of 620 ounces.

Probability %	Initial mine output for successful projects (ounces)	Initial mine output for failed projects (ounces)
90	626	109
80	760	284
70	856	366
60	950	451
50	1027	541
40	1110	753
30	1200	896
20	1304	1039
10	1463	1219

Appendix Table 3 Probability of minimum mine outputs for both successful and failed projects

Appendix Table 4. Percentage of simulations that the legal challenge was lost and the year the mine was found. The second mine must be found otherwise it would be a failed project hence why there Is no 'not found 'column.

	Year mine found					
Year legal challenge lost		1	2	3	4	5
	1	77.1	10.2	7.7	5	0
	2	54.7	16.1	23.3	5.8	0
	3	46.4	15.7	13.6	24.3	0
	4	48.7	13.3	13.3	21.0	3.6
	5	49.4	13.0	12.0	14.3	10.4

Appendix Table 4. All potential outcomes for simulations when the legal challenge was lost and when the mine was found.