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From theory to practice: a contractor's guide for operators to de-risking mine closure

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Abstract

Mine closure is frequently subject to higher cost and greater delivery risks than originally anticipated. This paper translates mine closure theory into practical guidance, drawing on a contractor's firsthand experience to help operators better prepare for closure-ready handover states, understand the true cost of closure, and ultimately de-risk closure programs.

A key focus is understanding what is required at handover to enable efficient, compliant and low risk closure execution. This paper explores the benefits of early contractor involvement (ECI) and uses practical scenarios to demonstrate how early engagement of delivery specialists during closure planning can improve schedule certainty and reduce overall cost. These scenarios illustrate how early engagement enables critical considerations such as Traditional Owner consultation, local and national regulatory requirements, and the selection of optimal decommissioning methodologies, to be addressed well before final operations cease.

The paper also examines why hazardous and legacy waste is consistently underestimated in mine closure programs. It outlines common drivers, including incomplete historic and legacy documentation and insufficient sampling and testing, while providing guidance on how operators can better anticipate and quantify hazardous materials through optimised assessment and planning.

Alignment between operators, consultants and contractors is another critical theme. Clearly defined objectives, shared assumptions and coordinated scopes of work enable all parties to 'sing from the same song sheet', improving program efficiency and certainty of outcome.

Ultimately, this paper provides operators with a practical, experience-driven guide to mine closure, moving beyond theory to address what is truly required to close a mine safely, and efficiently.

Ultimately, this paper provides an experience-based, practical guide to mine closure, focusing on the key mitigation strategies and opportunities to deliver safe, compliant, and cost-effective closure projects.

Keywords: *mine closure, early contractor involvement, risk management, stakeholder management, cost reduction, program optimisation.*

1 Introduction

Mine closure is highly complex and closure liabilities associated with decommissioning, deconstruction and remediation of large-scale mining infrastructure routinely extend decades beyond cessation of operations. Industry guidance has evolved to recognise mine closure should be addressed during the life of mine phase, as an integration with mine design, operational decision-making and progressive closure (International Council on Mining and Metals [ICMM] 2019; Department of Industry, Science, Energy and Resources 2016).

Despite this recommendation, deconstruction and demolition engineering is still introduced late in the life of mine (LOM), typically at or near execution. This diminishes opportunities to optimise cost and scheduling and reduce risk. As a result, closure cost estimates based on high-level benchmarking frequently understate

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true liabilities, most commonly when safety, environmental and regulatory risks remain unvalidated until late in the closure process.

Cost estimations have also not consistently accounted for the full scope of closure challenges. Common oversights can include the degraded or altered state of the assets, the presence and volume of hazardous materials, remote logistics, regulatory approval considerations, waste management, and local and Indigenous engagement.

This paper highlights an opportunity for technically capable demolition contractors to be embedded within mine closure planning from early stages, as strategic contributors to closure planning, risk identification, safety assurance and optimised financial provisioning and working alongside the right consultants at the right stage.

Drawing on Liberty Industrial's experience across more than 40 mining and heavy industrial closure projects in Australia and internationally, the paper presents a practical framework for integrating deconstruction engineering into mine closure planning through early contractor involvement (ECI), front-end engineering design (FEED), advanced structural simulation using the applied element method (AEM), and risk-based demolition methodologies for the best safety outcomes. The framework demonstrates that early engagement delivers materially improved closure cost certainty, enhanced physical and chemical stability outcomes, and reduced critical-path risk compared with conventional late-engagement approaches.

2 Early contractor involvement

The strategic value of ECI has been demonstrated consistently across large infrastructure, and industrial projects, where early engagement of technically capable contractors improves constructability, enables innovation, and materially increases cost and schedule certainty (Infrastructure Australia 2016). These benefits are easily translated for demolition and deconstruction scopes, where methodology selection, safety controls and regulatory pathways fundamentally impact project outcomes. In this context, the value of ECI lies in engaging a technically sophisticated demolition contractor early, enabling the closure pathway to be re-engineered from the outset and allowing the safest and most cost-effective approach to be identified before fixed decisions foreclose alternative options.

Conventional demolition cost estimation – typically applied through area-rate benchmarks at a corporate level – consistently produces inaccurate closure liability figures. These estimates fail to account for structural complexity, hazardous-material content, remote and logistically challenging site environments, regulatory approval timelines, and the full-cost implications of methodological choices that must be established early to remain effective. They rarely capture the cost of safety management systems, specialist engineering approvals, or the opportunity value of integrating demolition with progressive rehabilitation scheduling. The result is a closure liability that is materially understated, a financial provision that is insufficient, and a demolition program that enters execution without the technical foundation required for efficient delivery.

Liberty Industrial delivers ECI-model engagements through FEED studies and pre-feasibility studies, that integrate directly with mine closure plan frameworks and IFRS-compliant financial provisioning. These studies incorporate: drone-assisted 3D mapping and LiDAR scanning to generate a quantified asset register; detailed asbestos audit and hazardous-material inventory forming the basis of regulatory management plans; structural condition assessment informing preliminary methodology selection; waste inventory analysis incorporating scrap steel recovery value as cost offsets; and full-cost modelling of the demolition program across all safety systems, regulatory pathways, and site-specific logistics – producing a fully loaded closure cost rather than a construction-rate estimate.

These studies also identify structural design decisions during ongoing operations that will materially affect future demolition complexity and cost, enabling design-for-demolition principles to be applied while modification remains practicable. Mitigation strategies might include progressive demolition, or alternative demolition methodologies.

Early identification of high-risk demolition events requiring specialist methodologies – explosive or induced collapse demolition – provides adequate lead time for engineering development, independent third-party review, and regulatory approval, which may extend to twelve months or more for complex events. This eliminates critical-path risk at execution. Material recovery and recycling value – aligned with the circular economy–driven, integrative approach to mining waste management (Tayebi-Khorami et al. 2019) – when embedded in early LOM planning, can materially reduce net closure costs and produce more accurate closure provisioning than traditional late-stage estimates.

Integration of demolition scheduling with progressive rehabilitation enables cleared areas to advance toward revegetation while adjacent demolition continues, reducing total closure duration and the holding costs associated with areas awaiting final regulatory sign-off.

Successful transitioning to a demolition project requires alignment between the agreed methodologies, assumptions and sequencing into a coherent, executable program. Equally important is the continuation of a collaborative approach with asset owners, operators, contractors, subcontractors and consultants. Coordination between the contractor and specialist disciplines, such as environmental hygienist, electrical and waste services, can improve documentation, data and controls and eliminate duplication or misalignment between scopes. This collaborative refinement ensures the project is delivered to the right decommissioning requirements, while reducing the likelihood of disruption, rework or delay once physical works commence.

3 Structural simulation: applied element method

Advanced structural simulation provides a critical technical basis for physical stability assurance during deconstruction of complex, deteriorated industrial assets. The AEM, implemented through extreme loading for structures (ELS) software, uniquely captures progressive cracking, element separation, collision and debris interaction beyond the elastic range, enabling realistic prediction of collapse behaviour under demolition and extreme loading scenarios (ASI 2024). Independent comparative studies in structural engineering literature confirm that continuum-based Finite element method approaches are not capable of reliably simulating collapse progression or debris fields in post-elastic regimes (Ellingwood et al. 2006).

Access to AEM-based simulation during early closure planning allows multiple demolition scenarios to be evaluated digitally before physical execution, providing a defensible engineering basis for exclusion zone definition, third-party certification and regulatory engagement. Importantly, early simulation can demonstrate the viability of high-reach mechanical or induced collapse methodologies, eliminating the need for explosive demolition and avoiding lengthy approval timelines that would otherwise constrain execution schedules.

Integrated use of advanced structural simulation, risk-based methodology selection and first-principles cost modelling provides closure outcomes that are safer, more predictable and more economically efficient than conventional late-engagement approaches.

4 Hazardous-material identification and management

Early identification and removal of hazardous materials, including asbestos-containing materials (ACM), hydrocarbons and contaminated process residues, prior to demolition is consistent with good international industry practice and recognised health and safety guidance (Safe Work Australia 2023). Intrusive hazardous materials surveys, or HAZMAT surveys, when complemented by onsite Environmental Hygienists, can improve accuracy and ultimately provide more upfront and transparent cost and schedule models, while reducing risks associated with unknown volumes or contaminant classifications. Further complexity arises from evolving environmental and chemical regulations. Substances previously considered acceptable under international best practice may be reclassified or restricted within short timeframes, materially altering handling, treatment and disposal requirements. These dynamics reinforce the need for early, site-specific hazardous-material assessment and strategy development rather than reliance on legacy assumptions.

Common mistakes that lead to cost blow out happen when assumptions are carried forward from past reports that are not necessarily accurate or the state of the assets have changed or deteriorated. Regulatory approval processes also vary by jurisdiction, with delays of several months not uncommon if hazardous-material management intersects with issues such as fuelling infrastructure, construction-water access, public-road use for waste transport, or landfill acceptance criteria. Through a collaborative approach with asset owner or operator, contractors, subcontractors and Environmental Hygienists onsite, data and control measures can be properly identified and tested for more accurate costing, scheduling and risk mitigation strategies. This step in refinement ensures the project meets decommissioning requirements, while reducing the likelihood of disruption, rework or delay once physical works commence.

5 Circular economy and material recovery opportunities

Mine closure frameworks that embed material recovery and recycling strategies in early planning can improve alignment between demolition activities with circular economy goals (Tayebi-Khorami et al. 2019). The early quantification of recoverable steel, non-ferrous metals and reusable infrastructure improves net-cost modelling and prevents the loss of rebate value.

When planning is done at the early stage, mining companies can benefit from more competitive scrap purchasing options, as well as maximised recovery value by identifying additional recycling pathways for less common materials. This integrated approach supports more accurate closure provisioning and can materially reduce net closure costs.

6 Hazardous waste characterisation, treatment and disposal

Effective management of hazardous and contaminated waste streams is critically dependent on early, detailed characterisation of waste streams and the integration of waste strategy into the project. Where possible, collaboration between a waste consultant and an executing demolition contractor's in-house environmental engineer allows focused investigation of site-specific waste streams, including their composition, regulatory classification and variability across assets and operational history. This technical interrogation enables informed identification of viable treatment, re-use or disposal pathways, rather than defaulting to conservative assumptions that inflate cost and program risk.

Targeted trials and investigative works such as sampling, treatability testing and pilot processing, can generate the empirical data required to support preferred waste management methodologies and to accurately quantify the cost of implementation. Waste classification outcomes directly dictate handling and transport requirements, as well as the criteria for licensed offsite facilities capable of accepting the material. In many cases in mining's remote locations, offsite disposal options involve long distances and limited facility availability, rendering such pathways prohibitively expensive and increasing schedule risk. Understanding the site-specific constraints allows time to address the challenges such as onsite treatment or re-use options where wastes can be rendered safe and compliant with regulatory requirements.

Where onsite treatment or re-use appears technically feasible, early engagement with regulators is required to establish approval pathways and evidentiary thresholds. Integrating these discussions at the ECI stage ensures that regulatory approvals, validation testing and operational controls are sequenced well ahead of execution. Proactive management of hazardous waste streams in this manner materially reduces the risk of unexpected classification outcomes, approval delays or disposal bottlenecks interrupting demolition and rehabilitation works once project delivery has commenced. Early definition of waste strategy therefore functions not only as a cost-control measure, but as a critical safeguard against closure schedule disruption.

A case study in ICMM for BHP Iron Ore found a pre-feasibility study on the level mine layouts and schedules and a feasibility study (prior to mine execution) resulted in the following benefits to their waste program; 50% land disturbance reduction, reduced waste landfill deposits and reduced haulage road requirements developed in a manner that will reduce rework, optimise fleet utilisation and reduce capital expenditure. (ICMM 2019).

7 Early engagement with local and Indigenous communities

Early engagement with local and Indigenous communities is a critical path to many successful mine closure projects. Industry research consistently demonstrates that plans developed without early and ongoing Indigenous participation are more likely to encounter cultural-heritage constraints, social opposition and challenges achieving relinquishment or post-closure land use acceptance (ICMM 2025). Early engagement can provide clear identification of culturally sensitive areas, heritage exclusion zones, preferred access routes, and opportunities to stage works to minimise disturbance.

Successful engagement with local and Indigenous communities requires early and regular consultation, to ensure initiatives are geared towards relevant and sustainable long-term socio-economic outcomes. Importantly, early-stage engagement enables planning for meaningful Indigenous participation in closure activities, through workforce involvement, local procurement or environmental services, rather than attempting to retrofit participation during execution, when scope and schedules are already constrained (CRC TiME 2025).

8 Regulatory compliance and optimisation

The nature of the demolition industry involves varying risk and tightly regulated execution protocols. Early regulator engagement allows proposed demolition methodologies, hazardous-material strategies and structural stability assumptions to be tested and refined before approvals are required, reducing the likelihood of late-stage objections, approval delays or conservative redesign imposed under time pressure.

Industry guidance emphasises that mine closure is most effective when regulators are involved early in methodology development, risk identification and sequencing decisions, rather than being presented with near-final designs late in the process. A competent demolition contractor can ensure early regulatory engagement enables realistic approval timelines to be incorporated into closure schedules and financial provisioning, eliminating critical-path risk during execution.

9 Case studies

9.1 Case study 1: open cut hard rock mine closure, Western Australia

An open cut hard rock mine operated by a major global mining company in a remote region of Western Australia reached end of mine life, requiring full infrastructure demolition and site rehabilitation across an extensive footprint encompassing more than 400 discrete structures. Liberty Industrial was engaged under an ECI model well ahead of the execution phase. A comprehensive 3D asset register developed from aerial drone surveys and LiDAR scanning formed the basis of the detailed closure plan, quantity take-off, and IFRS-compliant liability estimate. A staged demolition program was integrated directly with progressive rehabilitation scheduling, enabling cleared areas to advance toward final revegetation while demolition of remaining structures continued in adjacent zones, materially reducing total closure duration. An engineered landfill cell program incorporating a compacted clay liner, leachate collection, and groundwater monitoring ensured long-term physical and chemical stability of in situ demolition material placement. The project was recognised with a 2024 World Demolition Award for Industrial Demolition.

9.2 Case study 2: processing facility demolition, Queensland

A large multi-story processing facility at an open cut mine in Queensland, operated by a major diversified mining and energy company, required progressive closure ahead of the full site timeline. The approximately 40 m steel structure incorporated extensive internal process equipment, conveyors, screens, and pipe infrastructure. ELS structural simulation confirmed the viability of a combined bottom-up and top-down high-reach mechanical methodology, demonstrating that retaining primary structural columns during bottom-up removal of internal flooring, process equipment, and cross-bracing maintained adequate load path redundancy – eliminating explosive pre-weakening and associated regulatory approval timelines.

Pre-demolition asbestos audit identified ACM in pipe lagging, gaskets, and sheet cladding throughout; all ACM was removed under encapsulated conditions before structural demolition commenced. Approximately 95% of recovered metals were recycled, with scrap steel rebates directly offsetting gross demolition cost.

10 Conclusion

Mine closure programs are complex and require significant analysis to ensure appropriate planning to assess the unique and true state of an asset prior to closure.

By including the following steps early in closure planning, all scenarios and conditions can be safely addressed before work commences.

- ECI done by a specialist contractor and team of experts during LOM can help save money and reduce delay. A collaborative approach with multiple stakeholders is recommended to ensure qualitative and quantitative data is captured upfront.
- Certainty in demolition methodologies can be achieved by leveraging AEM-based simulation technology.
- Hazardous waste is often underestimated and is likely to change or deteriorate over time. It is important to consult with experts onsite to ensure all potential contaminants are accounted for early, to plan the necessary regulatory, processing and waste streams and avoid disruption during project execution.
- Both risks and opportunities lie in effective waste and recycling programs that address site and asset requirements individually, based by data and thorough expert analysis, for best classification, disposal and recycling outcomes.
- Engaging early with regulatory compliance, local communities allow time to plan and prepare for compliant and sustainable outcomes.

Use of artificial intelligence disclosure statement

In the preparation of this work, the authors used M365 Copilot based on the GPT-5 to consolidate a magnitude of information gathered by multiple internal stakeholders. The authors have reviewed and edited the content and take full responsibility for said content.

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