Teach yourself how to build a Business Case for any industry

including mining

1i Hands On Modelling:

Cashstream #1 – Revenue, Sales & Operations

in mining

Spend only a few seconds on each page

This website may contain errors so always check your own work and have it audited by a competent person.

This module contain personal opinions.

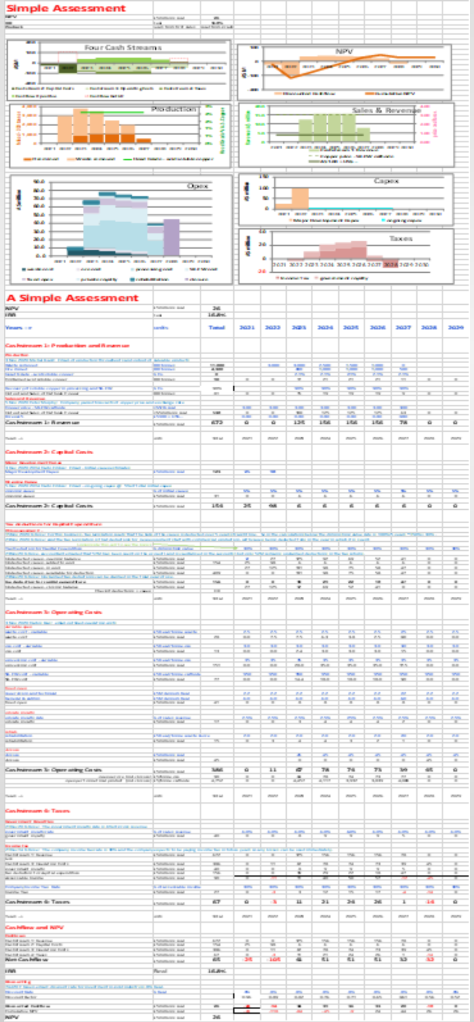
The purpose of this module is understand

Cashstream #1: Revenue, Sales, Operations in the **mining industry→**

Level 3: Decision making

Level 2: Evaluating the business/project

Level 1: Hands-on economic modelling



#2: Capex

#3: Opex

#4: Taxes

Cashflow
(incl NPV)

Contents

Two Monsters

Six Levers

1. Production and sales volumes
2. Head grade
3. Recovery
4. Product quality
5. Price forecast
6. Exchange rate forecast

The Two Monsters

In most mining/metallurgical businesses the economics are dominated by 'two monsters':

1. **The resources in the ground**

and at the other end of the business

2. **The markets for the products.**

These two largely decide the maximum value.
They decide the upper limit of how good the business can be!

The Two Monsters

Then sadly, each of the steps in between these two generally only reduce the value of the business: -

- Mining
- Processing
- Smelting, hydrometallurgy, electrolysis, etc
- Logistics
- Capex, Opex & Engineering
- Environment
- Community
- Governments
- Taxes
- Legal
- Risk

For example, deep ore with poor ground conditions, difficult processing, low recoveries, problem levels of contaminants, challenging transport to market, sited in a hostile country where capex and opex are high, will of course consume much more economic value than a surface deposit with easy mining, minimal processing, high recoveries, simple freight to a nearby smelter in a country with low costs and which actively encourages development.

The Two Monsters

In a viable mining business, the most important of parts of these two monsters and of the intermediary steps are the ones that directly impact ***REVENUE.***

Revenue, *of course, must be greater than the grand total of capex, opex and taxes - plus have a healthy surplus to justify investment and its impact on the world's environment.*

Revenue has six prime levers …

In mining and metallurgy, there are six powerful levers in 'Cashstream #1: Revenue, Sales & Operations'.

In their natural sequence from resource-in-the-ground through to sales-in-the-market they are:

1. **Production/sales volumes** – both annual rate & life
2. **Head grade**
3. **Recovery** in processing/smelting/hydromet/etc
4. **Product quality**
5. **Price forecast**
6. **Exchange rate forecast**

When modelling a project or business these six deserve your complete attention.
To get things into perspective, they are way more important to the business than capex and opex!

Prime Lever 1. Production/sales volumes – both annual rate & life
& Prime Lever 2. Head grade

In the evaluation of a mining business, the forecasts of **production & sales** and estimates of **head grade** are economic levers of utmost importance.

In most other industries the sales plan is developed first and then the production plan is generated to feed the sales. But in mining/metallurgy businesses the reverse seems to be common. This is because the global resources industry is so large that most individual businesses comprise only a tiny fraction of total output and so most can enter or expand without upsetting the market. This is especially so for businesses which produce global standard commodities such as copper, zinc, energy coal, nickel, metallurgical coal, iron ore … etc

There are only a few niche markets in mining where entry or expansion must be specifically tailored to customers' quality or volume needs.

Prime Lever 1. Production and sales volumes – both annual rate & life & Prime Lever 2. Head grade

In a very early stage evaluation of a mining project, estimates of sales, production and head grade might come from a crude mine schedule. The resultant cashflows would give an indication if further study is warranted.

For subsequent evaluations, the production and head grade almost certainly will be taken from a mine schedule produced by mining experts using proprietary software. Frequently its generation and checking will take days/weeks. These mine schedules will take account of the market including initial penetration rate, sales volumes, product qualities, price, ….

Prime Lever 1. Production and sales volumes – both annual rate & life & Prime Lever 2. Head grade

Trying to generate a mine schedule inside your evaluation model is naïve/stupid - unless the mine is singularly simple.

- Mine scheduling software is very sophisticated.
- There usually will be a range of mine schedules that need to be assessed: → Underground and/or open pit. Smaller or bigger. Bulk mining or selective mining. Ramp-up rates. Phased development possibilities. High grade short life or low grade long life. Most importantly, the economics of the whole business will need to be assessed over a range of open pit shells/underground possibilities.
- Software programs consider the economic value of each block of mineralisation and the cost of removing each block of waste. Only when it has finished do you know what mineralisation is 'ore' and what is 'waste.
- Mining needs be managed to a selection of criteria: cut-off grade, balanced use of mining equipment, capabilities of the plant with different ore types, etc, etc.

Unless for a very simple concept study, it is self-deceiving to start out in your evaluation model with the total ore to be mined and then each year subtract the ore mined to leave the ore remaining at the end of the year that can be mined in subsequent years. At best you would achieve nothing and most likely you would get yourself into error and derision. This is a common mistake by inexperienced evaluation specialists.

Prime Lever 1. Production and sales volumes – both annual rate & life

& Prime Lever 2. Head grade

A mine schedule is valid for only one set of economic parameters.

A significant increase/decrease in price forecast, exchange rate, annual throughput or mining inventory usually would require a complete re-computation of the mine schedule using the special software.
The same applies for major changes in capital and operating costs.
It would be unusual/dangerous to keep using an existing mine schedule after material changes in price, exchange rate, throughput and operating costs.

Let the experts produce the schedule: When you receive the mine schedule from the mining engineers make yourself very aware of the economic parameters and operating costs underpinning that set.

When you need to test higher and lower prices, lesser and greater throughput, different recoveries, longer and shorter life, higher/lower operating costs then first consult with the mining engineers. Do they need to generate new mine schedules?

Prime Lever 1. Production and sales volumes – both annual rate & life

& Prime Lever 2. Head grade

Reproduce the mine schedule produced by the mining engineers, in your model in <u>intuitive, small steps</u>.

Do not inflict sophisticated algorithms on others who might use your evaluation model! Use …

- Bold sub-heading
- Obvious work blocks
- A row note of the source of the mine schedule (not as a hidden comment)
- Full descriptors in Column A
- Unambiguous units in Column B
- Row totals in Column C so tonnes mined,

It is essential that you check you totals and averages in Column C against the source data in the mine schedule

Green font means it is referenced from another worksheet →

Blue font means the data is freshly inputted here →

Black font means a computation →

Cashstream 1: Production and Revenue

1. Mining

Calendar Year -->	units	Total	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
12 Nov 202X S Sadi Excel workbook of mining giving the three cases.												
Alpha Pit												
Waste mined - Alpha Pit	M dry tonnes	**492.0**		**37**	**37**	**35**	**60**	**60**	**48**	**38**	**38**	**38**
Ore mined - Alpha Pit	M dry tonnes	**58.0**			**6.0**	**8.0**	**8.0**	**8.0**	**8.0**	**5.0**	**3.0**	**3.0**
Cu head grade	% Cu	1.15%			0.80%	1.10%	1.35%	0.97%	1.22%	1.09%	1.27%	1.27%
Au head grade	Au g/t	0.24			0.18	0.24	0.19	0.28	0.24	0.18	0.30	0.30
Ag head grade	g/t	2.32			2.1	2.5	2.4	2.3	2.3	2.3	2.3	2.3
Moly head grade	% Mo	0.09%			0.090%	0.09%	0.09%	0.09%	0.09%	0.09%	0.09%	0.09%
contained copper - alpha pit	000 tonnes	**664**	0	0	48	88	108	78	98	55	38	38
contained gold - alpha pit	000 ounces	**453**	0	0	35	62	49	72	62	29	29	29
contained silver - alpha pit	000 ounces	**4,328**	0	0	405	643	617	592	592	370	222	222
contained moly - alpha pit	000 tonnes	**52**	0	0	5	7	7	7	7	5	3	3
Beta Pit												
Waste mined - Beta Pit	M dry tonnes	**547.0**							**42**	**52**	**52**	**52**
Ore mined - Beta Pit	M dry tonnes	**60.0**								**3.0**	**5.0**	**5.0**
Cu head grade	% Cu	2.18%								1.50%	1.90%	1.80%
Au head grade	Au g/t	0.07								0.18	0.18	0.20
contained copper - beta pit	000 tonnes	**1,306**	0	0	0	0	0	0	0	45	95	90
contained gold - alpha pit	000 ounces	**413**	0	0	0	0	0	0	0	17	28	31
Mining - Aggregate												
waste - aggregate	millions dry tonnes	**1,039**	0	37	37	35	60	60	90	90	90	90
ore - aggregate	millions dry tonnes	**118**	0	0	6	8	8	8	8	8	8	8
contained copper - aggregate	000 tonnes	**1,970**	0	0	48	88	108	78	98	100	133	128
ore stockpiles												
12 Nov 202X S Sadi - assume 6 weeks working stocks of ore for blending. (Use the following year's throughput to have proper stocks in first year and to have zero stocks on cessation.)												
ore stockpiles	weeks	6.00			6	6	6	6	6	6	6	6
ore stockpiles - closing - alpha ore	millions dry tonnes		0.0	0.0	0.9	0.9	0.9	0.9	0.6	0.3	0.3	0.3
ore stockpiles - closing - beta ore	millions dry tonnes		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6

Prime Lever 3. Recovery in processing/smelting/hydromet/etc

& Prime Lever 4. Product quality

You must create the **processing section** of your model so it is intuitive to everyone else: even when the flowsheet and reactions become quite complex. It may become very detailed and very long.

- Your model will show the processing sequence in small obvious steps
- Sometimes it is best to insert visible notes in blue font in a row above a processing stage to explain the processing flowsheet.

It is common for evaluation models of processing/chemical/smelters to incorporate the physical and/or chemical behaviours of the materials flowing through so the model computes from first principles, the quantities and qualities of saleable products and of waste products. The model may need to include complex chemical and/or physical algorithms.

So while the aim is for small intuitive steps, in processing it frequently becomes necessary to use algorithms that reproduce the behaviour of the various minerals during processing. For example you may need to include algorithms/tables that adjust the recovery as the head grade increases or decreases.

You need to create a layout so that people who are inexperienced in processing can follow the logic and understand the results

- Fresh data inputs must be obvious (blue font)
- with their source as a visible row note in blue font immediately above
- Data needed from another worksheet must be referenced across from another worksheet in that workbook as a complete row and colour coded (green).
- Referenced data (green font) MUST NOT be multiplied or divided or over typed
  (because impacts elsewhere would not flow back and because the change would be hidden)
- Algorithms must not have fresh data secretly entered into them (‘hardwired’).
- Instead every piece of fresh data must be exposed before being used in an algorithm.

Every piece of data must be visible and no data can be hidden in an algorithm or in overtyping.

Key inputs and key results should be shown in graphs for checking and for rapid understanding

2. Processing										
Calendar Year -->	units	Total	Year 1	Year 2	Year 3	Year4	Year 5	Year (		
1 Nov 2020 F Williams: Processing metallurgists' workbook of processing giving the three cases. (assume minor movements in head										
Ore feed										
ore feed to processing - alpha	millions dry to	58			5.1	8.0	8.0	8.0		
ore feed to processing - beta	millions dry to	60			0.0	0.0	0.0	0.0		
ore feed to processing - aggregate	millions dry to	118			5.1	8.0	8.0	8.0		
feed grade - copper	% Cu	1.38%	0.00%	0.00%	1.25%	1.25%	1.25%	1.25%		
feed grade - gold	Au g/t	0.1	0.0	0.0	0.2	0.2	0.2	0.2		
feed grade - silver	Ag g/t	1.0	0.0	0.0	2.0	2.0	2.0	2.0		
feed grade - moly	% Mo	0.04%	0.00%	0.00%	0.09%	0.09%	0.09%	0.09%		
i. Copper Concentrate										
Recovery - copper	% Cu	88.0%	88.0%	88.0%	88.0%	88.0%	88.0%	88.0%		
Recovery - gold	% Au	77.0%	77.0%	77.0%	77.0%	77.0%	77.0%	77.0%		
Recovery - silver	% Ag	65.0%	65.0%	65.0%	65.0%	65.0%	65.0%	65.0%		
Copper Concentrate Grade - copper	% Cu	31.0%	31.0%	31.0%	31.0%	31.0%	31.0%	31.0%		
copper concentrate produced	000 dry tonne:	4,613	0	0	180	284	284	284		
copper concentrate grade - gold	g/t Au	2.8	0.0	0.0	4.8	4.8	4.8	4.8		
copper concentrate grade - silver	g/t Ag	16	0	0	37	37	37	37		
copper conc - contained copper	000 tonnes Cu	1,430	0	0	56	88	88	88		
copper conc - contained gold	000 ounce Au	583	0	0	28	44	44	44		
copper conc - contained silver	000 ounce Ag	2,424	0	0	212	334	334	334		
ii. Molybdenum Concentrate										
1 Nov 2020 F Williams: Processing metallurgists' workbook of processing giving the three cases. (assume minor movements in head grade from year to yea										
Recovery - moly	% Mo	70.0%	70%	70%	70%	70%	70%	70%	70%	70%
Moly Concentrate Grade - moly	% Mo	55.0%	55%	55%	55%	55%	55%	55%	55%	55%
moly concentrate produced	000 dry tonne:	66	0.0	0.0	5.8	9.2	9.2	9.2	9.6	6.0
moly concentrate - contained moly	000 tonnes Mc	37	0.0	0.0	3.2	5.0	5.0	5.0	5.3	3.3
Value of contained metals in both concentrates										
copper conc - contained copper	US$ millions R	8,827	0	0	345	543	543	543	567	553
copper conc - contained gold	US$ millions R	583	0	0	28	44	44	44	45	39
copper conc - contained silver	US$ millions R	24	0	0	2	3	3	3	3	2
moly concentrate - contained moly	US$ millions R	564	0	0	49	78	78	78	81	51
Aggregate contained value		9,999	0	0	424	668	668	668	697	645
Calendar Year -->	units	Total	Year 1	Year 2	Year 3	Year4	Year 5	Year 6	Year7	Year 8
3. Sales Volumes										
i. Sales of Copper Concentrate										

Processing/smelting/hydromet/etc

If a ***processing flowsheet*** is straight forward then the processing section should be short.

A preliminary assessment of a gold mine may be just four rows: two for processing, one row for recovery and one row for gold produced.

You must make the processing section intuitive!

Here, the sequence is easy to follow: -

- Distinct work-blocks with clear headings
- Every input of data is easy to recognise in blue and is easy to check
- Every row of data is totalled or averaged in Column C
- The source of the original data is visible in the (blue) row note above.
- Use lots of small steps that can be checked quickly

2. Processing										
ore feed to processing - aggregate	millions dry to	118			5.1	8.0	8.0	8.0	8.3	7.7
Recovery - copper	% Cu	88.0%	88.0%	88.0%	88.0%	88.0%	88.0%	88.0%	88.0%	88.0%
Recovery - gold	% Au	77.0%	77.0%	77.0%	77.0%	77.0%	77.0%	77.0%	77.0%	77.0%
Recovery - silver	% Ag	65.0%	65.0%	65.0%	65.0%	65.0%	65.0%	65.0%	65.0%	65.0%
Copper Concentrate Grade - copper	% Cu	31.0%	31.0%	31.0%	31.0%	31.0%	31.0%	31.0%	31.[illegible]	31.0%
copper concentrate produced	000 dry tonnes	4,613	0	0	180	284	284	284	[illegible]	[illegible]
copper concentrate grade - gold	g/t Au	2.8	0.0	0.0	4.8	4.8	4.8	4.8	[illegible]	[illegible]
copper concentrate grade - silver	g/t Ag	16	0	0	37	37	37	37	[illegible]	[illegible]
Recovery - moly	% Mo	70.0%	70.0%	70.0%	70.0%	70.0%	70.0%	70.0%	70.[illegible]	70.0%
Moly Concentrate Grade - moly	% Mo	55.0%	55.0%	55.0%	55.0%	55.0%	55.0%	55.0%	55.0%	55.0%
moly concentrate produced	000 dry tonnes	66	0.0	0.0	5.8	9.2	9.2	9.2	9.6	6.0
moly concentrate - contained moly	000 tonnes Mo	37	0.0	0.0	3.2	5.0	5.0	5.0	5.3	3.3
Aggregate contained value		9,999	0	0	424	668	668	668	697	645

Processing done badly!

This is how a person who is self-focused and an **'expert in Excel'** might model the previous *processing flowsheet*

All of the steps in the example on the previous page would be reduced to just:

- seven rows of fresh data inputs and
- six rows of 'smart' algorithms

But you can't immediately recognise which are the seven rows of fresh data inputs! When and where was that data sourced? Is it the latest?
Can you follow the logic of the six algorithms? Are they using the right data and correctly? I knew one highly mathematical specialist who took pride in sending out models without the years being labelled and without units and totals – He told me that if I was smart I could work them out!

These sorts of 'experts in Excel' go home feeling proud and smug. Arrogant!!!
Colleagues are left to examine the model row by row, waste time trying to uncover what is what and to slowly untangle the 'clever' algorithms.

**These sorts of models are not intuitive and they alienate colleagues.
This evaluation specialist will lose relevancy and respect.**

2. Processing								
ore feed to processing - aggregate			5.1	8.0	8.0	8.0	8.3	7.7
Recovery - copper	88.0%	88.0%	88.0%	88.0%	88.0%	88.0%	88.0%	88.0%
Recovery - gold	77.0%	77.0%	77.0%	77.0%	77.0%	77.0%	77.0%	77.0%
Recovery - silver	65.0%	65.0%	65.0%	65.0%	65.0%	65.0%	65.0%	65.0%
Copper Concentrate Grade - copper	31.0%	31.0%	31.0%	31.0%	31.0%	31.0%	31.0%	31.0%
copper concentrate produced	0	0	180	284	284	284	296	289
copper concentrate grade - gold	0.0	0.0	4.8	4.8	4.8	4.8	4.8	4.2
copper concentrate grade - silver	0	0	37	37	37	37	37	24
Recovery - moly	70[illegible]	70.0%	70.0%	70.0%	70.0%	70.0%	70.0%	70.0%
Moly Concentrate Grade - moly	55[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
moly concentrate produced	0.0	0.0	5.8	9.2	9.2	9.2	9.6	6.0
moly concentrate - contained moly	0.0	0.0	3.2	5.0	5.0	5.0	5.3	3.3
Aggregate contained value	0	0	424	668	668	668	697	645

Worse is this same model where the 'expert in Excel' is too busy or too lazy to include a column for units and a column of row totals that is visible on the left side of the worksheet. How can anyone check if the rows are correct?

Prime Lever 3. Recovery in processing/smelting/hydromet/etc
& Prime Lever 4. Product quality

As your evaluation progresses, your model might need to become quite detailed and quite complex. Your model will not be 'simple' but it must be kept easy for others to follow.

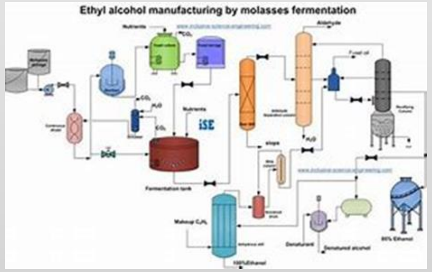
You are likely to work closely with a metallurgist or chemical engineer who will educate you on the process and help you create the model. Of course at the end, that person must audit those sections of the model.

Your model may step through an intricate flowsheet – but always in discrete work-blocks. The computations within some work-blocks may need to replicate the first-principles chemical reactions, flowrates and the known physical behaviour of the ore/feed through the mineral processing plant/chemical plant/furnace. Or your model may need to adopt the results of systematic metallurgical/chemical tests that have been statistically analysed to yield empirical formulae.

Once the mine schedule or feed schedule for each year has been inputted, your model may need to derive the recoveries and the quantity/quality of the saleable products and waste products.

It might use a combination of: -

- empirical formulae derived by metallurgical testing
- atomic weights
- chemical formulae
- stoichiometric chemistry
- reaction chemistry



If the ore can be processed through to concentrate or to metal in a variety of ways, you are likely to make at least a preliminary economic evaluation of each of these routes so you can narrow them to the better alternatives. Within each of these better alternatives there usually will be optimisation. A classical task is finding the trade-off between product quality and product recovery.

Some evaluation models of processing ore through to saleable products will become quite large and complex. They will not be simple but must be made easy-to-follow!

Prime Lever 5. Price forecast

Prime Lever 6. Exchange rate forecast

In most businesses, whether mining, transport, health, manufacturing, services, food, etc, the forecasts of price and exchange rate are amongst the top drivers of value and business direction.

But they are the most difficult drivers to estimate!

They are the greatest unknowns!

I am staggered that in so many companies the forecasting of commodity prices and exchange rates is delegated to a specialist economist. This person might work very diligently and research intensely. But then it is this person's interpretation that become two of the biggest levers of the mining project. If a specialist from a different background generated the price and foreign exchange forecasts they might be very different. The difference might have a huge impact on the apparent viability of the business. To me this is very poor management!

Prime Lever 5. Price forecast
Prime Lever 6. Exchange rate forecast

In many companies the price forecast and the exchange rate forecast:

1. Are created by reviewing and selecting forecasts by experts inside and outside the company,
2. Approved/adjusted by senior management and the Board and then
3. Used for budgets, evaluations and planning.

In the mining and metallurgical industry there often looks to be an inverse relationship between price and exchange rate. Generally they move in opposite directions. So every business should forecast and publish these two as pairs. ***Every price forecast should have its matching exchange rate forecast.***

Remember that when you change prices and exchange rates, you must update the brief row note of its source and date immediately above these new inputs. This allows each user/reader of your model to confirm that the forecasts are the latest.

Prime Lever 5. Price forecast

Prime Lever 6. Exchange rate forecast

It is common for prices to be forecast to be at three or five levels:

Minimum
Low
Mid
High
Maximum

And each would have its paired exchange rate forecast.

Case or Scenario	Price	Exchange Rate
Minimum		
Low		
Mid		
High		
Maximum		

Some businesses try to avoid this pairing and have just one exchange rate forecast. But this means that by default they are forecasting the same exchange rate for each of the five price forecasts. This is inadequate. They cannot run away!

END