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Closing the gap: closure cost estimation trends and pathways to improved maturity

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Abstract

In an ideal scenario, the upper and lower confidence limits of a closure cost estimate should align with the base estimate as mine closure planning progresses; however, this is rarely the case. As mines approach closure, cost estimates typically rise. Despite various approaches proposed to improve cost estimate accuracy over the years, cost overruns remain common. The authors suggest that the issue lies not only in the estimation approaches but also in the misalignment between the maturity of closure planning and the level of cost estimate accuracy required.

Current estimating tools and approaches are not flawed; instead, robust closure planning and design are often inadequately applied. The paper suggests actions to improve closure design maturity at each stage of the mine life, ensuring cost estimate inputs mature appropriately as the closure date approaches. Examples and case studies highlight the common disconnect between closure maturity and cost estimate accuracy.

A review of closure cost estimation tools and approaches over the past 20 years shows that cost overruns are widespread, indicating that estimation approaches might not be the sole issue. With growing scrutiny on closure-related environmental, social and governance commitments, the mining industry needs to produce more confident, accurate and transparent closure cost estimates. This paper underlines existing and practical methods for improving estimation inputs.

Keywords: *closure cost estimation, closure planning, closure maturity, case study*

1 Introduction

As the criticality of responsible mine closure has become apparent over the last several decades, our understanding of the extensive planning, design and implementation that accompanies closure has also developed. With this, the requirement for detailed closure cost estimates of various types has become the norm from the earliest stages of mine planning. The drive for closure cost estimation comes from an understanding that closure can be a significant financial liability: inadequate closure cost estimates can mean that an unprofitable mine is established, that capital investment decisions are misguided and/or that financial assurance provision is insufficient. The prevalence of divestment of assets and mining company bankruptcy as assets near their planned end of operations reflect that closure has not been adequately valued or planned for (Woolley & Hutton 2006; Laurence 2006).

The mining industry and governments are discovering the risks of closure costs through several highly publicised cases of cost escalation in mature mining regions (Table 1). For example:

- Closure costs for Giant mine in Canada's Northwest Territories were reported as being over CAD 1 billion less than five years ago, only to have that increase to over CAD 4.3 billion more recently (Government of Canada 2022; Minogue 2020).

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- Life of asset (LOA) closure costs for Ranger mine in the Northern Territory, Australia, increased from an estimated AUD 1 million in 2004 (Energy Resources of Australia [ERA] 2004) to AUD 512 million in 2018 (ERA 2018) to over AUD 2.2 billion as recently as 2023 (ERA 2023).

These escalations make successful closure achievement challenging (or impossible) without additional revenue streams. It also damages reputation and reduces the confidence of lenders, thereby affecting the ability for companies to secure additional financing. Similarly, it can lead to an undervaluation of the financial assurance provision required by governments such that they may undertake closure activities themselves should the owner/operator be bankrupted. This often means that taxpayers are left to cover the costs (as in the case of Giant mine).

Four main types of closure cost estimates are presented by the International Council on Mining and Metals (ICMM 2019):

- life of mine (LOM) or LOA cost estimate
- financial liability/asset retirement obligation (ARO) cost estimate
- sudden closure cost estimate
- regulatory financial assurance.

Each estimate type serves a distinct purpose and is compiled under distinct assumptions (Table 2). Accordingly, each will have different line items and total values. Comparisons between cost estimates can be helpful to understand trends or inconsistencies, but only across the same type of estimate (i.e. comparison of two or more LOA closure cost estimates).

Due to the importance of having an accurate closure cost estimate, and the propensity for actual (or late stage) closure costs to be orders of magnitude more than early estimates, cost estimates have been a recurring topic of conversation during the last 20+ years of the Australian Centre for Geomechanics (ACG) International Conference on Mine Closure series. While other global conferences and journals exist, the ACG's International Conference on Mine Closure series serve as a snapshot of the content being generated and discussed by the mine closure community.

A search of the online repository of International Conference on Mine Closure papers (total of 872) since 2006 for 'cost estimate' returns 18 papers (2%) that discuss closure cost estimates as their central topic. Of these papers, nine (1%) stated what type of estimate they were focusing on while the other nine either spoke to all types or did not specify. Older papers were more likely to have stated clearly what type of estimate the paper applied to. As the papers were reviewed and themes were extracted, each paper fell under at least one theme. The four themes identified were:

- case studies
- a new approach or tool proposed for improved cost estimation
- tips for improved estimation
- new international or regulatory guidance.

The papers can be split into two time frames: six papers were identified between 2006 to 2011 and 12 between 2019 and 2023 (Figure 1), with no papers identified between these time ranges. 'Case studies' and 'tips for improved estimation' papers were most common between 2006 and 2011 (three instances each), while 'tips for improved estimation' (six instances) and 'new approaches or tools' (four instances) were most prevalent between 2019 and 2023. Although the data points here are few it would appear that both the prevalence of generalised papers on cost estimation, and those with recommendations on improving accuracy, are increasing; meanwhile the prevalence of documented case studies has remained unchanged. Despite the many proposed approaches, tools and tips (i.e. Dunow & Kalisch 2022; Fletcher et al. 2011; and others), cost overruns persist. This begs the question: are more tips, tricks, and tools needed to get our estimates right? Examples of accurate cost estimation do exist, as do standardised approaches endorsed by the American Association of Cost Estimators (AACE) and the like: they simply tend not to receive much publicity (the authors are aware of several confidential examples). In our experience, the problem lies not with the approach to cost estimating but rather with the inputs and immature planning provided as a basis to estimators.

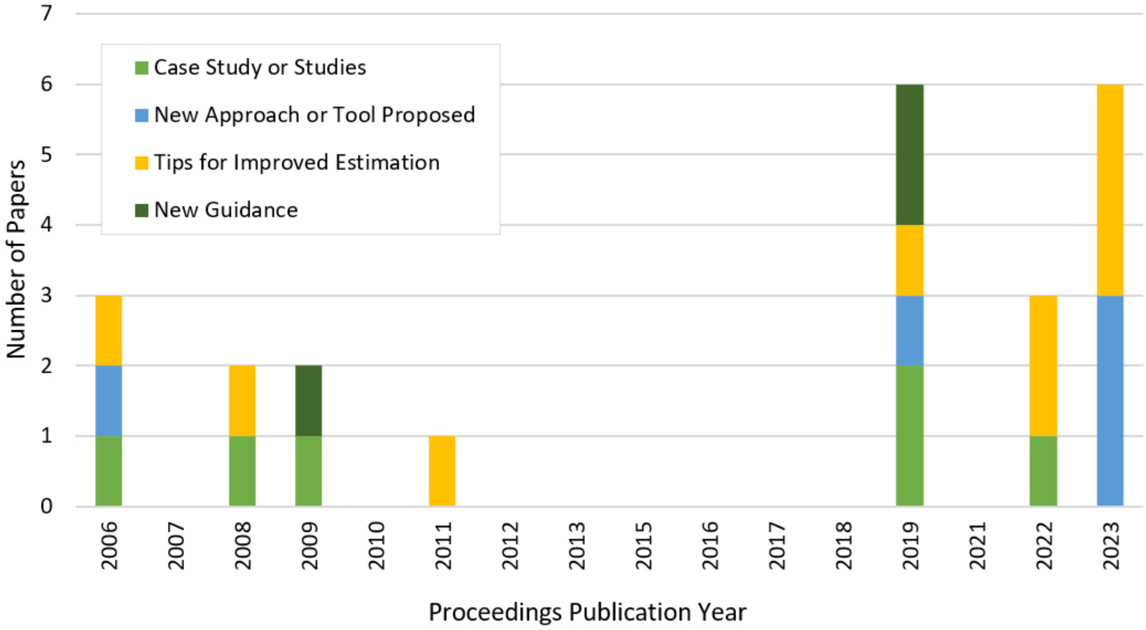

Figure 1 Major themes of papers published in the International Conference on Mine Closure proceedings (Australian Centre for Geomechanics [ACG] 2024)

This paper compiles examples of mine closure cost estimate overruns from previously published sources to illustrate: the pervasiveness of overruns; the cost estimation tools, approaches and standardised descriptions of what is required for each of the cost estimate types; and the necessity of maturity* in closure planning and related actions to achieve improved closure planning and design to the degree that would justify the class of cost estimate required.

2 Comparison of cost estimates and actual closure costs

A summary of example closure costing within the public realm is summarised in Table 1. For any mine asset, there is a wide range of closure cost values from early-stage development to mature operations to pre-closure execution. Many of these can be attributed to progressive mine expansion and associated incremental liability; however, many of the cost estimate overruns can be attributed to poor planning.

Certain closure cost aspects are regularly impacted by poor planning and can lead to:

- a lack of alignment with/communication of the closure vision (e.g. post-mining land use, PMLU) — with technical components/specialists not being considered when developing a cover design, resulting in a cover that does not support the agreed-upon PMLU re-design)
- inadequate stakeholder engagement on key aspects driving the final post-mining performance (e.g. land capability or capacity, PMLU(s), design basis and closure success criteria) — particularly asking closed-ended questions or providing insufficient background information for informed feedback

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* Closure maturity is defined as how well the systems, processes and practices of an organisation are developed and can reliably produce required outcomes. In the context of mine closure, the ICMM maturity framework allows '*operations to understand and evaluate where they are positioned today, track their performance towards implementing sustainable closure, and identify what elements are needed to strengthen their systems, processes or practices to reach their aspirational maturity level*' (ICMM 2022).

- the slow progression and integration of closure risk-informed design over the LOA (i.e. concept to feasibility within the last few years of closure). This includes supporting design and costing of the preventative design controls required to meet the intent of as-low-as-reasonably-practicable
- bulk material movement including tailings removal, pit backfill, regrading and impractical engineered cover designs
- inadequate characterisation and assessment of water-related risks (e.g. metal leaching and acid rock drainage, and flood routing) including optimistic projections of water treatment time frames. The Equity Silver case study (Goldcorp 2018) demonstrates that even after closure implementation there remains a wide range of cost uncertainty* (e.g. water treatment plant lime consumption, unit rates and interest rates)
- an increased level of specificity in designs without trials or field testing onsite (i.e. a conceptual cover listed as 'at least 30 cm thickness inclusive of subsoil and topsoil' becomes '20 cm subsoil and 10 cm topsoil with subsurface scarification and live stake planting of Salix spp. in fall' at the detailed design stage but, as no aspects have been tested onsite despite the increased specification, this remains at a conceptual level of maturity)
- a lack of resilience in the design including unplanned event-driven loading conditions (flood, seismic biological, human/social and repeat or cumulative effects of these).

Table 1 Examples of closure cost estimates

Site	Location	Status (operating life — years)	Mine type (commodity)	Initial cost estimate (year)	Final cost or most recent estimate (year)	Increase (%)	Cost estimate type
Ranger mine	Northern Territory, Australia	Closed in 2021 (35 years)	Open pit (uranium)	AUD 1M (2004)	AUD 2.2B (2023)	220,000	Financial liability
Victor mine	Ontario, Canada	Operations ceased in 2019. Active closure completed 2023 (17 years)	Open pit (diamonds)	CAD 74M (2017)†	CAD 190M (2023)‡	256	Life of mine
Equity Silver	British Columbia, Canada	Closed in 1993 (13 years)	Open pit (gold, silver, copper)	CAD 32M (1990)	CAD 87.2M (2018)	272	Regulatory financial assurance
Giant mine	Northwest Territories, Canada	Closed in 1999 (51 years)	Open pit (gold)	CAD 0.9 billion (2012)	CAD 4.3 billion (2022)		Life of mine

From the publicly available closure cost reporting, the most recent estimate overrun with supporting detail is Energy Resources Australia's (ERA's) Ranger uranium mine. Initial escalation of closure costs for ERA were collated for the period 2003 to 2016. These costs, sourced from ERA's annual reports starting in 2004, increased from AUD 2.7M in 2003, decreased to AUD 1M in 2004, then increased to AUD 600M in 2015

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[*] Uncertainty is defined as any of the following: *'(1) a synonym for all risk (i.e. all events of conditions both positive and negative whose probabilities is neither 0 or 100 percent); (2) the total range of events and conditions that may happen and produce risk (uncertainty = threats + opportunities); and (3) background variability, with a probability occurrence of 100% that may typically result from causes such as (i) inherent variability, (ii) estimating error and (iii) bias in estimation or prediction'*. Association for the Advancement of Cost Engineering (AACE 2024)

[†] https://www.spglobal.com/marketintelligence/en/news-insights/trending/xtazomktxhrqnfu9gp-bda2

[‡] https://www.timminspress.com/news/victor-mine-site-to-be-closed-by-fall

(ERA 2004, 2018, 2023). These costs are reported as provisions (i.e. ARO cost estimates) and are therefore likely to be discounted[*] and exclusive of socio-economic costs and contingency[†]. No basis for the significant escalation was provided by ERA although indications of additional unfunded liabilities and the need to call on support from parent company Rio Tinto to meet final closure costs were revealed.

In 2016 ERA commenced pre-feasibility studies for the closure of Ranger. These studies are expected to have challenged the strategies presented within ERA's conceptual closure plan, which is likely to have formed the basis of earlier closure cost provisions. This was demonstrated by ERA's reported closure provision increasing to AUD 830M in 2018 following completion of the pre-feasibility study (ERA 2018) and then to AUD 1.2B in 2020 following completion of the feasibility study (ERA 2022). The 2020 provision was determined following ERA's revision of its LOM cost estimate, which placed total closure costs between AUD 1.6B and AUD 2.2B. The increases were reported as being due to changes in strategy around the transfer of tailings to Pit 3, additional water treatment infrastructure, and higher site services and owners' costs. Such changes have been heavily influenced by incorrect assumptions regarding ERA's ability to complete works during the dry seasons and the volume of water needing to be dealt with following the wet seasons.

Beyond these chosen examples, additional instances are documented in the references provided. However, a core challenge in remedying this issue is the relatively small number of thoroughly documented case studies in the public domain, both for instances or poor practice and leading practice.

3 Common tools and approaches

There are various approaches used to estimate closure costs, based on the purpose and therefore the intended end user. ICMM's Financial Concepts for Mine Closure (ICMM 2019) and the AACE website (https://web.aacei.org/resources), amongst others, provide useful guides to the different types of costing, accounting and reporting requirements.

Building from ICMM (2019), Table 2 summarises the types of closure costing and example tools used for each.

Fundamentally, each cost estimate model includes inputs (closure activities and prescriptions that inform quantities, unit rates and timing for implementation) and outputs (costs for direct and indirect elements, spend forecast). These are guided by the closure plan and supporting agreed success criteria, technical studies and the engineering required to provide a degree of certainty that supports the cost estimate and schedule.

Each cost estimate, regardless of type, must provide sufficient transparency to enable reviewers and financial auditors (required for an ARO estimate) to determine how calculations on the quantities and unit rates are made, linking to the basis of estimate.

Furthermore, the US Sarbanes-Oxley Act of 2002 (United States of America 2002) requires the asset owner to establish and assess a system of internal controls over financial reporting. Companies are required to disclose material liabilities that could impact their financial position, including significant estimates related to mine closure costs. Financial auditors must report on the effectiveness of that system. This may require additional levels of governance from a company aiming for closure cost estimates to be compiled to the same standard across its asset portfolio.

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[*] Discounting is a term used in finance that speaks to the process of assessing the present value of a sum to be spent or received in the future; for example, closure and reclamation costs scheduled for a future time are cheaper on a balance sheet than closure and reclamation costs paid tomorrow. Accordingly, some cost estimate types are discounted while others are not.

[†] Contingency is defined as 'an amount added to an estimate to allow for items, conditions, or events for which the state, occurrence or effect is uncertain and experience shows will likely result in aggregate, in additional costs. Typically estimated using statistical analysis or judgment based on past asset or project experience' (AACE 2024).

Table 2 Closure cost estimate types and example tools (modified from ICMM 2019)

	Life of asset/life of mine cost estimate	Financial liability/ provision/asset retirement obligation cost estimate	Sudden closure cost estimate	Regulatory financial assurance
Overview	Closure according to the projected LOM Cost for closure activities at the end of operations Discounting used	Net present value estimate of (1) reclaiming the current disturbed footprint or (2) settling liability/ transfer to third party on reporting date Discounting used	Represents the cost to close the mine tomorrow and used to evaluate internal business risk No discounting used	Basis for cash security, bonding and other financial securities Assumes external rates for closure activities Discounting rules vary by regulator
Frequency of update	Varies, typically every 3–5 years	Annual	As required/event-driven	Typically every 1–5 years
Example tools	None (from first principles), company-generated cost models, etc.	Same as LOA costs	Same as LOA, project-specific cost model	Regulator-provided cost model (i.e. Standardized Reclamation Cost Estimator [SRCE]) or mutually agreed-upon alternative
Unit rates applied	Typically operator/ internal rates	Operator/internal rates and/or third-party rates	Same as LOA	Government cost model rates or justified alternative
End user	Generally internal use only	Market, financial auditors	Generally internal use only	Regulator
Publicly accessible?	No	Yes, at a corporate level, not asset level	No	No

Historically, closure cost estimates have been prepared by closure or technical practitioners who have focused on the ‘knowns’ or direct costs, which are built up through first principles (i.e. quantity × price). As such, the ‘unknowns’ or uncertainty within the estimate (which include costing elements such as escalation, growth, contingency and risk) have not been effectively addressed through adequate closure planning and an increase in design maturity. This leads to the typical and unacceptable cost increases that we are now seeing within closure costs (Figure 2).

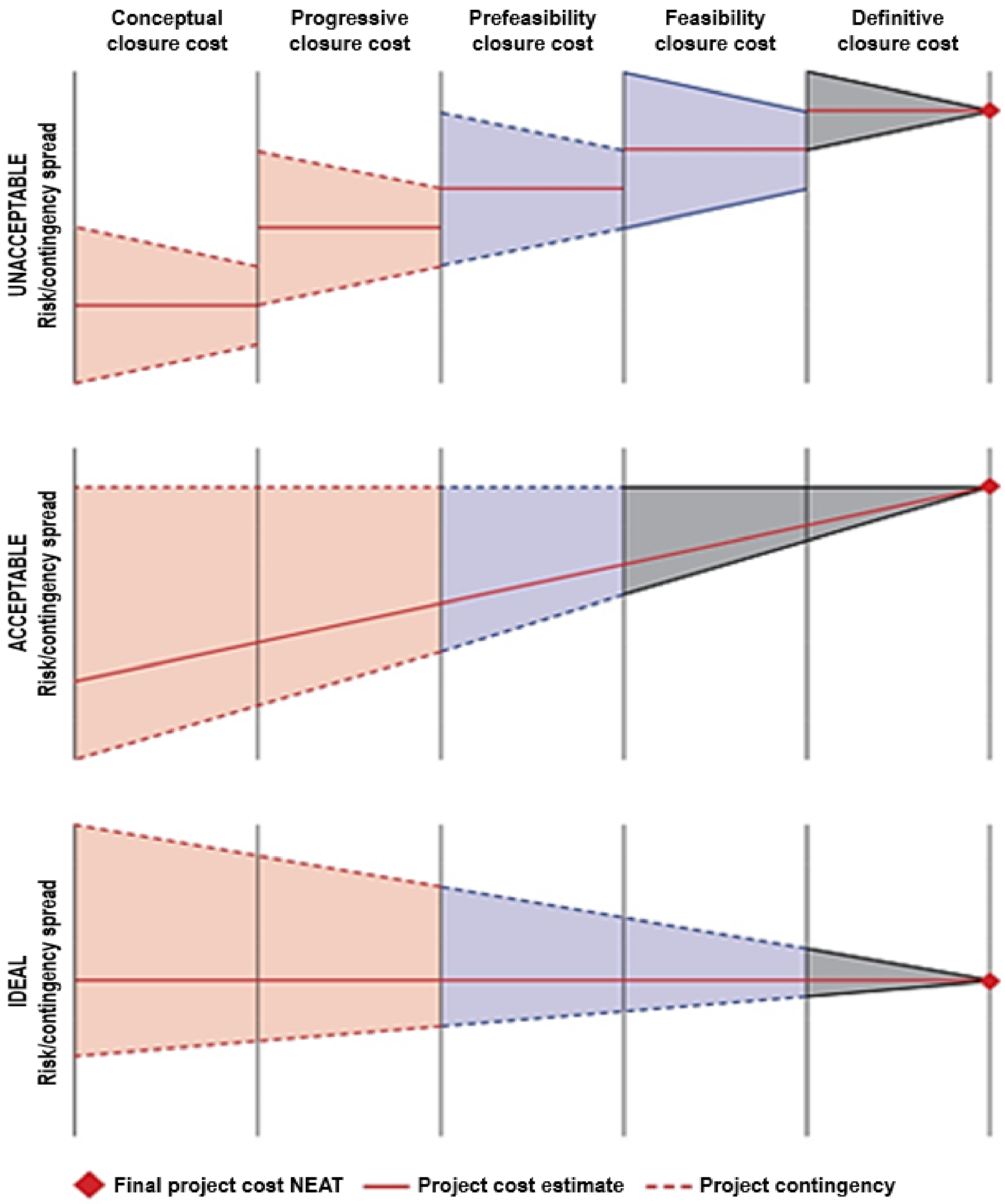

Figure 2 Comparison of likely project cost history based on consideration of cost uncertainty (adapted from the Queensland Government 2017)

As described by Reilly et al. (2015), uncertainty in the cost estimate should be described on the basis of estimate and can be accounted for through various cost estimating approaches. The purpose of the basis of estimate is to provide transparency around the approach taken (see Table 3) and additional detail that could not be clearly communicated within the estimate itself. This is a major feature of any cost estimate; the two should be reviewed in conjunction and packaged as a pair. Figure 3 and Table 3 summarise the approaches typically employed to support a LOM closure cost estimate.

Table 3 Benefits and challenges of various cost estimation approaches (adapted from Reilly et al. 2015)

Estimating approach	Overview	Benefits	Challenges
Deterministic	Estimation approach that provides a single, precise estimate of the total cost without accounting for uncertainty or variability	One single figure Well-known and industry accepted Quick Can be performed manually with little experience	No probability information for single value Higher probability of cost overrun Excludes value of risk information (maximum potential loss with a given confidence level due to market fluctuations)
Bandwidth	Estimation approach that provides a range or band' of potential costs. This range reflects different scenarios or potential outcomes, acknowledging that exact costs are uncertain and can vary due to various factors	Creates a range (optimistic, base case, reasonable worst case) Quick Can be performed manually	Same as deterministic
Square root	Estimation approach based on scaling factors. It is often employed when assessing the costs of projects with similar characteristics but varying scales	One single value Quick Can be performed manually	Range limits are extreme and unlikely
Probabilistic	Estimation approach accounting for uncertainty and variability. Provides a range of possible outcomes based on different scenarios and probabilities	Full probability information	Needs probability approach and experience Requires time and software support

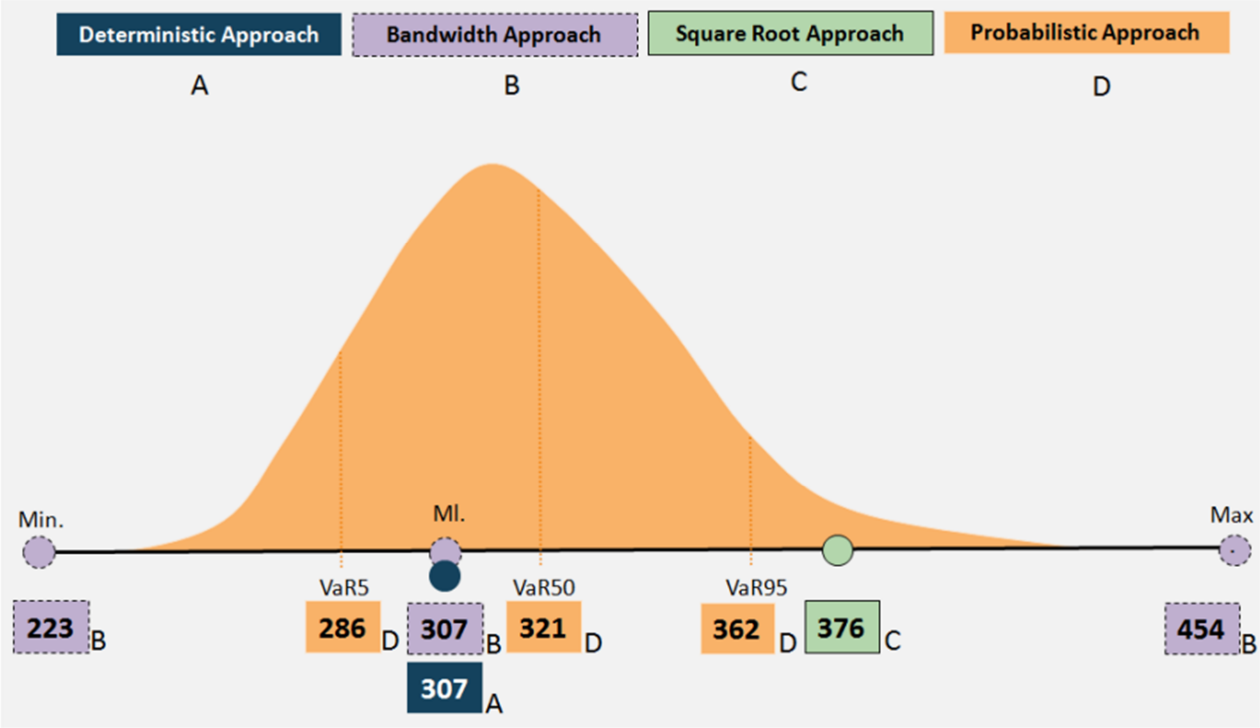

Figure 3 **Visual representation of cost estimation approaches within a normal distribution (Reilly et al. 2015)**

The closure planning process begins with very little information and progresses in an iterative fashion as the mine plan is developed and inputs from various technical disciplines lead to mine plan refinement and revision. Once a closure plan is developed at its most rudimentary stage it requires testing and advancement of the individual components to move beyond that stage. For instance, a conceptual cover design might include cover goals and objectives, and an approximate thickness for the purpose of evaluating material balance; simply adding definition to the materials and thickness leads to a false sense of maturity until field trials of the cover have been evaluated, the design has been modelled and/or material availability is confirmed in the volumes necessary.

The ICMM Closure Maturity Framework (ICMM 2022) provides one method for assessing the current maturity level of the closure design or plan, generating a common understanding of the pieces lagging and requiring advancement, and can be used to drive conversations between operations and business/financial leadership. With an improved understanding of the maturity level of the closure plan, the appropriate level of corresponding cost estimate can then be developed.

4 Discussion and proposed actions for improved alignment

In *How Big Things Get Done* (Flyvbjerg & Gardner 2023), the authors demonstrate how megaprojects (> USD 1B) with little repetition or high levels of uniqueness are more likely to lead to cost overruns. Their collation of over 16,000 megaprojects discovered that less than 1% of megaprojects come in on time and on budget while also delivering the claimed benefits. The mean cost overrun for megaprojects ranges from 238% (nuclear storage) to 27% (mining) to 1% (solar), with the percentage of > 50% project overruns ranging from 48% (nuclear storage) to 17% (mining) to 2% (solar).

The causal factors for these megaproject cost escalations are common and parallels can be expanded to include mine closure costing exceedances. Expanding on Flyvbjerg & Gardner (2023), heuristics for improving the planning and execution of large-scale projects include:

- Involvement of a 'master builder', qualified team and strong governance.
- Thinking right to left — Ask 'why', start with the end goal in mind and work backwards to identify the necessary steps to achieve it.
- Thinking slow and acting fast — First introduced by Kahneman (2011), the concept of 'thinking, fast and slow' according to the task at hand can be applied to planning and design. Good planning is detailed and deliberate, ensuring that every aspect is scrutinised before execution. This slow and methodical planning phase allows for rapid and efficient implementation once the project begins.
- Take the outside view through reference class forecasting, which involves using empirical data from similar past projects to make more accurate predictions about costs, timelines and potential risks.
- Master the unknown unknowns. Prepare for unforeseen challenges by understanding that many risks are unpredictable and planning accordingly. Strategies include robust risk management systems, scenario planning including predictive modelling and sensitivity analysis, and building resilience into the design (i.e. contingency for flood routing/spillway design, etc.) and contingency action plans.
- Modularity — with non-unique components that can be scaled up.
- Managing optimism — Project managers often fall into the trap of being overly optimistic about timelines and costs. Using historical data, expert judgments and team diversity to promote divergent thinking and sensitivity analysis helps in creating more realistic estimates and managing expectations.
- Active and iterative planning — Planning should be an active process involving continuous testing, simulation and refinement. This approach increases the likelihood of identifying and resolving issues before they escalate during the project's execution phase.
- Risk management — Proactively identifying and managing risks through tools like risk registers is essential for handling uncertainties and ensuring the project remains on track. Ensuring risks (threats and opportunities) and preventative and mitigative controls are adequately captured into the closure cost estimate.
- Reflection upon the tools and approaches used and/or mandated for closure cost estimation over the last 20 years indicates that cost estimate blow outs are ubiquitous, and the tools used for estimation may not be the only issue at play.

Building on the above points, a key priority for closure costing must be establishing a basis of estimate that clearly defines the type of estimate, the maturity of the scope development, technical studies/engineering/constructability used to establish material take offs, and uncertainties for each mine closure component. Strategic and tactical actions can be applied at each stage of the mine and to each mine closure component to improve the closure design basis and maturity such that cost estimate inputs are similarly maturing as the time to closure decreases.

Table 4 summarises an example of maturity improvement by the LOM stage that the cost and execution schedule can be aligned with. Where progressive rehabilitation is being applied, the maturity of the scope and engineering, and consequently the class of the cost estimate, should be tied to the domain, feature or facility being progressively rehabilitated and not to the mine or operation as a whole. As such it is expected that some elements of the cost estimate will have a higher class and accuracy than others.

Table 4 Example of closure cost maturity progression and inputs

Project phase (design accuracy)	Phase name	Example target date (years prior to end of mining)	Typical mine closure planning inputs (studies/ assessments)
Detailed design (+/–10%)	Class 1/ execution	< 2	Refine the closure engineering with inputs from FS forward works programs As-built designs
Feasibility study (–10 to +15%)	Class 2/front-end loading (FEL) 3	2 to 8	Refine the closure engineering with inputs from pre-feasibility study forward works programs Construction trials
Pre-feasibility study (–15 to +25%)	Class 3/FEL 2	8 to 15	Refined closure engineering with inputs from PFS forward works programs Agreed post-mining land and infrastructure use(s) Social transition engagement and integration, including infrastructure repurposing Agreed closure objectives and success criteria Clear closure obligations and legal requirements Consolidated knowledge base and spatial data management Closure design basis including climate change considerations Closure risk and opportunities assessment Closure scenario options assessment for each closure domain (guided by post-mining land use/s and closure objectives) Life of mine plan opportunities (mine rock handling, growth medium stockpiling, tailings deposition, water management, etc.)
Concept (–35 to +100 %)	Class 4 or 5/FEL 1	> 15+ years	Identified post-mining land use, depending on time to the end of operations Infrastructure decommissioning plan Closure social programs Closure vision, objectives and success criteria Closure risk and opportunities assessment Closure scenario options assessment for each closure domain (guided by post-mining land use/s and closure objectives)

Cost estimating should reflect the closure design uncertainty, especially in the very early stages of projects where neither the exact quantities nor unit rates are fully known. With a deterministic approach, uncertainties and their characteristics cannot be easily taken into consideration. A probabilistic approach can more reasonably address this type of uncertainty and identify this range of probable costs. Accordingly, different approaches may be appropriate for different components of the closure cost estimate.

From recent experience, the authors identify the following key levers for improved closure costing:

- Establish a supporting basis of estimate document. It should clearly articulate the cost type, purpose, method and basis from which the estimate is made.
- Front-end load the closure costing with a supporting pre-feasibility closure design early in the mine life to build scope and maturity within the closure costing. Accordingly, your confidence in the associated cost estimate is based on sound understanding, assessment of options and worst-case scenarios.
- Establish strong corporate governance systems and effective tools that set the minimum requirements for LOA planning and the management of closure activities.
- Establish a clear closure vision that all levels of senior management endorse, and which aligns with the business plan, closure objectives and measurable success criteria.
- Integrate risk and opportunity assessments to align closure stakeholders and identify LOA threats and opportunities requiring priority and capital expenditure. The integration of risks effectively into the closure cost estimate is an area that needs more focus and is perhaps one of the many reasons closure cost estimates are underdone in the early stage of the mine's life. Key items that continue to dominate the cost estimate share are integrated water management, tailings/mine waste design and social performance.
- Progressively influence business/mine planning and budgeting cycles early in the LOM to integrate the closure designs, and optimise the mine plan alignment with the closure vision and success criteria rather than with compliance-driven action and reactive planning.
- Progressively improve the knowledge base, support these intended success criteria and identify risks/opportunities. Performing progressive rehabilitation and/or closure trials at an early stage in the LOM can significantly add to the knowledge base.
- Understand the full range of obligations (legal and constructive) including social performance and stakeholder engagement outcomes.
- Engage experienced closure planning practitioners to prepare the closure plans and cost estimate, with support from technical specialists, site operators and contractors. Utilising a project estimator early in the mine life to advise/review on the basis of estimate and cost work breakdown structure can be of value.
- Implement independent review mechanisms to challenge existing bias, assumptions and uncertainties.

As a final note, the underwhelming availability of case studies and publicly available data on closure and execution costs continues to be a key barrier for improvement of the industry's state of practice. The general acceptance from industry that closure cost estimates are many times (if not orders of magnitude) less than the actual cost is a point of failure to be learnt from and improved upon.

5 Conclusion

Closure cost estimation is increasingly having a material impact on business decisions, financial reporting and company stakeholders.

It is the authors' opinion that more guidelines or tools for closure cost estimation will not materially improve the status quo; however, by critically examining the inputs to our cost estimates we can respond accordingly with an understanding of the risk associated to each aspect of the estimate, corresponding contingencies and appropriate cost estimate class labelling: as noted above, some portions of a cost estimate may be developed to a higher classification than others, depending on the maturity of inputs. The range of uncertainty in the closure cost is a result of the level of maturity within the risk-informed closure planning and management system.

The authors of this paper issue a general call to owner/operators to publish more case studies with lessons learnt: both for accurate and inaccurate estimates (and the reasons why). Closure is increasingly being viewed as an opportunity for competitive advantage, but poor closure action due to inadequate planning and/or resources perpetuates negative stereotypes of the mining industry, working against us all. Knowledge sharing on closure aspects that are not region- or climate-specific would be beneficial.

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