Mine Closure 2023 - Behrooz Abbasi, Jeff Parshley, Andy Fourie & Mark Tibbett (eds)

doi:10.36487/ACG_repo/2315_099

Meaningful evaluation of rehabilitation and closure in the early stages of the mine life cycle

C Tomlin *ERM, Australia*

C Gimber *ERM, Australia*

Abstract

Historically, key closure risks have been studied during operations and then further assessed as cessation of mining approaches. Only in the past couple of decades or so has progressive rehabilitation and closure become an integral part of regulatory frameworks, sustainable mine planning and more recently, new project and development planning.

It is now broadly accepted that the best closure outcomes occur when rehabilitation and closure are properly considered up-front, during the early stages of a mine development project and well before mining occurs. Increasingly, regulatory processes are requiring more diligence on closure planning early in the environmental impact assessment (EIA) and approvals process, rather than later during dedicated closure study phases. There is an opportunity to use the information generated during this phase to make better decisions on project selection, design, mining methodology and all other facets of the mining operation.

Incorporation of rehabilitation and closure risks and criteria in early project feasibility and planning phases can improve decision-making in order to reduce whole-of-life costs and maximise Environmental, Social and Governance (ESG) benefits. Whilst typically option assessments and Multi-Criteria Analyses (MCAs) touch on high-level closure considerations, mining options and mine design development are rarely based on future, detailed progressive rehabilitation and closure requirements. Furthermore, preliminary costings for these activities are often largely underestimated.

Implementing meaningful closure considerations in the options selection process can lead to many benefits that may result in a change to the project design (including location of infrastructure and activities), construction methodology, complexity of approvals pathway/processes and operational procedures. This paper explores ways in which rehabilitation activities and closure options and costs should be considered in upfront project planning and decision-making processes to minimise long-term costs and residual liability.

Keywords: *progressive rehabilitation, closure, closure costs, project selection, option selection, MCA, project design, ESG, planning opportunities*

1 Introduction

There is increasing awareness in the mining sector that planning for mine closure in the early project planning and development phases leads to better outcomes. There is strong focus on mitigation and/or minimisation of environmental and socio-economic impacts, as well as promotion of sustainable mining and post-mining land use and practices. The renewed focus on rehabilitation and closure is partly due to more stringent guidelines, regulations and expectations held by stakeholders and regulators, but also driven by organisations with commitments to impeccable ESG and corporate social responsibility. Furthermore, there has been an increasing number of mines that are reaching their end of life, and a considerable number of legacy sites left behind, spotlighting rehabilitation and closure issues and the requirements for pro-active management and planning well in advance of the end of the life of the mine.

This includes thought and planning around progressive rehabilitation and revegetation; availability and sourcing of suitable capping materials for cover design; erosion and long-term stability of final landforms; water management (surface water runoff, flooding, seepage to groundwater); socio-economic impacts; and availability of resources and capital for closure and post-closure activities, including monitoring and maintenance.

Whilst conceptual planning for rehabilitation and closure generally occurs at the commencement of a mining operation and is a key part of operational procedures and plans, the level of detail known at the early stages of a mine or project poses limitations to undertaking a comprehensive evaluation of closure risks or foreseeing future closure issues.

Typically, preliminary closure studies and risk assessments commence 15-10 years out from closure, and ideally, dedicated closure studies are undertaken within 10 years of cessation of mining. In practice however, this is often not the case, with many closure studies and investigations only advancing within 5-2 years of site closure, leaving little room for changes to the mine plan, resulting in missed opportunities for progressive rehabilitation and presenting a series of challenges for closure execution.

Incorporation of rehabilitation and closure risks and criteria in early project concept, feasibility and planning phases can improve decision-making by reducing whole-of-life costs and maximising ESG benefits.

2 Barriers to incorporating closure in option selection

There are a number of aspects that make incorporating closure considerations in early stage option selection difficult. These include level of understanding, inadequate processes / frameworks in place, optimism, bias, timeframe and funding as illustrated in Figure 1 and outlined in Section 2.

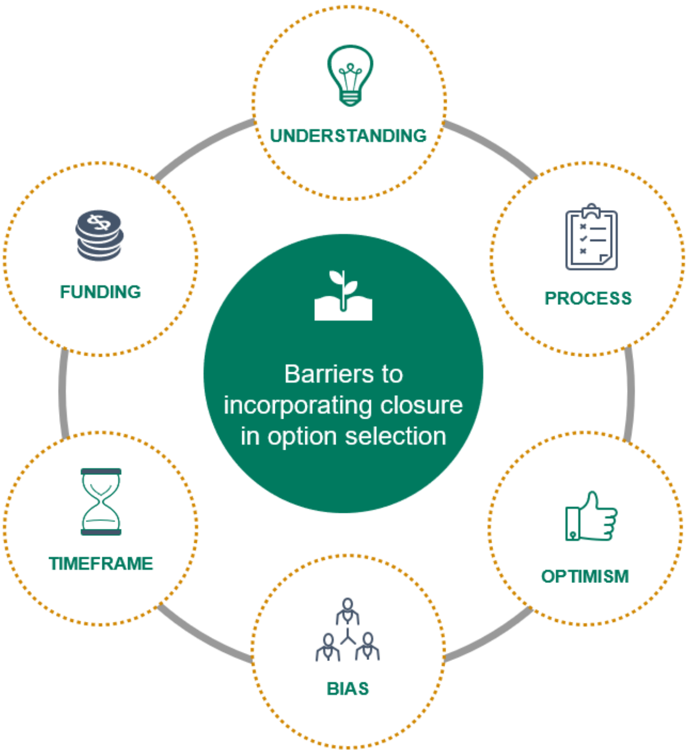

Figure 1 Barriers to early closure planning

2.1 Understanding

The level of information available on a project is in its infancy at the beginning, and gradually matures throughout its development and operation. Often the true risks related to closure are not well understood, quantified or may not even have emerged (e.g. community sentiment) at the early stages of project planning.

This makes it difficult to develop a rehabilitation and closure strategy/ plan tailored to the specific challenges of the site, as well as predict closure outcomes and success.

Furthermore, a lack of forethought around post-mining land use and clarity around the closure vision for the site can lead to the absence of guidance around progressive rehabilitation and closure activities during operations. For this, coordination and planning between various stakeholders including mining companies, neighbouring operations, local communities and government agencies is essential in the early mine or project planning phases, identifying potential cumulative issues but also giving rise to opportunities for collaboration and regional planning.

2.2 Process

Most organisations have well developed processes for making decisions and selecting projects (or project components) to be carried forward into various stages and further development. However, these processes often do not give sufficient weight to the closure-related aspects of a project. Closure is often given a cursory glance, rather than a detailed review that truly affects project selection.

Additionally, within a regulatory context, a detailed closure planning process is often considered a requirement towards the end of the project / mine life and not an upfront requirement prior to project selection, impact assessment and approval. Often at impact assessment phase, onerous conditions are accepted to get an approval and at a later stage, are renegotiated to be more appropriate and representative of planned mining activities.

Lack of clear regulations governing early assessment of closure and closure options can leave operators with a great deal of discretion and result in missed opportunities and poor outcomes.

2.3 Optimism

Before mining occurs, the project team envisages how the operation will develop and how the project will unfold, often incorporating best practice features with good intention, such as encapsulation of Potentially Acid Forming (PAF) materials, for example. Assumptions are also made that operations will run according to plan – waste will be properly characterised; sent to the correct location; paddock dumped and traffic compacted; and a suitable cover will be available and constructed. There are many aspects that can go wrong, but before the project starts there is a tendency to assume everything will run along the ideal path and schedule.

Closure is a complex process and requires careful thought, planning and execution, as well as the ability to adapt and be flexible to ever-changing operational, environmental and socio-economic circumstances.

2.4 Bias

At the project selection phase many of the stakeholders are motivated, either consciously or subconsciously, to get the project off the ground. Focus is usually on developing a financially viable project often with short term objectives in mind and looking to reduce the payback period of the capital and operational expenditure. This can come at the expense of long-term, whole-of-life cost analysis.

Moreover, the perception around closure and consideration of closure prior to project commencement or mining, could be viewed as controversial and may not generate the support required early on. There can be a negative connotation associated with mine closure, including potential environmental harm and legacy that is left behind, agreement on post-mining land use and regional planning vision, and socio-economic impacts including job loss and economic disruption.

2.5 Timeframe

Closure issues manifest themselves over the life of the operation and may change accordingly. They often will not appear until later in the mine life cycle, or even after mining has ceased. For many projects or developments, the problems are unlikely to be managed by the people making the early decisions around project selection and design, and this can lead to reduced incentive, responsibility and ownership from the project and execution teams.

Furthermore, staff turnover and loss of corporate and site knowledge over time can lead to inconsistencies in rehabilitation and closure approaches and methodologies, which may result in inefficient and unsuccessful planning and practices.

2.6 Funding

Rehabilitation, closure and post-closure activities including long-term maintenance and monitoring can be costly, with many mining companies reluctant to commit focus and funding to these activities until such time the mine or project can be deemed profitable. To this end, closure planning may not be assigned a priority and funds may not be set aside upfront as required. Additionally, preliminary costings associated with rehabilitation and closure are often largely underestimated.

3 Embedding closure in project design and option selection

The best way to overcome closure planning barriers is to be conscious of them at the project options and selection phase. The biases, timeframe, knowledge gaps and uncertainties will always be present, but with the correct processes in place and specialists with experience across these disciplines, it is possible to properly embed closure into the decision-making process. This can be achieved by:

- Learning from the past – not repeating mistakes, early research and consultation, improving historical practices, sharing successes and failures (between sites, industry and communities) and understanding regional planning constraints and opportunities.
- Building a comprehensive knowledge base – dedicating time, money and effort to conducting early site investigations and studies to understand knowledge gaps and key technical risks, thereby informing practical closure options associated with each project option being evaluated.
- Assembling the right teams – having a dedicated mine closure working group or committee comprising truly multidisciplinary teams involved in decision making upfront. This should include representation by technical specialists in community and social performance, closure design and execution, environmental management, a range of engineering disciplines, site-based teams (where applicable), schedulers and cost control.
- Costing – considering costs over the full life cycle of an operation and undertaking a detailed closure cost estimation early on, to be regularly reviewed and contemporised to remain current.
- Having the right processes and tools in place – making sure that development teams follow a consistent and clear process. The selection process should not bias any particular outcome. One of the main tools used in option assessments and subsequent selection of a preferred project option, are Multi-Criteria Analyses (MCAs).

3.1 Options assessment tools and opportunities for incorporation of closure considerations and criteria

MCAs provide a systematic approach and methodology to assess and evaluate a number of different project options based on a suite of financial and non-financial measures, enabling informed decision-making to select a preferred project option. The versatility and use of MCAs can provide many benefits to the project planning process, including:

- Transparency – a process whereby stakeholders can provide input, feedback and reasoning for their option selection.
- Objectivity – collaboration between a number of subject matter and content experts with a different focus area or lens, as well as varying ideas around weighting criteria.
- Efficiency – streamlined decision-making considering all aspects relevant to the project in one process or place.
- Value– thought leadership and presentation of any trade-off studies that may lead to improved project outcomes.

MCA processes have been successfully utilised for decades, customised to be project specific and fit-for-purpose. There is no right or wrong way to conduct an MCA, and it is not suggested to re-invent the wheel by reviewing or changing these processes, particularly ones that are already well established within an organisation. Rather, consideration should be given as to how these existing decision-making tools can be augmented to properly capture closure considerations when selecting options. This should be informed by properly informed closure studies to feed into the project planning process, rather than after an option has been selected and constructed.

There are a number of MCA methods in use by the mining industry. Most of them can be readily customised to include closure considerations as part of the criteria, although some methods are better suited than others. Some of the more common MCA methods include:

- Analytical Hierarchy Process (AHP) - AHP is one of the more broadly used and applied MCA methods, which orders complex decision problems into a hierarchal model based on importance and scale of preference (Saaty 2008). Some of the benefits of utilising the AHP method include a more structured decision-making approach which quantifies relative importance of criteria and alternatives, using pairwise comparison. This involves comparing two elements of a set, outlining the importance of one element over another. Pairwise comparisons are then quantified by applying a scale of preference relating to importance and developing a hierarchy consisting of goals, criteria and alternatives. Although AHP is a useful decision-making tool, it is a complex and time-consuming method and hierarchical structures can be difficult to conceptualise. Furthermore, pairwise comparisons rely heavily on large data sets and can inherently create human bias and subjectivity, which could result in inconsistencies in the process.
- Preference Ranking Organisation Method for Enrichment Evaluation (PROMETHEE) – PROMETHEE is an MCA used to rank alternatives based on a selected number of criteria. Application of PROMETHEE has been used to improve a framework for assessing remedial options at a mine site in British Columbia, Canada (Betrie et al. (2013)). Results indicated that the method provided a reliable way of selecting multiple alternatives by quantifying the impact on different criteria. However, the method can be computationally intensive, requiring a large number of preference values and alternatives and therefore expertise is required to use effectively.
- Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) – The TOPSIS method can be used to help decision-makers choose a best alternative using ideal and anti-ideal solutions i.e. determining the alternative that has the shortest distance from the ideal solution and farthest distance from the negative solution (Opricović et al. 2004). The TOPSIS process follows a typical MCA process in terms of identifying decision criteria and alternatives, and associated weighting and performance scores. However, the tool is sensitive to weighting and does not take into account interactions between criteria or imprecise data.

- Weighted Sum Model (WSM) - The WSM is a more simplified MCA method, assigning weight to criteria and adding the weighted scores of each alternative to obtain an overall score, with the highest scoring alternative considered the preferred option (Saaty, T. L. (1980)). Although easy to use and implement, the WSM has limitations around interactions between criteria and sensitivity around criteria weighting, therefore may only be suitable for simple closure options or applications.
- Strengths, Weaknesses, Opportunities, Threats (SWOT) Analysis – SWOT is an easy to use and simple qualitative MCA tool, which involves the development of a SWOT matrix, with alternatives scored and decisions ranked based on highest to lowest scores to determine a preferred option. Although ideal for assessment of closure criteria that is fairly descriptive, quantitative data (including closure cost estimations) can be difficult to interpret and incorporate into SWOT Analyses.

Cost is always an important consideration at the option selection phase. If the true cost of closure is understood, bearing in mind all of the barriers identified in Section 2 which can make this difficult, then this cost will have a significant bearing on the preferred option. Cost can be included directly in an MCA as a selection criterion or more commonly, it is excluded from the criteria until the final stage. At the completion of the MCA it is possible to calculate a Value For Money (VFM) score (i.e. MCA score / Cost), with the option having the highest VFM score being the preferred option. The cost is best calculated on an undiscounted basis, and should include allowances for uncertainty and risk.

3.2 Closure considerations in decision-making tools

Closure is a category typically considered in the risk breakdown and evaluation structure of a decision-making tool, however the details and criteria behind the category can be vague, particularly within early stages of project concept and design. It is common to see ranking of closure risks and opportunities based on a very conceptual understanding of closure, without any technical support, studies or validation to adequately inform these rankings.

To gain a true understanding of the closure threats and opportunities of each project option, thought should be applied to expanding and clearly defining the criteria informing the closure category. This could include, for example, details around the whole-of-site closure vision, final landform, post-mining land use and regional planning, sensitive receptors, air quality, land tenure and ownership, groundwater and surface water, biodiversity, cultural heritage, socio-economic impacts, legal obligations, financial liabilities, schedule, progressive rehabilitation and performance targets/ indicators. These aspects should be considered in conjunction with the environmental and social context, values and objectives of the project and broader site.

Once rehabilitation and closure criteria are well-defined and established, there is a need to assess each project option against these criteria, assigning consequence, management measures/ detailed actions and control effectiveness to achieve the criteria. Careful consideration should also be given to the weighting of closure against other criteria with and without cost, to ensure outcomes are not skewed.

During the assessment, design and decision-making process, project teams should be asking questions like:

- Has the project location considered proximity to sensitive receptors (environmental, social and cultural heritage) that may be impacted during construction and operations, as well as during closure and post-closure (i.e. potential nuisance dust, visual amenity)?
- Will any of the options result in differentiating rehabilitation outcomes (i.e. slope angle or length that may influence the ability of vegetation to establish on embankments)?
- Will a liner or additional seepage control measures be required?
- Will the surface be free-draining?

- Has the project considered probable maximum floods (PMFs) or predictive climate change at closure and post-closure?
- Has a materials balance, characterisation or topsoil inventory been completed for each design option and will there be sufficient, suitable materials available not only for erosion stability, progressive rehabilitation and reshaping of the final landform, but also for the construction of a cover system?
- Will the Post-Mining Land Use (PMLU) be achieved by the final landform of each option considered and is the closure vision proposed in line with the existing site-wide closure objectives and vision?
- Are there opportunities during construction to strip and stockpile topsoil resources or use cleared vegetation as mulch for progressive rehabilitation purposes?

These are just a few of the potential rehabilitation and closure considerations that should be thought about when planning new developments and selecting options. Furthermore, upfront development of detailed rehabilitation prescriptions and closure completion criteria can also reduce uncertainty with Regulator's acceptance of project approvals and minimise delays to final relinquishment.

Additionally, determining detailed costs of the identified rehabilitation and closure activities and building these costs into CapEx and OpEx allocations is essential. For example, having an in-depth understanding of material deficits on-site based on the project design and life-of-mine plan, as well as an understanding of volumes required for progressive rehabilitation and final capping, allows for early planning and investigations into the cost of sourcing materials, and may lead to a re-focus of effort looking further into alternative available materials or opportunities to rehandle materials during operations compared to the cost of importing materials to site.

4 Conclusion

Implementing meaningful rehabilitation and closure considerations in the options selection process can lead to many benefits that may result in a change to the project design (including location of infrastructure and activities), mining and construction methodology, complexity of an approvals pathway/process, and operational procedures.

There are various options assessment and decision-making tools available to assist with guiding these processes. Early incorporation of detailed rehabilitation and closure challenges and opportunities into these tools and a revision of closure category weighting may influence project design, options considered, and selection of a preferred option. It is fundamental that these approaches are developed early on to ensure closure-related risks and opportunities are captured when designing a project, which is the time where there is the best opportunity to influence closure outcomes.

References

Betrie, G.D, Sadiq, R, Morin, K.A, Tesfamariam, S 2013, *Selection of remedial alternatives for mine sites: A multicriteria decision analysis approach*, Journal of Environmental Management, Volume 119.

Opricović, S, Tzeng, G.H 2004, *Compromise Solution by MCDM Methods: A Comparative Analysis of VIKOR and TOPSIS*, European Journal of Operational Research.

Saaty, T.L 1980, *The analytic hierarchy process*, New York: McGraw-Hill.

Saaty, T.L 2008, *Decision Making with the Analytic Hierarchy Process*, International Journal of Services Sciences.