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Effective strategies for estimating design growth in mine closure

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Abstract

In 2018, the International Council on Mining and Metals (ICMM) surveyed its members to assess the status and profile of mine closure across its membership. Although there are several new mines coming onstream on an ongoing basis, the survey found that over the next 25 years, more than 40% of the operations that responded to the survey are expected to close based on commodity prices and mine life estimates at that time, and almost 20% are expected to close in the next 10 years.

With many mines expected to close around the world in the coming years, it is becoming more important than ever for mining companies to accurately quantify, estimate, and report on the total cost of closure.

Planning for closure and its associated costs needs to commence from the early developmental stages of the mine itself and continue through final relinquishment of the site (Dunow, 2022). Improved understanding of mine closure costs will empower the mining industry to enable a more sustainable transition to post-closure land uses that leave behind a sound and stable environment and self-sustaining communities. Turner & Townsend has been working on closure projects for over ten years and our data shows that mine closure costs can double from the initial estimate. There are many reasons for the overruns such as site changes, acceleration or delay of closure, closure assumptions, and legislative changes. Implementing effective strategies to account for these changes in the estimate is the purpose of this paper.

A typical estimate is made up of various parts that endeavour to account for the total cost of a project. This includes direct costs, indirect costs, allowances, contingencies, and escalation. Direct and indirect costs are based on known scope and costs, whereas allowances, contingencies, and escalation are amounts to account for unknown scope that is known to exist or will exist as the project progresses.

Specifically, an allowance is an amount added to the estimate to account for costs that are certain to occur but cannot be identified with any accuracy (Dobre, 2023). Estimate allowances are typically divided into two separate categories: design growth (changes to design assumptions as the engineering progresses) and quantity/cost growth (inaccuracy in material take-offs or pricing assumptions). We propose the use of a third allowance specific to mine closure to account for those items listed previously.

We will use data we have gathered in developing mine closure estimates and managing closure execution projects in North America, Australia, and Africa, and present a methodology to determine a closure cost allowance that can be included in the cost estimate.

This paper will be valuable to mining professionals involved in estimating the costs of mine closure and those setting aside the funding needed to deliver on mine closure plans.

Keywords: *mine closure costs; estimating; asset value creation; mine closure best practice; mine closure capital requirements*

1 Introduction

Successfully delivering closure and decommissioning programs requires a strategic and collaborative approach, a focus on the mine site itself, the expectations of the surrounding communities, socio-economic considerations, regulatory requirements, and strong commercial skills.

Planning for closure and its associated costs needs to commence from the early developmental stages of the mine itself and continue through final relinquishment of the site (Dunow 2022). Improved understanding of mine closure costs will empower the mining industry to enable a more sustainable transition to post-closure land uses that leave behind a sound and stable environment and self-sustaining communities.

Closure is not something that can wait until the end of the asset's life. Planning and pre-closure activities must be integral to the planning, design, construction, and operation of the asset.

As shown in Figure 1, planning for closure follows planning for the construction of the asset.

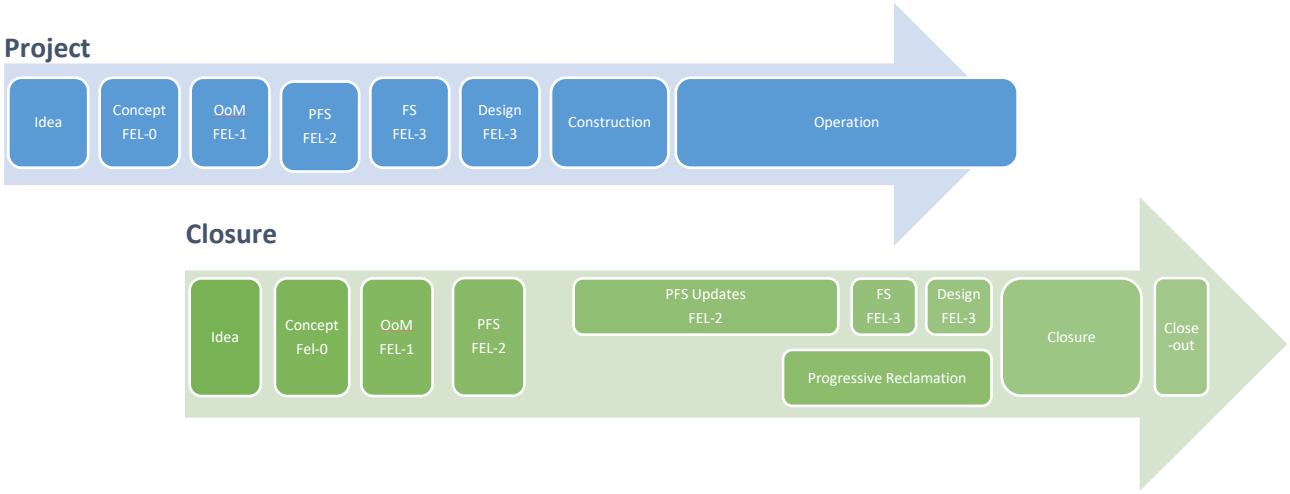

Figure 1 Closure planning phases aligned to project phases

As the asset moves into construction, the closure plan and estimate are updated to reflect any changes in the construction. Also, during the operations phase, the closure estimate is regularly updated (every five years is recommended) to reflect any site changes, including the progressive reclamation.

Failure to properly plan and execute the mine closure may have a significant impact on the mining company. Some of these impacts are:

- License to operate (inability to continue operations)
- Less capital for development or expansions
- Claims & disputes (contractors, community, regulator)
- Delayed revenue opportunities in re-purposed sites
- Increased bonding requirements
- Reputational damage
- Inability to meet sustainability and environmental, social and governance (ESG) requirements
- Increased indirect costs if insufficient cash available

2 The challenge in accurate closure estimating

As noted in the term, 'estimating' does not often give the exact amount of a certain activity. This is especially true in construction and closure cost estimating. Closure can be challenging to estimate correctly and there is considerable industry experience where the final estimate has differed considerably from estimated values. This potential variation is a risk for the mining company. (ICCM 2019)

As noted in our previous paper (Dunow 2022), closure estimates typically overrun the original prefeasibility estimate by between 50-100%. Challenges to accurately estimating mine closure costs include changes to the mine layout over time, execution methodologies, rapidly changing legislation, and managing the multiple disciplines involved in creating a tailored remedial solution that aligns with community and other stakeholder expectations. Further adding to complexity is the often remote location of the mine.

> *"Even with the best will in the world, accurately forecasting closure costs is extremely difficult; the best that might be expected is an approximation. The temptation could be to overestimate to ensure that there is no shortfall in fund, but this should not be done to the detriment of the financial viability of the project". The World Bank (2009)*

To make the process even more difficult, mine closure costs are an expense which will not result in revenue for the company. The pressure to minimize the costs can be intense and cause the estimator to be more optimistic than would otherwise be the case. In addition, closure "costs are mostly incurred at, or toward the end of the mine life and the view is thus often taken that these will be dealt with once closure approaches, or alternatively, the operation is sold in an attempt to divest responsibly for closure". (Nehring 2016)

The concern for miners is that poor closure estimates underestimate capital investment decisions and may lead to incomplete reporting of financial obligation (liability) resulting in impacts to their future license to operate. The following table (Table 1) shows cost changes from prefeasibility to execution stages of closure cost development for the entire closure process. As each mine site is unique, there is not an easily referenced metric to be used as a cost basis, but the primary information is the percent increase to the cost as the closure requirements are defined and the cost impacts estimated (Dunow 2022).

Table 1 Sample of cost changes through stage development for closure projects (millions)

Location	Commodity	Prefeasibility	Feasibility	Forecast/ Actual (Execution)	% Increase
Canada	Diamond	CAD 245	CAD 318	CAD 350	42.8
Canada	Diamond	CAD 185	CAD 206	CAD 289	56.2
United States	Copper	USD 985	USD 1,782	n/a	80.9
United States	Copper	USD 205	USD 260	USD 376	83.4
United States	Uranium	USD 106	USD 214	n/a	101.8
United States	Aluminium	-	USD 218	USD 260	19.2

Typically, prefeasibility and feasibility study estimates include the disturbance footprint and planned closure strategy, whereas the forecast/ actual (execution) estimates reflect the actual end of mine closure cost. Although not shown in the table and analysed as part of this paper, the timing between the pre-execution and execution phases of mine closure projects may play a part in cost overruns. This is challenging to calculate due to the many factors that influence an operator's decision to close the mine, and the ongoing closure cost updates.

The closure estimate affects many parts of the project: initial viability and business case, design considerations, construction decisions, operations methodology, and, of course, closure. If the full closure

costs are not understood and included, the initial business case for the project may be flawed. Designing and constructing for closure will allow early planning and closure cost updating throughout the course of the project. Operating with closure in mind will also minimize changes and allow for accurate cost updates over the life of mine. Use of progressive closure will also minimize overall closure costs and probability of overruns.

Accounting for all the parts that will make up the final closure costs is challenging and may (and often does) result in an understated closure estimate.

3 Preparing the closure estimate

3.1 What is needed?

What is necessary to determine an accurate closure estimate and schedule? Key to success and to understanding the true cost of closure is planning for closure early and regular re-baselining of the closure estimate throughout the study phases, detailed design, construction execution, and operation. A structured and consistent approach to closure planning will provide the best chance of success for all parties. To prepare an effective closure estimate, there are many variables to be considered.

- Scope - The most important variable in determining closure costs and schedule is a complete understanding of the scope. If the scope of decommissioning, demolition, and reclamation is not fully understood, it will be impossible to develop an accurate cost estimate or closure schedule.
- Regulator and stakeholder requirements – understanding what the various stakeholders will require is a key aspect of closure estimating, and one of the hardest to understand. Frequent and open communication with all parties is needed to understand what is expected.
- Timelines for closure activities and on-going monitoring – as we will describe later in this document, the timelines involved in closure play a significant role in the overall cost estimates.
- Project management expertise – using the proper strategy and team is critical in determining the overall cost. The execution plan, contracting strategy, and logistics plan all play an important role in the closure estimate.
- Availability of resources – as closure activities will likely happen years or even decades in the future, understanding the availability of construction resources is challenging.
- Bonds and insurance – over the life of mine governments, communities, and regulators may change financial requirements placed on the miner. These changes including any update to the cost of the bond or insurance should be incorporated into the closure estimate as soon as possible and tracked.
- Risks – over the course of construction and operation, the risk profile will likely change. These changes need to be recognized and incorporated into the overall closure estimate.

As mentioned earlier, this process starts at an early stage, with focus during the operational life of the mine, and must be continually updated and re-baselined as the mine develops and changes. Understanding these impacts, and using lessons learned to determine the best approach will help in controlling cost and schedule overruns.

3.2 Who should prepare?

A significant question in preparing the closure estimate refers to which party shall carry out the estimate. Because mining companies tend to underestimate to minimise costs (CSPP 2023), many regulators delegate closure estimate development to an independent third party or request an auditor to review the mine company’s calculation before granting the approval (van Zyl 2012). This approach increases the cost for the mining company, but provides assurance to the mining company itself, the community, regulators, and other stakeholders that the full cost of closure is understood.

Another related issue, sometimes overseen, is the need to prepare the estimate under the assumption that closure and reclamation will be conducted by a third party, which can result in higher costs for hiring contractors.

> *"Sometimes assumptions are conservative although often, however, assumptions are based on an optimism bias, in which case these assumptions really equate to risks if the assumptions do not come to fruition. It is therefore imperative that all underlying assumptions in a closure plan that can potentially have a material impact on outcomes and cost are identified and documented. However, the closure plan cannot simply just list and thereafter ignore them. The risks of the assumption not eventuating need to be assessed and incorporated into the closure risk register and possibly into a revision of the closure plan itself. Those risks will also need to be analysed and quantified in terms of the potential impact to closure costs." Byrne (2019)*

The use of an independent third party can help reduce the optimism bias as they typically have no vested interest in the outcome of the estimate, other than it being correct and fit for purpose.

4 Closure cost estimate components

A typical closure cost estimate should include the following components (ICCM):

- Direct costs (not all inclusive):
  - Decommissioning, decontamination, and demolition, and disposal of existing structures
  - Inventory, disassembly, and disposal or heavy equipment and other assets
  - Investigation, treatment or removal, and disposal of contaminated materials
  - Earthworks, including regrading, borrow development, cover, erosion controls
  - Rehabilitation, including topsoil replacement, tilling, disking, fertilizer, seeding, planting
  - Water management, surface (channels and/or/ponds), groundwater (wells), treatment plant
  - Underground mine access controls
  - Site access control and signage
  - Mobilization/demobilisation costs
- Indirects (not all inclusive):
  - Owner's team including project management, project controls, legal, human resources, community relations.
  - Procurement, contract management, and contract administration
  - Corporate level costs (insurance, technical, information technology)
  - Staff retrenchment
  - Costs associated with licenses, leases, and rights of way
  - Engineering, scientific, and other consultant costs
  - Site investigations to inform and assist in development of the closure designs
  - Construction management
  - Health & safety
  - Quality assurance and quality control
  - Site facilities

  - Site services (water, power, access, fuel, camp, etc.)
  - Contractor/EPCM overheads and profits
  - Permitting
  - Contingency
  - Escalation
  - Management reserves
- Closure specific items:
  - Regulator and stakeholder obligations and commitments
  - Socioeconomic programs
  - Company obligations to manage the site for the entire period
  - Operational costs for long term care & maintenance
  - Environmental monitoring and reporting
  - Post closure monitoring and maintenance
  - Post closure site security
  - Management of future or long-term activities related to residual risks.
  - Power, water, fuel, and supplies for post-closure activities
  - Ongoing safety inspections and reviews (tailings facilities, open pits).

Cost estimators are typically good at including the direct and indirect items in the estimate. However, the closure specific costs are often omitted or underestimated due to a lack of experience with closure estimating or lack of clarity on the requirements. “This lack of clarity in expectations regarding cost growth can lead to communication confusion later. Key stakeholders often remember or see the recorded input cost numbers used in studies and this can lead to anchoring bias on their part, i.e., stakeholders may unreasonably resist later estimates that differ from the original number”. (Hollmann 2022).

5 The use of allowances in estimating

An allowance is a percentage or lump sum added to the cost estimate to account for costs that are certain to occur but cannot be identified with any accuracy. In general cost estimating, two types of growth allowances are used: design growth and quantity/price growth. During the development of a cost estimate, the cost estimator will assess if cost allowances are required to be included. Whenever a cost is identified as required but cannot be determined, an allowance should be included in the cost estimate.

Design growth refers to the development of the design through the various phases. Examples of design growth are routing of piping, cable sizes, and footing dimensions. Examples of closure related design growth include modifications to assets, not recorded within the asset management system. Design growth does not include any additional scope outside of that identified in the design criteria. The engineer should specify the design allowance and communicate that with the estimator. The allowances should include all costs: material, labour, equipment, indirect costs, overhead and profit. The estimator’s role is to include them in the cost estimate as specified.

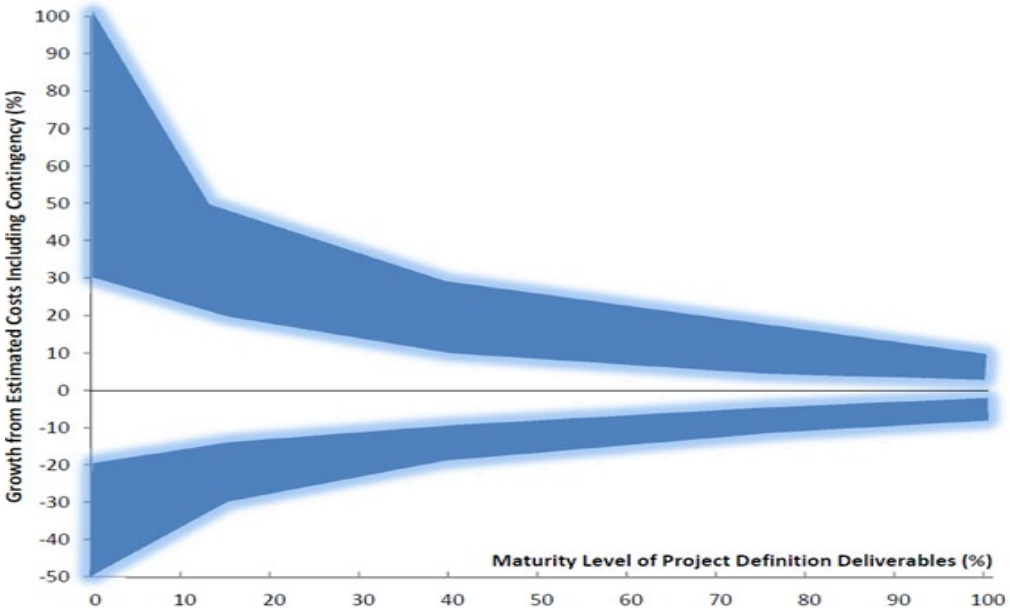

Figure 2 Maturity Level of Project Definition Deliverables % (AACE)

As an estimate is just that, an estimate, there are inherent uncertainties in the quantities and unit costs that make up the estimate. The quantity/price growth allowance accounts for this uncertainty by adding percentage to the estimated costs. The quantity/price growth refers to the accuracy of the information included in development of the estimate, specifically around quantities and unit rates.

The allowance typically varies by trade or commodity but is ultimately determined by the estimator and their experience.

Figure 2 above shows how the cost growth is related to level of design maturity. As the design progresses, the costs become more accurate as the number of potential changes decrease. The estimator uses this relationship to determine an appropriate growth allowance. The cost for a particular component of an estimate is determined by:

$$\text{Total cost} = \text{Quantity} \times \text{unit cost} \quad (1)$$

Where:

$$\text{unit cost} = \text{labour} + \text{construction equipment} + \text{materials}$$

The reasons why some costs cannot be determined can vary: no reliable data source available, not enough time to perform a detailed cost estimate, production rates not validated, construction methodology and schedule not certain, etc. The key point is that any scope of work that is covered by an allowance represents a risk to the contractor. It is advisable to keep allowances to a minimum to reduce the risk of project overruns. (Dobre 2016).

Many major mining companies have set guidelines for growth allowances based on their experiences with multiple capital projects over many years and many regions. As such, these allowances work well for most capital construction projects, but do not account for the peculiarities of closure projects.

6 Addition of a separate allowance for closure project

As noted in section 4, there are several components to make up the closure estimate. Many of these components differ from those in typical mining projects and are therefore not considered (or under-considered) in growth allowances mentioned in section 4. Cost estimators are typically good at including the direct and indirect items in the estimate. However, the closure specific costs are often omitted or underestimated due to a lack of experience with closure estimating or lack of clarity on the requirements.

Over the past ten years working on mine closure projects, we have identified three primary categories of overrun specific to mine closure.

1. Unknown scope - This item is especially critical for mines that have been in operation for a long time or on legacy sites. Engineers and estimators do their due diligence to identify and price, but there are often items that are hidden, buried, or otherwise unknown. These work items are not quantified (or even discovered) until work has commenced.
2. Regulator/stakeholder requirements – throughout time people and regulation change. These changes may impact the expectation and requirements that are imposed on the miner at the time of closure. Even if the mine is closed within regulations, if expectations are not met it may impact their long-term license to operate.
3. Long term costs – the final item is the long-term costs of closure. Obvious scope items such as demolition and reclamation are relatively easy to quantify. However, the scope related to long term monitoring and maintenance is more difficult. This may be as simple as areas requiring re-seeding due to poor germination to more difficult items such as changes in groundwater regulations requiring additional monitoring and/or treatment.

For each of these items, we have identified an initial growth allowance ranging that can be used during the development of the estimate. These results are shown in Table 2.

Table 2 Proposed closure growth allowances by item

Description	Concept	Order of Magnitude	Pre-Feasibility Study	Feasibility Study
Unknown scope	20%	15%	10%	5%
Regulator/stakeholder requirements				
Significant community/indigenous relations	10%	8%	5%	3%
Limited community/indigenous relations	8%	5%	3%	2%
Long-term monitoring				
Less than 25 years	5%	3%	2%	
25-100 years	8%	5%	3%	2%
More than 100 years	10%	8%	5%	3%

7 Conclusion

The sample size used for this paper includes three of the project listed in Table 1. Additional study will be needed to finalize an approach that is statistically sound.

According to Parshley and Bauman, “now that the issue of closure cost estimates has made it to the corporate boardroom, the availability of resources and need to standardise estimating methods is likely to push closure cost estimating technology forward faster than any time in the past 30 years. (2009)

Accounting for all components that will make up the final closure costs is challenging and may (and often does) result in an understated closure estimate. The use of a closure-specific allowance will make accounting for the undefined and changing portions of the closure costs easier and result in more accurate closure estimates.

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