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What is my block cave worth? Valuing risk in block cave mining

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Abstract

As a wider variety of orebodies are evaluated for their suitability for the block cave mining method, engineers must clearly articulate the associated value proposition. While the method's low operating costs and high productivities – driven by efficient mining systems and substantial mining blocks – are attractive, the economic assessment is often complex due to significant capital requirements, lengthy development timelines, and numerous modifying factors.

Engineers are adept at quantifying risk within ore reserve estimates, factoring in elements such as dilution, early drawpoint collapse, boundary drawpoint losses, and cave wall underbreak. While the associated capital cost ranges and variability in construction and ramp-up schedules can be communicated, the combined message is not always fully appreciated by stakeholders.

The scale of costs and production inherent to block caving means that a project's economics can be significantly affected if multiple risks materialise during execution and early ramp-up phases. To achieve what is perceived as a realistic outcome, study teams may be inclined to incorporate layers of conservatism into ore reserve estimates and production schedules. Within a competitive capital landscape, this approach can result in otherwise robust projects being deprioritised for capital allocation and development. Conversely, overly optimistic assumptions can lead to uncomfortable value write-downs and reductions in ore reserves.

Advances in technology now enable the processing of a wide range of inputs to generate multiple project schedules, allowing risk to be considered as a spectrum of possible outcomes. It is essential to engage stakeholders in adopting a mindset that views project risk as a continuum rather than a binary outcome.

Drawing on the author's 30 years of experience in designing, evaluating and operating block cave operations, this paper presents methodologies for valuing risk and highlights key factors that have historically influenced caving project valuations.

Keywords: *block caving, panel caving, scenario analysis, valuing risk*

1 Introduction

The block cave mining method is being applied to a steadily wider range of orebodies. Lower head grades, deeper deposits, and the need to extract value from orebodies that were once considered marginal have all driven this trend. Coupled with growing experience in rock mass preconditioning, the method is now considered to be technically applicable to a much broader range of orebodies.

The appeal of mass mining underground orebodies is well understood. Block caving delivers among the lowest operating costs of any underground method and the highest productivities by an order of magnitude. It is an underground method which rivals operating costs of open pit mining with less surface expression, and much less waste to stockpile. With sufficient column height and orebody extents, the method can sustain production for a decade or more, and it can extend through commodity-price cycles. However, these attractions are tied

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to a capital and timing profile that can be unforgiving. Capital is committed years before revenue arrives. The scope of the cave is largely fixed once undercutting commences and infrastructure excavation and construction is underway. Geotechnical conditions discovered during construction can be difficult to respond to without affecting either the production ramp-up or the integrity of the production horizon.

As technical professionals, we tend to be comfortable expressing caving-related risks in our own language: ground support requirements, dilution entry, early drawpoint loss, undercut lead-lag control, cave wall geometry, fragmentation, fines migration. We layer modifying factors into ore reserve estimates, and we constrain production schedules with ramp-up assumptions. These modifications of what could be possible are necessary to create 'realistic', or most-likely, production profiles and costs. However, these expressions of risk are rarely translated effectively into the language of business – net present value (NPV), mine life, cash flow over time, peak funding requirement, and capital intensity. When a downside materialises, leaders are often surprised, even when that particular set of technical risks was reported earlier. As technical people, we think we communicated, but business leaders, who rarely have deep mining expertise, rarely understand.

Critically, we almost never tie financial upside and downside exposure to the supporting actions taken and mitigating actions planned.

The premise of this paper is that the gap between technical risk language and business value language can:

- result in the de-prioritisation of fundamentally strong projects because layered technical conservatism has eroded the apparent return
- leave the individual business unprepared for foreseeable time or capital shifts from the approved business case
- most significantly, prevent business leaders from understanding where investment in capturing the upside or protecting against the downside can change the risk profile and outcomes for the project.

Throughout this paper the mining method is referred to as block caving, however panel caving exposures to risk are almost identical, even though the mining methods are subtly but distinctively different. All of the exposures discussed, and the methodologies suggested for quantifying risk apply to both mining methods.

2 Communicating value and risk in cave mining

Technical teams describe risk in technical terms, each expert understanding their own segment of the process of planning and executing a mine. A geotechnical engineer can describe the consequences of a slow-moving undercut in terms of pillar damage, potential for seismic activity, and the ground support rehabilitation requirements. A mine planner can describe a slow-moving undercut in terms of the difficult blasting conditions, metres per day impact and the subsequent reduction in drawbells commissioned per month (assuming an advanced undercutting sequence is in use). neither description, on its own, tells the leadership team how the issue will affect the cash flow profile, or where to invest to maintain or improve the project's value.

A more meaningful approach is to translate risk into value, ideally continuously, but at the very least at project approval stage gates. Every material technical risk should have a value implication attached to it, expressed in the same currency the business uses to make capital decisions usually: NPV, free cash flow by year, mine life, payback period, peak funding, and unit operating cost. Where a risk also has an upside variant – and many do – the upside should be translated in the same way. The discipline of describing upside and downside exposures removes the asymmetry that makes risk discussions feel like bad news, and reframes them as a conversation about the range of outcomes for a strong project. Detailing upside cases also usefully draws out situations where the base case assumptions are all optimistic.

Importantly, the value drivers differ between projects. For one project, NPV may be dominated by the time to first production and the steepness of the ramp-up. For another, the dominant lever may be mine life and the cave column height. For a third, it may be unit operating cost in a low-grade, high-tonnage configuration. Identifying which value drivers matter, and ranking them, is a project-specific exercise that should precede the construction of upside and downside cases.

3 Block caving characteristics amplify the consequences of risk

A number of the characteristics of block caving combine to make risk consequences greater, and value harder to recover, than in other mining methods.

3.1 Geotechnical unknowns

Even with high-quality drilling and modelling, the rock mass that is intersected during lateral development is the first true large-scale sample of the caving horizon. Caving is well suited to faulted and fractured rock mass conditions, yet these can be difficult to fully characterise and locate accurately from drillhole data alone. Variation from models can affect the development of vertical ventilation infrastructure, location and size of ore handling facilities, ground support quantities, lateral development rates, caveability and more.

3.2 High capital before revenue

Caving projects typically commit large amounts of capital before any saleable production arrives. Laterally developed accesses, vertical shafts and raisebores, primary crushing, and conveying will be substantially complete before the first drawbell is fired. Any delay or cost overrun during this pre-production development phase compounds the funding model risk as there is no or limited offsetting revenue if the mine production is wholly dependent on the block cave under development.

3.3 Long lead time

Caving projects take many years to develop following a long period of data collection and analysis. This is particularly evident in the caving ‘mega’ projects with high production rates. Much of the data required is expensive to collect, with many deep drillholes needed to determine the extraction horizon elevation and placement of infrastructure. Ventilation, critical to ramp-up activities, can take significant time to establish via deep ventilation rises or blind shaft development.

3.4 Schedule risk is amplified by scale

The tendency to select the highest NPV business case often results in the highest production rate case being selected for execution. The higher the production rate, the more complex the supporting production system. Risk is amplified by complexity which is easy to underestimate. More people are required to construct larger infrastructure, more ventilation is required to support the mine, and more skilled workers are required to execute the project and operate the mine. In the planning phase, it is challenging to estimate the impact of the complexity of a higher production rate, but mega construction projects developed around the world provide examples where complexity relating to scale has contributed to schedule and cost overruns (Flyvbjerg et al. 2023).

3.5 Sequence dependency

The undercut, extraction level, and ore handling system must be developed in sequence – there is typically a dual critical path to production – one through the on-footprint undercut and extraction-level development and the other through the excavation and construction relating to the ore handling system. A delay in one activity propagates into all downstream activities, and the chain is long enough that small early slippages compound into material schedule impacts. Critically, to improve the schedule to first production, both critical paths must be shortened and delays to either critical path will delay first production.

3.6 Diminishing optionality

Once development on the future footprint commences, via undercut, extraction level or infrastructure locations and their accesses, the extents of the cave are largely set. Production rate, ramp-up rate, drawpoint spacing, and footprint extents become very difficult to alter. Decisions made during the study phase become locked in, and the consequences of those decisions can play out over decades.

3.7 Limited ability to interrupt

During the cave initiation phase, the operation must continue to develop to the extents of the planned extraction level and continue to draw the cave or risk difficulties in restart, extraction level stability and cave back propagation. Although production rates can be significantly reduced if required, compared to other mining methods, there is a limited opportunity to break the extraction level and undercut development sequence or pause production for any significant period.

Set against these challenges are the well-documented strengths of the method:

- the lowest underground unit operating costs of any method
- the highest productivity per worker
- automation-friendly characteristics
- reduced exposure of personnel to some safety risks
- a mine life exposed to one or more commodity-price cycles.

The strengths and the risks are not separable – they are different consequences of the same scale. This is why the value conversation must be framed as a range, not as a point estimate, and why the range must be visible to those who allocate capital and critically, can support the work to capture any upside and mitigate against the downside. While compliance with regulators and stakeholder expectations require one business case to be the base case for the project, within the business, the understanding of the range of possible outcomes is invaluable to maximise value and minimise downside exposure.

4 Mine-life phases and value drivers

Value drivers and their associated risks are not uniformly distributed across the life of a caving operation. The phase in which a risk materialises determines both the size of its value impact and the options available for response. Table 1 summarises the indicative value-impact exposure by mine-life phase, in generic terms applicable to most block and panel cave operations. Figure 1 conceptually demonstrates variability over the mine-life phases.

Two observations follow from this phase view. First, the largest single value impact for most caving projects is concentrated in the pre-production development and production ramp-up phases. This is where compounding tends to occur – a slow undercut feeds a slow drawpoint construction rate and difficult undercut blasting conditions result, potentially weakening extraction level pillars. A slower drawpoint construction rate causes a slow ramp-up, which in turn delays the point at which capital begins to be returned to the business. Second, the upside opportunities concentrated in the sustaining and decline phases – extended column height, additional lifts, lower-than-modelled dilution – could be more easily ignored by an organisation that is focused on near-term metrics. This compounding effect is why combined upside and downside cases need to be considered, rather than risk exposure based on singular variable sensitivities. A balanced presentation of value, and focus on more than NPV, instead evaluating impacts on annual cashflows over life of mine and other metrics is necessary.

Table 1 Indicative value-impact exposure across mine-life phases for a block cave operation

Mine-life phase	Indicative value-impact exposure
Access development	Schedule slippage (or improvement) to the footprint area (rock mass conditions, development rates, scope growth); access decisions (decline, shaft, conveyor) lock in capacity constraints – or at least increments – for life of mine (production rate, ventilation capacity). Pertains to both the dual critical paths to production via access to on-footprint development and access to ore handling infrastructure
Footprint development and construction	Lateral development rates, ventilation availability, ground support quantities, sequencing dependencies that drive critical path (undercut lead/lags, extraction level geometry constraints) Undercutting rate, drawbell construction rate, cave initiation and critical hydraulic radius variability and draw strategies. The first of 2 critical paths to production
Infrastructure excavation and construction	Mass excavation rates, ground support requirements, logistics to support workforce, critical component transport, scope growth, complexity of project due to scale. The second of the 2 critical paths to production
Production ramp-up	Draw rate maturity, fragmentation, secondary breaking demand, ore handling availability; early loss of drawpoints – this is where compounded downsides are most visible in cash flow
Sustained full production	Drawpoint maintenance and rehabilitation rates, cave wall geometry and dilution entry, fines migration, mill feed grade
Production ramp-down	Mine-life extension or contraction, grade tail value impacted by performance and actions taken early in mine-life. Production system capacity challenges, ore quality challenges

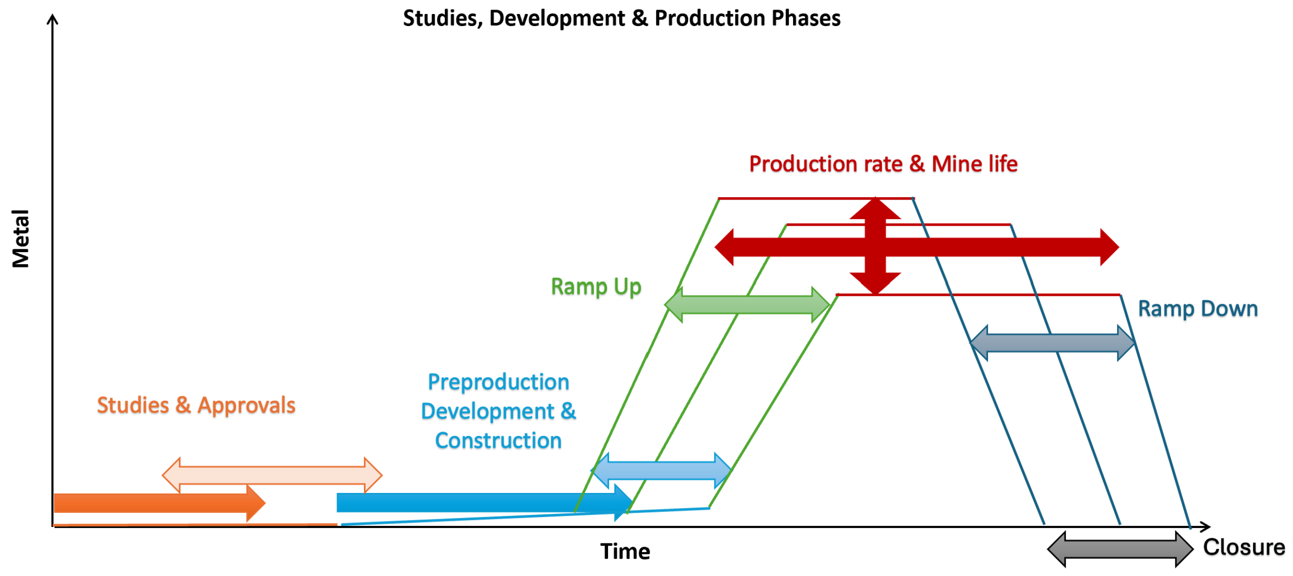

Figure 1 Mine-life phases and conceptual variability in the metal production profile

5 Understanding planning decisions in terms of business value

Translating a mine plan into business value requires a financial model. During study phases, the financial model is typically maintained by the business analysis team, and its use is often rationed because each run requires the analyst's time. This rationing has a real cost. Mine planners who cannot iterate quickly on the value implications of small planning decisions tend to make those decisions on physical metrics alone, and to discover the value implications later.

A more productive arrangement is for the mine planners to have access to a simplified financial model that uses the same key assumptions as the corporate model and that returns approximate NPV, cash flow shape, and mine life within minutes. The corporate model remains the source of truth, but the simplified model allows the planning team to explore the value space of their decisions in real time. Differences between the simplified model and the corporate model should be reconciled at key study milestones.

Where this arrangement is in place, the conversation between the mine planning team and the business analysis team changes character. The planning team brings physical scenarios that have already been pre-screened for value; the analyst brings the financial rigour to confirm the result. Both groups spend less time on cases that turn out not to matter, and more time on cases that do. Changes to the mine plan from pre-production development duration to cave initiation sequence and other variables can be communicated in terms that are understood across the business.

6 Traditional approaches to risk valuation

The traditional approach to developing sensitivities to support a caving study is to flex one variable at a time. Capital is increased by some percentage. Production rate is reduced by some percentage. Time to first ore is delayed by some number of months. Each case is run through the financial model and the result is plotted, often as a tornado chart, in order of the magnitude of value impact.

The tornado chart is a useful tool for one specific purpose: identifying which input variables, considered independently, have the largest effect on the value metric of interest. It tells the engineer where to focus analytical effort and where, conversely, accuracy is less critical. When coupled with the study team's knowledge of the project, geotechnical conditions and other issues, the most likely exposures can be drawn out into combined variable cases. Figure 2 illustrates the magnitude ordering of value drivers for a generic caving project. All numbers are conceptual and do not represent any known project.

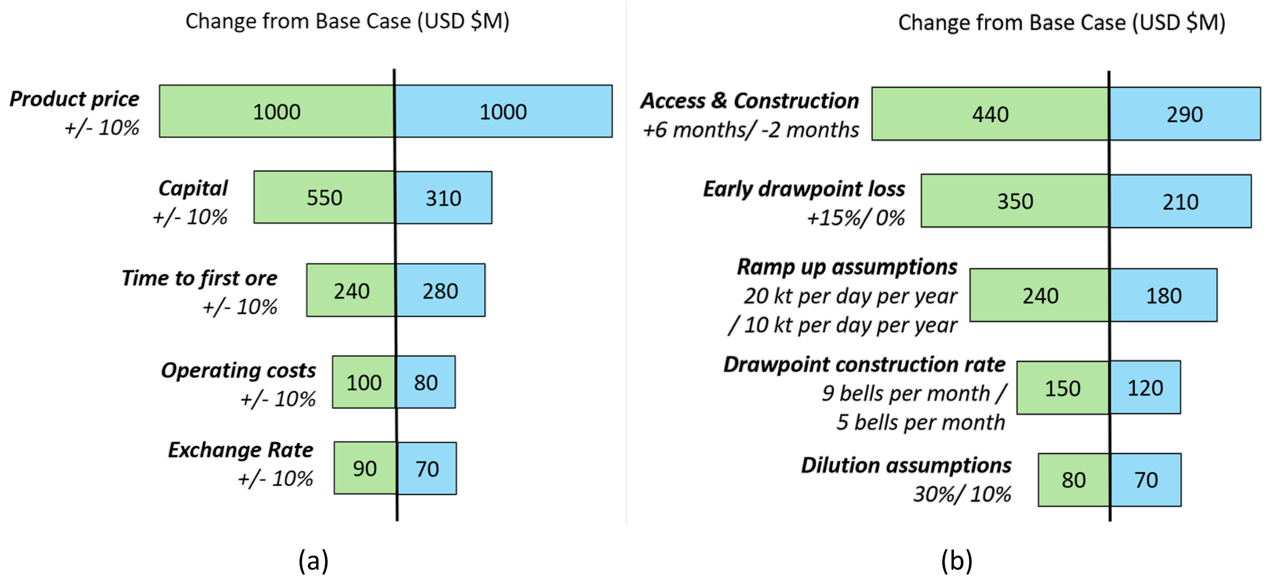

Figure 2 Generic tornado charts illustrating single-variable sensitivity of project net present value to typical parameters. (a) Flexed by finance professionals; (b) Generic key cave planning inputs

The example tornado chart in Figure 2b has 2 limitations. First, it implicitly assumes that input variables are independent. In practice, many credible downside drivers for a caving project are correlated. Later than planned access to the footprint and slower undercut drawpoint construction rates can share a common cause in ground conditions or in resource constraints. A late start to production and a slower-than-planned ramp-up may both stem from the same underestimation of pre-production development or rock mass quality. Treating these as independent and reporting only their individual sensitivities understates the joint downside that the project is actually exposed to.

Second, the tornado chart says nothing about how downside events are likely to be experienced over time, or about the cash flow shape that results. A 20% NPV reduction can mean very different things to the business depending on whether it is concentrated in the first 3 years of production (in which case it affects funding and may threaten covenants) or distributed across a long mine life (in which case it is closer to a long-tail economic exposure). For a capital-allocation conversation, the shape of the cash flow over time is at least as important as the magnitude of the NPV change.

A more useful complement to the tornado chart is a set of combined business cases – including a minimum of a credible upside and a credible downside – in which related drivers are flexed together to reflect their real correlation. The word ‘credible’ is deliberate, in preference to ‘extreme’. An extreme case is not what most organisations are exposed to in practice, and it tends to be discounted by leaders as unrepresentative. A credible case, by contrast, represents a plausible compounding of related events, and its value implications are taken seriously. Ideally, many scenarios are undertaken to understand the landscape of possible outcomes for the project. The focus must be on both the greatest value exposures and those which are of significant value and can be mitigated by action during the mine life.

7 Constructing a credible range of business cases

7.1 Typical caving parameters to consider

A practical approach to communicating value as a range is to develop, in addition to the base case, at a minimum one credible upside and one credible downside case in which related parameters are flexed together. Ideally, many cases are developed to understand the full range of potential outcomes. These should be built jointly by the mine planning and business analysis teams, so that the physical changes in the mine schedule are properly reflected in the financial model keeping the resulting NPV, cash flow, and mine life internally consistent. The most influential variables should be identified by flexing inputs to understand the most influential for each individual mining situation.

Table 2 sets out a generic parameter set that can be useful as a starting point developing credible cases which vary from the base case. The specific values are illustrative; the appropriate magnitudes for any project should be informed by the general mining circumstances as well as other work, such as the simulation work described in Section 6. An approach adopted by some organisations is to gather subject matter experts and workshop input ranges based on the mine’s specific situation.

Three principles should guide the use of a table of this kind. First, the parameter ranges should be informed by site-specific information wherever it is available, including drilling, mapping, the geotechnical model, the development time-study, and the simulation outputs. Second, the downside parameters should be flexed together where they share a common cause, treating them as independent understates the joint downside. Third, upsides should be developed with the same rigour as downsides. An organisation that only flexes downwards will systematically present its projects at the wrong end of the value range, and over time will allocate capital in a manner that reflects that bias rather than the underlying opportunity. Where investment or planning is required to capture upside, the value identified should motivate the team and justify any cost impacts.

Table 2 Indicative technical parameter ranges for constructing credible upside and downside business cases for a block or panel cave project

Parameter	Credible downside	Base case	Credible upside
Time to start of production	+6 to +12 months delay	Study schedule	Improvement of 2–4 months where realistic
Capital cost (pre-production)	+20 to +30% on base estimate	Study estimate	Study estimate
Drawpoint construction rate	Slower than study	Benchmarked rates (6 drawbells/month)	Construction rate increased by 20–30% where supported by simulation
Ramp-up constraints	Ramp-up limited via reduction in drawpoint construction rate, reduced draw rate ramp-up (production rate curve)	Study rate informed by simulation and benchmarking	Ramp-up using faster drawpoint construction rate, draw rate limit relaxation where simulation supports upside
Full production rate (drives and draw rate)	Apply productivity constraints and allow other downside inputs to limit rate	Base case rates	Higher draw and tramming rates where layout and equipment support it
Early drawpoint loss (unrecoverable collapse)	Double the base case loss assumption	Base case loss assumption	No early drawpoint loss (contestable)
Drawcolumn height maximum	<400 m (and economic limit)	400–500 m (or economic limit)	>500–600 m (and economic limit)
Drawpoint spacing, centre of drawcone and drawcone coverage	Reduced effective drawzone radius and gaps in coverage	Modelled drawzone radius	Full extraction-level coverage
Cave wall geometry	Overbreak into lower grade material, higher dilution	Draw limited to modelled cave shape	Underbreak, draw area constrained, resource recovery impacts
Maximum column height (and shut off grade)	Reduced height (e.g. 500 m)	Study height (e.g. 600 m)	Extended column (e.g. 800 m) considering geotechnical conditions and economics
Ground support cost	+20% on base	Base case	Base case or better if geotechnical experts are supportive
Secondary breaking	Higher oversize, production impact from rig demand	Base case rig demand and impact	Reduced oversize where preconditioning is effective
Dilution	Higher fines dilution entry	Modelled dilution profile	Lower fines dilution, late-life grade benefit

7.2 Using discrete event simulation to create a range of outcomes

Discrete event simulation has been used in caving studies for many years, but it has often been confined to a single subsystem – most commonly the extraction level or the ore handling system – and to a single phase of operation, most commonly steady-state production. Used in this way, simulation is useful but this approach does not make the most of the tool. It can confirm whether a given extraction-level layout can deliver a target draw rate. It cannot, on its own, identify which mine planning decisions drive value across the life of the project.

A more powerful application of the same technique is full-system simulation, in which the undercut, extraction level, ore handling, secondary breaking, ventilation, and equipment fleet are represented together and run from the start of footprint development through the end of full production, effectively aiming to produce a digital twin for the mining system. Within this framing, the simulation becomes a central information repository for the design and the operating plan, and changes to any one input flow through the entire production system. This was the approach taken on the Oyu Tolgoi underground project, where the simulation was developed in parallel with the design and used iteratively to inform mine planning decisions (Labrecque et al. 2012). Over 50 trade-offs were tested against the simulation during the feasibility study, including orepass location, drawpoint geometry, and undercut initiation sequence; each contributed measurably to the final design. This simulation, once developed and calibrated could, be used to inform sensitivities on production rate, lateral development, drawpoint construction rate, column height and other key value driving inputs.

A complementary body of work used simulation to estimate lateral development rates for the Oyu Tolgoi pre-production phase, using onsite time-study data and a mining-specific simulation package (Wolgram et al. 2012). That work calibrated modelled rates against actual onsite advance rates and identified, perhaps unsurprisingly, that the daily skipping capacity of the shaft was the binding constraint on development at the time. Both bodies of work share a common observation: when simulation is built early and used iteratively, it informs design decisions; when it is built late and used only for validation, the opportunity to influence the design has largely passed. In addition, these simulations can be used to justify business investment to capture the upside (for example more equipment) and expenditure to justify protecting against the downside – and not just from revenue changes; reliable cost forecasts can be produced from this kind of simulation.

From a value-communication perspective, the most important property of a full-system simulation is that it produces physical outputs – metres per period, drawbells per month, equipment operating hours by year, ground support quantities by period – that can be fed directly into the business model. This converts a technical schedule into a cost and revenue profile, and allows upside and downside scenarios to be expressed in dollar terms. It exposes upside opportunities that conventional planning tends to miss, such as the equipment, materials, and crewing implications of construction rates that are better than planned, and it allows those opportunities to be planned for in advance rather than missed during execution.

7.3 Capturing upside and defending against downside in practice

The execution team also has a role in this discussion. Upsides that are not anticipated cannot be captured. For example, a drawpoint construction rate that is materially better than planned will only translate into earlier production if the ground support consumables, the concrete batching capacity, and construction crewing have been sized to support that rate. Anticipating credible upside in the planning stage is what allows it to be realised during execution. The same logic applies to the downside: a mitigation that is planned in advance can be implemented quickly when the trigger appears, whereas an unplanned response is invariably slower, less effective and more expensive. The best way to record the actions necessary to capture upside or avoid downside is to utilise a typical risk management framework during study and execution.

8 Tools for communicating value and risk

Following the development of credible upside and downside cases, they need to be communicated in a way that supports the conversation with business leaders. The tools listed below are useful in this context and are provided as examples of supporting documentation for practitioners.

8.1 Cash flow over time, net present value and mine life

Where tools like the tornado chart show the impact of single variables on a value metric, a cash flow-over-time chart shows when in the project life the value impact is felt. Where possible, the credible upside and downside cases should be shown as cash flow profiles alongside the base case, with peak funding, payback period, and mine life identified (Figure 3).

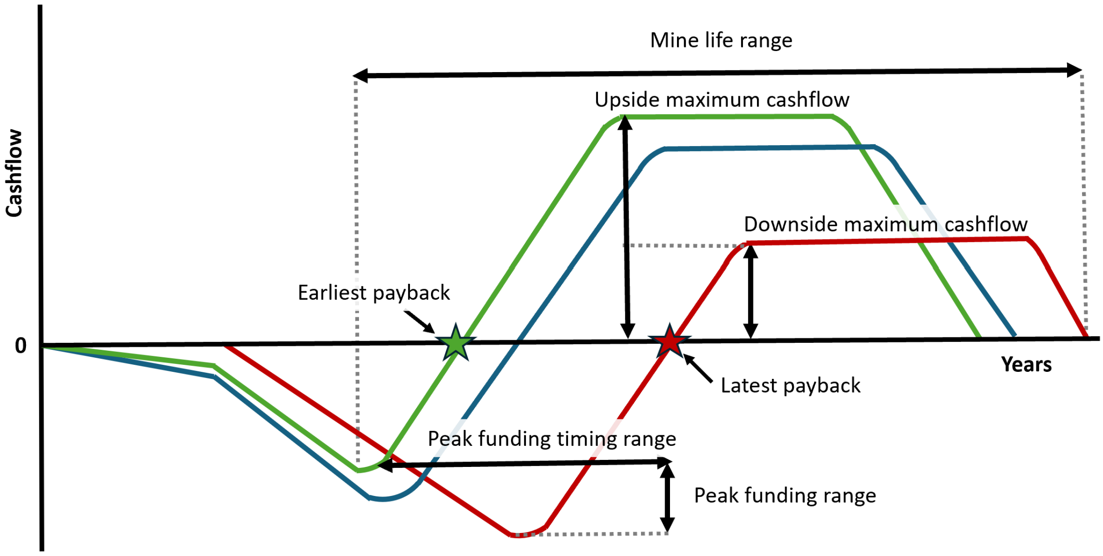

Figure 3 Conceptual cash flow over time for the base case (blue) bracketed by credible upside (green) and credible downside (red) cases, with peak funding and payback period variability shown

8.2 Production profile range chart

A production profile chart showing the base case as a central line, bracketed by credible upside and credible downside lines, is a useful visual expression of the range of plausible outcomes (Figure 4). The same approach can be applied to the metal quantity profile and to the cash flow profile. The visual immediacy of a range – particularly where the area between the upside and downside is shaded – communicates the message that the project is exposed to a band of outcomes rather than to a single number.

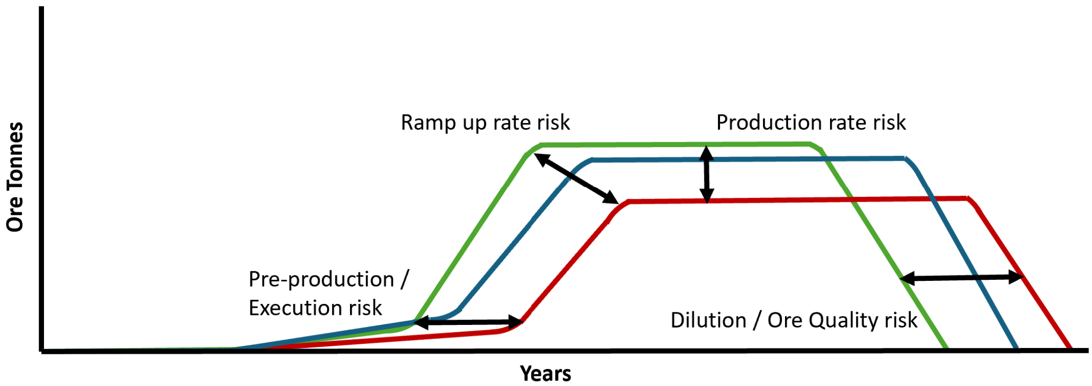

Figure 4 Production profile expressed as a risk range, with credible upside (green) and credible downside (red) cases bracketing the base case (blue)

8.3 Visualisation of simulation outputs

Simulation outputs are most useful to a non-technical audience when they are visualised in a way that connects the simulated activity to the production schedule. Animations of cave development and drawpoint construction over time, when shown alongside the production and cash flow profiles, help leaders see how the physical work onsite translates into financial outcomes. This is particularly effective for explaining why an apparently small delay in the undercut has a disproportionately large cash flow consequence later in the project life. Where simulation has been used to support trade-off decisions, the comparison between the trade-off options can be shown using the same visualisation, making the basis for the decision transparent.

8.4 Dashboards to communicate updates and track actions

Where many production cases have been developed, dashboards are a very useful method of communicating many data trends on ‘a page’. Engineers typically use dashboards with an expert eye conditioned to almost instantly understand and interpret updated information. It can be useful to design dashboards early in a study or project execution phase and condition leaders to seeing data in this format, enabling dashboards to be an effective way to quickly communicate updated information. Dashboards can include any key metrics graphed over time as well as tables containing actions, responsibilities and progress.

9 Conclusion

Block caving projects are exposed to a wider range of outcomes than can be communicated by a single-point study estimate. The scale of capital, long pre-production period, and dependencies between undercut, extraction level, and ore handling construction all combine to make compounding downsides more likely and their consequences harder to recover from. The same characteristics also create real upside opportunities that are systematically underrepresented when only downsides are flexed, or layered into the base case.

Technical teams have a responsibility to translate this range of outcomes into the language of business value, and to present it as a range, resisting one-point estimates. Full-system discrete event simulation, used early and iteratively, is an effective tool currently available for generating the physical schedules that underpin a credible range. Combined business cases built around these schedules, expressed in cash flow over time, NPV, mine life, and peak funding, allow business leaders to engage with the project as it really is – a strong opportunity with a meaningful, but bounded set of risks – rather than as either an over-conservative or an over-optimistic point estimate.

Technical personnel intuitively understand risk in terms of opportunity and threat, understanding context quickly. However, deep expertise in underground mass mining remains rare in senior leadership; therefore, to do justice to the projects we are committed to study and build, we need to consistently translate risk in the language of business.

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Use of artificial intelligence disclosure statement

In the preparation of this work, the author used Claude Opus 4.7 (Anthropic) to assist in the drafting and formatting of this paper. The author has reviewed the content and edited it where required and takes full responsibility for this content.

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