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From guidance to governance in developing and operationalising an integrated closure framework for a global mining portfolio

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Abstract

Mine closure has advanced from a technical end of life rehabilitation obligation into a strategic enterprise governance and risk management challenge with significant financial, environmental, legal and social dimensions. Increasing expectations from regulators, investors, communities and global environmental, social and governance frameworks now require closure to be embedded across the full life of asset, from early studies and capital allocation decisions through to relinquishment and post-closure stewardship. Despite this shift, achieving consistent cross-functional integration of closure across planning, finance, operations, environmental management, risk, legal and social performance systems remains an industry-wide challenge.

This paper presents the structured development and operationalisation of a multi-level integrated closure framework designed to reposition closure as a core business discipline rather than an isolated compliance function. The framework was informed by systematic gap analysis against contemporary International Council on Mining and Metals guidance, cross-functional workshops and alignment with existing capital project standards, environmental and social standards, sustainability metrics and enterprise risk management systems. It integrates closure vision, progressive rehabilitation, risk management, social transition planning, cost modelling and relinquishment readiness within life of mine planning and financial provisioning cycles. Particular emphasis is placed on planning-to-cost traceability, proportional scaling of technical expectations to asset maturity and risk profile, and disciplined mechanisms for progressive liability reduction. The framework responds to emerging industry pressures, including long-term performance uncertainty, legacy asset exposure, tightening financial disclosure requirements, and rising expectations for defensible relinquishment and sustainable post-mining outcomes.

Implementation insights demonstrate that a portfolio-wide closure framework is most effective when it creates clear accountability, traceable planning-to-cost linkages, proportional expectations and evidence-based assurance pathways rather than adding procedural complexity. The proposed approach offers a transferable blueprint for mining organisations seeking to modernise closure governance, strengthen financial transparency, manage long-term environmental and social risk, and bridge technical and executive perspectives in sustainable resource development.

Keywords: *integrated mine closure; closure governance, financial provisioning, life of mine planning, enterprise risk management, progressive rehabilitation, relinquishment readiness*

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1 Introduction

For large mining companies, particularly those operating across multiple regions and regulatory settings, closure now represents a broad governance, risk, financial, environmental and social challenge that must be managed across the full life of the asset. Evolving expectations from regulators, investors, host communities and sustainability frameworks increasingly require closure to be considered from the earliest stages of project development and integrated into planning, decision-making, financial provisioning and long-term stewardship, rather than being deferred until the end of operations. This shift is reflected in the International Council on Mining and Metals (ICMM) Integrated Mine Closure: Good Practice Guide (ICMM 2025a), which describes integrated closure as a dynamic, iterative process that should be treated as part of the mine's core business.

Despite this advancement in industry expectations, mining organisations still face practical challenges in embedding closure consistently across business systems and functions (Boggs et al. 2025). Closure is often fragmented across technical, environmental, financial and social workstreams (Bainton & Holcombe 2018), disconnected from life of mine planning and capital decision processes, or treated as a compliance obligation rather than a business discipline. This can create weak traceability between closure objectives, design, implementation planning, risk controls, cost estimates and long-term outcomes, particularly in portfolios where assets vary significantly in maturity, risk, disturbance footprint and regulatory context (World Bank 2021). The core challenge addressed in this paper is therefore how to translate integrated closure guidance into a practical governance and implementation framework that can operate consistently across a diverse mining portfolio. In this paper, 'guidance' refers to external good practice and internal corporate expectations, 'framework' refers to the structured governance and planning model developed from that-guidance, and 'operationalisation' refers to embedding that model into asset-level planning, decision-making, implementation, assurance and continuous improvement processes.

This paper describes the development and operationalisation of an integrated closure framework for a global mining portfolio aimed at repositioning closure as a structured business and governance function rather than an isolated technical or environmental process. The framework links governance, life cycle integration, closure planning, knowledge development, progressive closure, implementation planning, financial provisioning, stakeholder engagement, monitoring, assurance and relinquishment readiness. It incorporates a 3-level governance and assurance model comprising asset-level accountability, corporate-level oversight and external assurance.

The purpose of this paper is twofold. Firstly, it describes the rationale and method used to translate contemporary closure good practice into an operational governance framework for a global mining company. Secondly, it reflects on implementation insights from that process, including the importance of governance clarity, cross-functional alignment, proportionality and integration into existing business systems. Although developed within a specific corporate context, the approach is intended to be transferable to other mining organisations seeking to strengthen closure governance and improve long-term closure planning and delivery.

2 Industry context and problem statement

Across the mining industry the challenge has moved beyond recognising that closure should be integrated across the life of asset to embedding that expectation consistently into governance, planning and delivery systems. This challenge is particularly pronounced in large and geographically diverse portfolios, where assets vary in life cycle stage, technical complexity, disturbance footprint, regulatory setting, social context and closure maturity (ICMM 2025b).

Closure-related responsibilities are also commonly distributed across multiple functions, including planning, operations, environment, finance, social performance and risk, each with different planning horizons, systems, performance drivers and decision pathways. Without a clear governance and technical framework this can result in inconsistent closure expectations; limited traceability between objectives, design, risk and cost; and poor visibility regarding closure liabilities and long-term obligations at both the asset and corporate levels (Commonwealth of Australia 2016). For example, a closure design assumption may be developed

within a technical study, reflected differently in a cost estimate and not fully carried through into life of mine planning, stakeholder commitments or closure performance criteria. This type of disconnect can weaken confidence in both closure planning and financial provisioning.

A further challenge lies in the gap between good practice guidance and operational implementation. While industry guidance provides a strong conceptual basis for integrated closure, mining companies still require internal governance instruments that translate those principles into clear accountabilities, minimum requirements, decision pathways and technical expectations (Santos et al. 2025). In the absence of such instruments, closure can remain vulnerable to inconsistent interpretation, duplicated effort and limited integration into core business systems such as life of mine planning, capital stage-gates, cost estimation, enterprise risk management, stakeholder engagement and assurance (Anglo American 2019).

Within this context, the problem addressed in this work was not simply the need for more closure activity but the need for an operationally integrated closure framework that could function consistently across a global mining portfolio. The goal was to provide a framework that could move closure from guidance to governance, clarify what must be done at the corporate and asset levels, scale expectations according to maturity and risk, and create defensible linkages between the closure vision, design, implementation, cost, monitoring and relinquishment readiness.

3 Key drivers for framework development

The development of the integrated closure framework was driven by a combination of strategic, technical, financial and organisational pressures affecting closure across a global mining portfolio. The need for change was not triggered by a single compliance gap but by the recognition that closure expectations had expanded beyond the capacity of fragmented guidance, discipline-specific practices and asset-by-asset interpretation. A more structured framework was required to align closure with ongoing good practice while making it workable across different assets, jurisdictions and business functions. These drivers were prioritised according to their materiality to closure outcomes, relevance across multiple functions and assets, and potential to improve governance consistency, implementation confidence and liability transparency.

A primary driver was the need to align closure practice more closely with industry guidance, particularly the ICMM Integrated Mine Closure: Good Practice Guide*,* 3rd Edition (ICMM 2025a). This required a shift from a largely guidance-based approach towards a more explicit governance and implementation framework underpinned by clearer requirements and stronger integration across strategy, design, execution and assurance.

A second driver was the need to strengthen governance clarity and accountability. Closure-related responsibilities already existed across multiple functions, including planning, environment, social performance, finance, operations and technical disciplines, but were not always framed within a single integrated model. The new framework was therefore designed to establish clearer governance pathways supported by defined roles, governance forums and review interfaces. This was intended to improve consistency, visibility of material risks and obligations, and confidence that closure remained integrated within business decision-making.

A third driver was the growing importance of financially defensible closure planning. Closure cost estimation and financial provisioning are now subject to greater internal and external scrutiny, particularly where they support recognised liabilities, regulatory financial assurance, sustainability disclosures and long-term capital and operational decision-making. This includes alignment with International Accounting Standard (IAS) 37, Provisions, Contingent Liabilities and Contingent Assets, where relevant to the recognition, measurement and disclosure of provisions and contingent liabilities (International Financial Reporting Standards Foundation (IFRS), 2023). The framework, therefore, placed strong emphasis on planning-to-cost traceability, estimate purpose, update triggers, accuracy and contingency, and alignment between closure cost estimates, approved scope, risk and implementation planning.

Another significant driver was the need to scale closure expectations more effectively across assets with different maturity and risk profiles. Within a global portfolio, some assets are in early study phases, others are in active operations with progressive closure opportunities, and others are closer to closure execution or long-term stewardship. The framework was therefore intentionally designed to be proportional, with closure expectations scaling according to the life cycle stage, closure maturity, the scale of the disturbance, the risk profile and the level of execution activity.

The increasing importance of stakeholder engagement, community and workforce transition and long-term social outcomes was also a major driver of change, including the need to better understand the cost and governance implications of social transition. The updated framework recognises that closure is not solely a technical and environmental process but also a social transition, with far-reaching implications for communities, workers, contractors, land users, custodians and regulators (Svobodova et al. 2025). As a result, the framework places greater emphasis on stakeholder engagement, social transition planning, residual social risk, infrastructure handover and post-closure stewardship within the closure framework itself.

Finally, there was a strong practical driver to avoid adding unnecessary procedural complexity. The aim was to embed closure more effectively into existing decision frameworks such as life of mine planning, stage-gate reviews, annual business planning, enterprise risk management, environmental and social systems, and assurance processes. This principle shaped the framework into a structured yet operationally integrated model for closure planning, governance, and implementation. These drivers created the case for a more structured and operationally grounded integrated closure framework, capable of translating good practice into governance and governance into consistent implementation across a complex global mining portfolio.

4 Methodology for framework development

The integrated closure framework was developed through a structured, iterative and cross-functional process designed to translate closure good practice into an operational governance and implementation model. The methodology focused on seven linked stages, with the key activities including diagnostic review and gap assessment, cross-functional engagement and design alignment, framework structuring and drafting, and iterative review, testing and refinement. Figure 1 summarises the overall development approach.

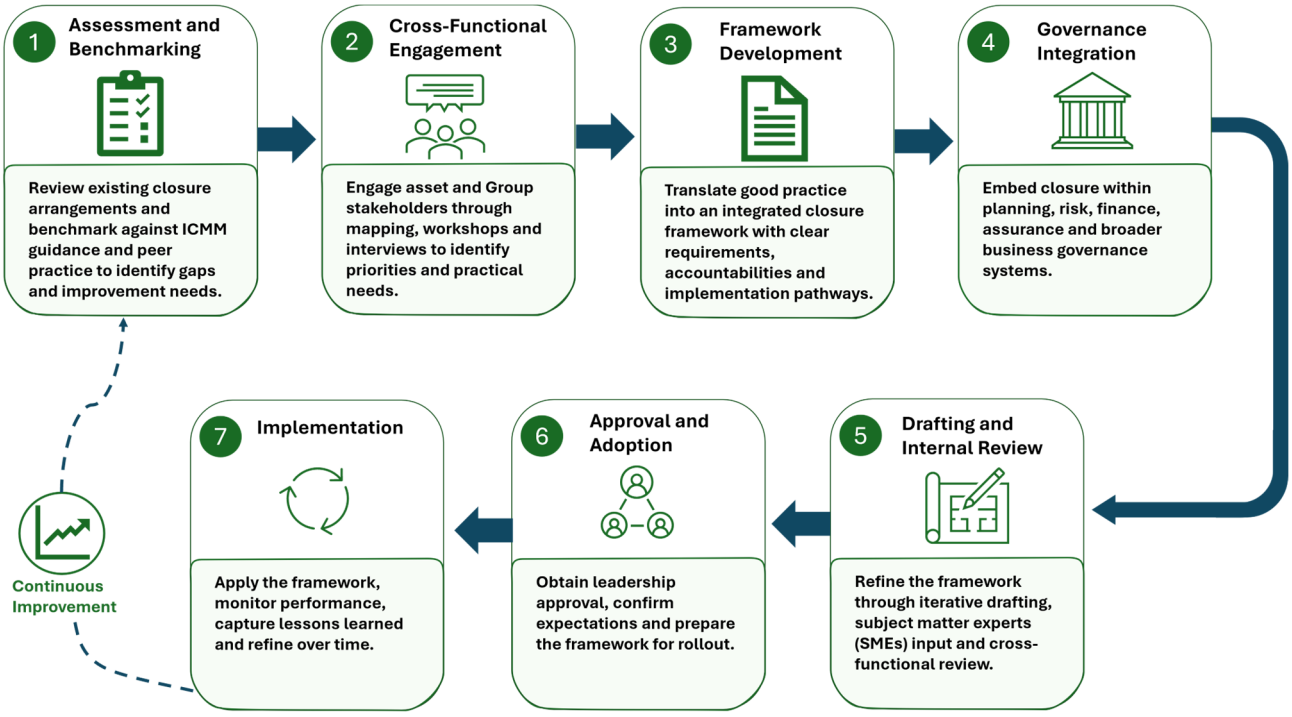

Figure 1 Methodology adopted to develop the integrated mine closure framework

4.1 Diagnostic review and gap assessment

The first stage involved reviewing the existing closure-related document suite, governance arrangements and planning interfaces to identify where closure expectations were already defined, where they were split across functions, and where material gaps or ambiguities existed. This review considered how closure was represented in life cycle planning, risk management, financial provisioning, stakeholder engagement, technical design, implementation planning and post-closure performance processes. The review considered closure-related inputs across 6 operating regions and 10 asset contexts, including corporate standards, closure planning documents, cost estimation processes, risk management interfaces, and supporting environmental, social and technical guidance.

This internal review was then benchmarked against existing good practice, with particular reference to the ICMM Integrated Mine Closure: Good Practice Guide, 3rd Edition (ICMM 2025a). The benchmark considered both closure content areas and the degree of integration across the life of asset, including knowledge development, closure vision and objectives, progressive closure, social transition, implementation planning, governance, monitoring and relinquishment. The aim was to identify where existing approaches were aligned with good practice, where they lacked clarity or enforceability, and where stronger integration into business systems was required.

The gap assessment also considered alignment with existing internal management systems and corporate controls, including capital project and study processes, enterprise risk management, closure cost estimation, stakeholder and social performance systems, document governance requirements and technical assurance pathways. This was important because the objective was not to create a parallel closure bureaucracy, but to develop a framework that could operate through existing corporate systems and decision pathways.

4.2 Cross-functional engagement and design alignment

Structured cross-functional engagement was arranged to test the practicality of the framework and confirm that closure requirements could be integrated across relevant disciplines. Inputs were sought from closure, mine planning, finance, environmental, social performance, human resources, capital project development and other technical functions through working sessions, targeted review discussions and iterative drafting feedback.

The purpose of this stage was to clarify the roles, interfaces and accountabilities needed for closure to function as an integrated business process. It also tested whether the proposed framework elements were practical and scalable across assets at different life cycle stages. Particular attention was given to interfaces that commonly create implementation gaps, including those between closure and life of mine planning, cost estimation, social transition, technical design, management of change and assurance.

This stage also informed the proportionality principle embedded throughout the framework. Rather than applying a single undifferentiated level of detail across all assets, the framework was intentionally shaped so that expectations scale according to life cycle stage, closure maturity, scale of disturbance, risk profile and level of execution readiness.

4.3 Framework structuring and drafting

Building on this process, the findings of the diagnostic review and stakeholder engagement were translated into a structured, integrated framework. The framework was organised around the core elements needed to move closure from guidance into an operational system of governance, planning, implementation and assurance. These elements were grouped around governance and accountability, life cycle closure planning, technical delivery, financial and social integration, monitoring and verification, and readiness for relinquishment or long-term stewardship.

During this stage the framework was deliberately structured to reinforce traceability across the closure pathway. This meant creating clear linkages between closure vision, post-closure land use, objectives, risks, design criteria, closure activities, implementation plans, cost estimates, success criteria, monitoring requirements and relinquishment evidence. The intent was to improve consistency and auditability while

strengthening the ability of assets and corporate functions to make informed decisions based on aligned planning assumptions (Pérez Gómez et al. 2025).

Another important feature of this stage was the explicit integration of closure into established governance pathways. The framework was designed to interface with annual business planning, life of mine and life of asset planning, capital stage-gates, enterprise risk systems, financial review cycles, social performance planning, document control and assurance mechanisms. In this sense the framework was developed not as a standalone technical manual but as a governance-enabled operating model for closure.

4.4 Iterative review, testing and refinement

Progressive review and refinement of the framework were completed through repeated drafting cycles, targeted technical review and governance discussion. Draft content was reviewed not only for technical completeness, but also for clarity of accountabilities, usability across functions, alignment with existing business systems, and potential for implementation across different assets and regions.

Several important refinements emerged through this stage. These included strengthening the role of the mine closure plan (MCP) as the primary integrated asset-level closure planning document, clarifying the relationship between implementation planning and execution planning, improving treatment of post-closure land use and success criteria, strengthening the linkage between closure planning and financial provisioning, and incorporating the updated governance and assurance model.

The review process also reinforced an important principle: that governance clarity and integration into existing decision systems are more effective than adding further process layers. As a result, the framework was refined to remain structured and enforceable while avoiding unnecessary duplication of systems already operating across the business functions.

5 Framework guiding principles

The integrated closure framework was shaped by a set of guiding principles intended to make it practical, scalable and capable of operating consistently across a multi-asset mining business. These principles emerged from the gap assessment, stakeholder engagement and framework development process, and were used to guide both the structure of the framework and its interface with existing business systems. The principles summarised in Table 1 reflect a deliberate shift away from viewing closure as a narrow end of life task and towards treating it as an integrated business process. Together, these principles provide the conceptual foundation for the framework architecture discussed in the following section.

The guiding principles were validated through benchmarking against recognised closure guidance, cross-functional review, subject matter expert input and governance discussions. This helped confirm that the principles were aligned with good practice and practical for application across assets with different maturity levels, risk profiles and closure contexts.

Table 1 Framework guiding principles and their intended purpose

Guiding principle	Purpose in the framework
Closure as an integrated business discipline	Positions closure within core business planning, governance and decision-making rather than treating it as a separate end of life obligation
Life cycle integration	Embeds closure from early studies through operations, progressive closure, closure execution, post-closure management and relinquishment or successful transition
Proportionality and scalability	Allows closure expectations to scale with asset maturity, disturbance footprint, risk profile and level of closure execution activity while retaining clear minimum requirements
Traceability	Strengthens linkages between closure vision, post-closure land use, objectives, design criteria, closure activities, implementation planning, cost estimates, monitoring, success criteria and relinquishment evidence
Governance clarity and defined accountability	Clarifies accountability, escalation pathways and oversight responsibilities across asset, corporate and external levels, improving ownership of closure-related risks and decisions
Progressive reduction of risk and liability	Treats progressive rehabilitation and other progressive closure activities as planned operational measures that reduce risk, build evidence and improve readiness for final closure
Integration rather than duplication	Supports implementation through existing business systems and processes wherever possible, avoiding the creation of a separate parallel closure management system
Evidence, assurance and defensibility	Supports verification, auditability, regulatory confidence, financial transparency and relinquishment readiness through evidence-based planning, implementation and assurance

6 Overview of the integrated closure framework

The integrated closure framework developed through this process was designed as a single, connected system for governing and operationalising closure across the life of asset. Rather than treating closure as a standalone environmental or end of life activity, the framework integrates the governance, planning, technical, financial, social, implementation and assurance elements required to manage closure as an integrated business process (Worden et al. 2024).

At a high level, the framework comprises 3 interdependent layers. The first establishes the governance and accountability architecture for closure, including asset-level accountability, corporate-level oversight and external assurance. The second defines the closure planning and implementation pathway across the asset life cycle, from knowledge development, closure vision, objectives and post-closure land use through to progressive closure, technical design, implementation, monitoring and relinquishment readiness. The third provides the supporting systems and evidence base needed to demonstrate that closure requirements are being implemented consistently and are supported by defensible information and clear traceability. The overall architecture of the integrated closure framework is summarised in Figure 2.

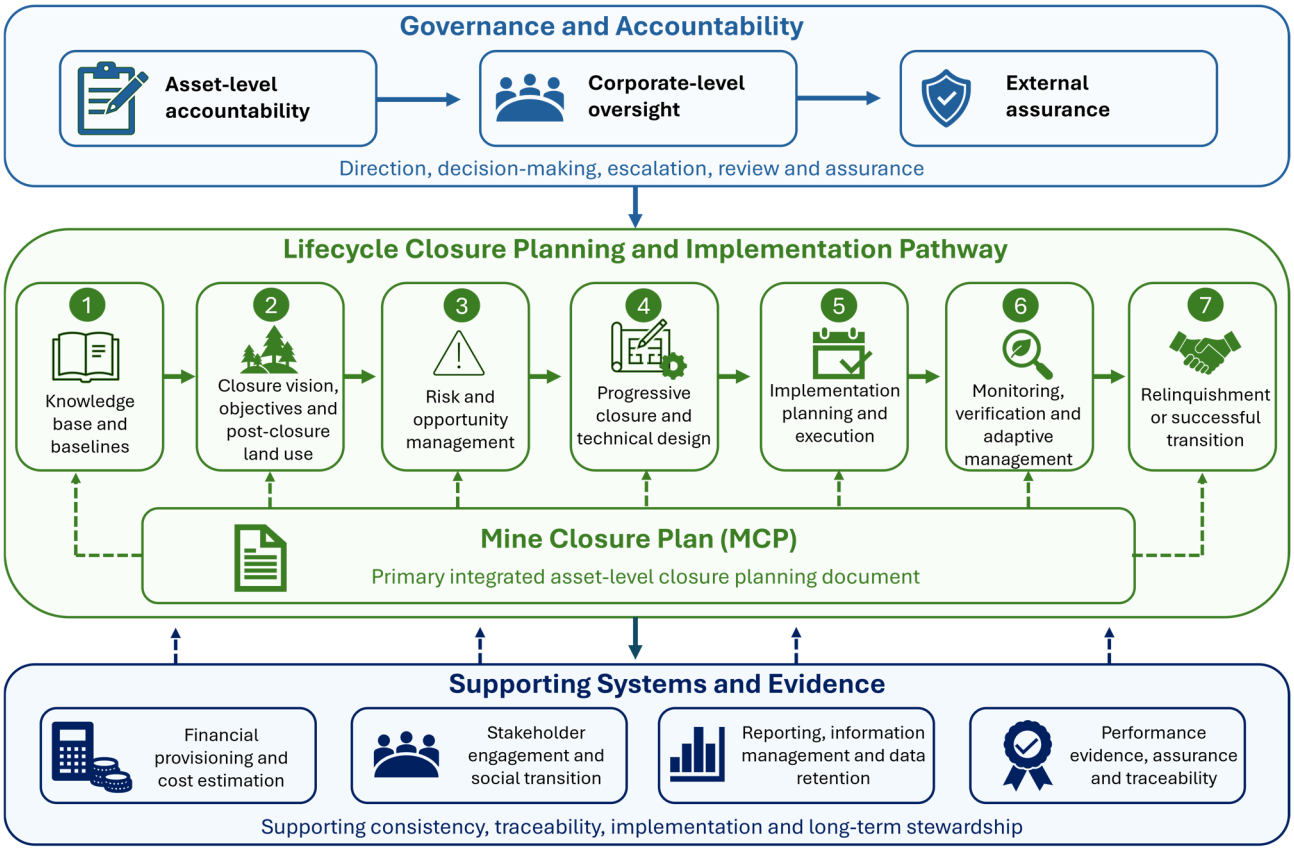

Figure 2 High-level architecture of the integrated closure framework

A central feature of the framework is the MCP's role as the primary integrated asset-level closure planning document. The MCP acts as the central reference point within the framework, consolidating closure vision, objectives, design basis, risk context, implementation requirements, monitoring framework, cost assumptions and supporting evidence. It is intended to provide a coherent and traceable record of how closure objectives will be achieved for each asset, while aligning supporting plans, cost models, risk registers and operational planning processes.

The framework also places strong emphasis on life cycle integration. Closure is embedded from early studies and project development through operations, progressive closure, pre-closure, closure execution, post-closure management and relinquishment or successful transition (ICMM 2025b). This life cycle structure is supported by stage-based planning expectations, review and endorsement points, and it interfaces with life of mine and life of asset planning, annual business planning, capital study processes, stakeholder engagement and social transition processes, and management of change triggers. As a result, closure is positioned as a governing design factor and planning requirement rather than as an activity triggered only when operations are nearing closure.

Another key aspect of the framework is traceability. Core closure elements are linked in a logical sequence, closure vision informs post-closure land use and closure objectives, objectives inform design criteria and closure activities, closure activities inform implementation planning and cost estimation, and monitoring, success criteria and assurance provide the evidence needed to evaluate performance and support transition or relinquishment decisions. This planning-to-cost-to-performance linkage is particularly important in strengthening confidence that closure liabilities, progressive closure priorities and long-term stewardship requirements are grounded in consistent assumptions rather than disconnected workstreams.

The framework is deliberately cross-functional and designed to support implementation without creating unnecessary parallel systems. It works through existing governance pathways, business planning cycles, capital processes, assurance mechanisms and management systems wherever possible. In practical terms,

this means closure is embedded within existing decision forums and controls while still supported by dedicated closure planning logic, implementation structure and verification requirements. This balance between integration and specificity is one of the framework's defining features and central to its intended transferability beyond the portfolio in which it was developed.

7 Key framework components

The integrated closure framework comprises a set of interdependent components that collectively support closure as an operationally embedded business process. Together these components form a connected system that links governance, planning, design, implementation, financial provisioning, stakeholder engagement, performance verification and transition planning across the life of the asset. At the asset level, the MCP serves as the primary integrating management instrument, while supporting governance, technical, financial, social and assurance systems provide the broader operating environment within which closure is planned, implemented and verified. The components were developed and refined through benchmarking, cross-functional review and testing against different asset life cycle contexts, including early-stage planning, active operations, pre-closure and post-closure transition. The principal components of the framework and their practical contributions are summarised in Table 2.

These components show that the framework is not simply a closure planning structure but a broader operating model for integrated mine closure. Its practical value lies in connecting strategic governance, asset-level planning, technical delivery, financial transparency, social transition and performance verification into a coherent system. This enables closure to be managed more consistently across a diversified asset base while remaining adaptable to differences in maturity, risk profile and closure context.

Table 2 Key components of the integrated closure framework and their practical contributions

Framework component	Primary purpose	What the component addresses	Practical contributions to mine closure practice
Governance, accountability and assurance	Position closure within formal governance and decision-making systems	Establish who is accountable for closure at the asset level, how corporate oversight is exercised, when independent or external review is required, and how closure issues, risks and decisions are escalated, reviewed and acted on through formal governance pathways	Improve accountability and decision visibility Strengthen consistency across assets Support more defensible closure governance and assurance
Life cycle integration and closure planning	Embed closure into planning and business processes across the life of asset	Require closure to be considered from early studies onwards and integrated into life of mine and life of asset planning, annual business planning, project stage-gates and management of change processes. Also position the MCP as the primary asset-level document that brings closure planning together in a single, structured format	Move closure upstream into project and operational decision-making Reduce late-stage redesign and liability surprises Improve traceability between planning assumptions and closure outcomes
Closure knowledge base, baselines, vision and post-closure land use	Establish the strategic and technical basis for closure planning and design	Bring together the information needed to plan for closure, including environmental, social, technical and regulatory baselines, identify knowledge gaps and investigations needed over time, define the intended long-term closure outcome through a closure vision and objectives; and link these to realistic post-closure land use options based on land capability, stakeholder expectations and long-term feasibility	Improve the technical defensibility of closure strategies Create clearer alignment between end state intent and closure activities Support long-term planning confidence
Risk and opportunity management	Integrate closure into enterprise-style risk and opportunity assessment	Requires closure-related risks and opportunities to be identified, assessed and reviewed in a structured way over the life of the asset, including long-term physical, environmental, social, regulatory and financial risks. It also links closure risk management to scenario testing, design assumptions, implementation priorities and ongoing review through corporate risk processes	Promotes risk-informed closure planning Helps identify emerging closure constraints earlier Supports more proactive and adaptive management
Progressive closure, technical design and implementation planning	Translate the closure strategy into staged delivery and progressive liability reduction	Cover the practical design and delivery side of closure, including landforms, waste and tailings facilities, pits and voids, infrastructure decommissioning, rehabilitation and progressive closure works undertaken during operations. Also includes how closure works are sequenced, quality-controlled, integrated with operations and translated into implementation and execution planning	Shifts closure from intent to delivery Builds evidence through implementation Reduces deferred liability and improves readiness for final closure

Framework component	Primary purpose	What the component addresses	Practical contributions to mine closure practice
Financial provisioning and cost traceability	Align closure scope, risk and implementation with defensible financial estimates	Defines how closure costs are estimated for different purposes, how those estimates are linked to approved scope, technical assumptions, risks and implementation timing, and how they are updated as the asset changes. Also addresses estimate purpose, contingency, accuracy, update triggers and governance review so that financial provisions remain current and defensible	Improves financial transparency Strengthens the linkage between planning and provisioning Supports more robust liability recognition and decision-making
Stakeholder engagement and social transition	Integrate social performance and transition planning into closure governance	Covers how stakeholders are identified and engaged through closure planning, when and how workforce and community transition issues are considered, how social commitments and residual obligations are managed, and how infrastructure handover or post-mining transition arrangements are planned. It also recognises that closure has social and human consequences, not just technical ones	Makes social closure more visible and structured Strengthens transition readiness Reduces the likelihood that social risks are treated as secondary to technical closure considerations
Monitoring, success criteria, verification and relinquishment readiness	Provide the evidence base for closure completion, long-term performance and transition	Defines how closure performance is monitored, how success criteria are set and verified, how corrective or adaptive actions are triggered if performance is not being achieved, and how assets demonstrate readiness for relinquishment or another agreed transition outcome. This component turns closure completion into an evidence-based process rather than a judgment based only on completion of works	Connects closure implementation to measurable outcomes Supports regulatory confidence and assurance Improves readiness for long-term stewardship or relinquishment
Reporting, information management and maturity assessment	Maintain traceability, performance visibility and long-term continuity of closure knowledge	Covers how closure information is reported, stored, controlled and retained over time; how progress and performance are tracked through indicators and reviews; and how closure planning maturity is periodically assessed to identify gaps and improvement priorities. It helps maintain continuity of knowledge across long time frames, personnel changes and post-closure phases	Strengthens organisational learning and consistency Preserves closure knowledge across long time frames Supports auditability, transparency and continuous improvement

8 Operationalisation across a global portfolio

A key objective of the integrated closure framework was not simply to define better closure requirements but to make those requirements operational across a geographically diverse and technically varied mining portfolio. This required the framework to function across assets at different life cycle stages, with different closure risk profiles, regulatory settings, social contexts and levels of closure maturity. In practice, operationalisation depended on balancing 2 competing needs:

- maintaining sufficient consistency to support governance, comparability and assurance
- retaining enough flexibility to accommodate asset-specific conditions and jurisdictional requirements.

Figure 3 illustrates the operationalisation pathway used to translate the integrated closure framework into consistent practice across a multi-asset mining portfolio.

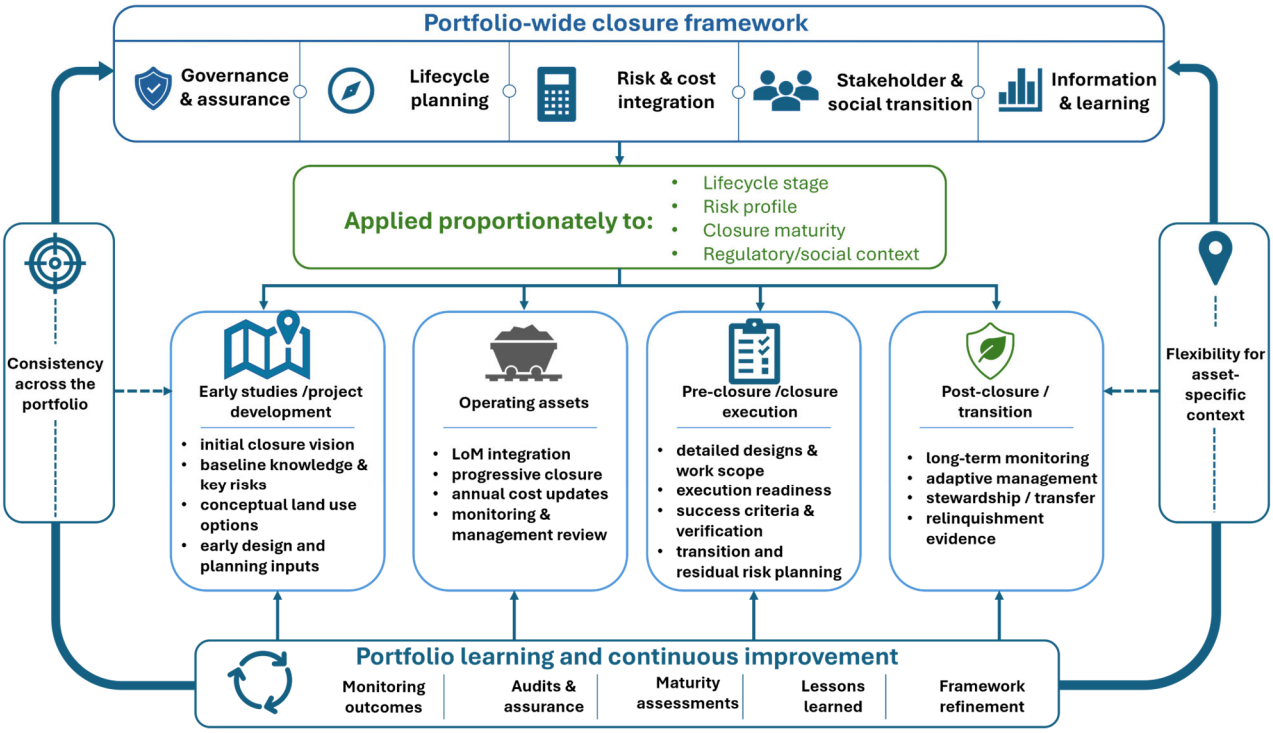

Figure 3 Conceptual schematic showing how the integrated closure framework is operationalised across a multi-asset mining portfolio

The framework addresses this challenge through a proportional and life cycle-based model of application. Closure requirements are not intended to be applied identically across all assets. Instead, expectations scale according to life cycle stage, disturbance scale, closure maturity, risk profile and level of closure execution activity. Early-stage projects are expected to demonstrate closure integration through conceptual planning, early risk identification and the development of an initial knowledge base, while more mature assets are expected to demonstrate stronger integration into life of mine planning, progressive closure, monitoring, cost estimation, execution readiness and transition planning. This proportional approach is central to making the framework usable across a portfolio without reducing it to a lowest-common-denominator standard (Boggs et al. 2025).

In portfolio settings, implementation is more likely to succeed when closure uses established decision pathways and control systems than when it relies on standalone processes that sit outside normal business rhythms (Anglo American 2019; Gómez et al. 2025).

A further aspect of operationalisation is governance scalability. The framework recognises that closure needs both local ownership and broader oversight. Asset-level teams are responsible for applying the framework

in a way that reflects local operating conditions, commitments and risks, while corporate-level oversight provides consistency in expectations, review, assurance and escalation of material issues. External assurance adds a further layer in which independent review, regulatory inspection or external verification is required. This multi-level model is particularly important in a portfolio context because it allows closure to remain locally grounded while still being governed through a common portfolio-wide closure framework (ICMM 2025a; Global Tailings Review 2020).

The framework also places strong emphasis on operational learning. Progressive closure, monitoring, implementation outcomes, maturity assessments, audits and management review processes are all intended to generate feedback that can be used to refine closure planning, improve assumptions, strengthen cost forecasts and support continuous improvement across the portfolio. This is particularly relevant when assets differ significantly in technical complexity or closure maturity, because learning from one asset can inform practice elsewhere. In this sense, operationalisation is not treated as a one-time deployment exercise, but as an iterative process in which the framework matures through application, assurance and learning.

Operationalisation across a global portfolio requires a framework that is stable in its principles but adaptable in its application. Some assets may be focused on early planning and option definition, others on progressive liability reduction during operations, and others on execution-phase closure or long-term stewardship. The framework described in this paper attempts to address this by standardising the core logic of closure governance and planning while allowing the level of detail, evidence and supporting documentation to advance with asset conditions and risk.

9 Key insights and implications

The development of the integrated closure framework generated several insights relevant beyond the immediate portfolio for which it was developed. These insights arose not only from drafting the framework itself but also from testing how integrated closure could be translated into governance, planning and operational practice across assets with different maturity levels, risk profiles and closure contexts. Taken together, they suggest that effective closure frameworks depend less on the volume of closure documentation than on the quality of integration, accountability, planning logic and evidence they create.

A first insight is that governance clarity adds more value than additional layers of procedure. In mining businesses, closure already involves multiple functions, but these activities are not always structured within a clear system of accountability, review and escalation. The framework development process confirmed that stronger governance pathways, role clarity and assurance interfaces were more effective than creating additional standalone closure processes. For broader industry practice, this suggests that the next step in closure improvement is not necessarily more closure documentation but stronger governance systems that make closure visible within formal business decision-making (World Bank 2021).

A second insight is that integrated closure depends on its connection to core business systems. Closure became more practical and credible when it was explicitly linked to life of mine planning, annual business planning, capital study processes, risk management, cost estimation, stakeholder engagement systems and assurance pathways. This is consistent with broader industry guidance emphasising life cycle integration and regular updating of closure plans in response to operational, environmental and social change. The implication for industry is that closure is most likely to become operational when embedded in the planning and control systems that already shape mine development and operational decisions, rather than being managed as a parallel end of life process (IFC 2007; Anglo American 2019).

A third insight is that proportionality is essential for portfolio-wide implementation. A multi-asset framework cannot be applied in identical form to all assets without becoming either burdensome or superficial. Requirements need to scale according to life cycle stage, closure maturity, disturbance footprint, risk profile and closure context. This supports a broader industry move away from one-size-fits-all closure requirements and towards structured but risk-based and life cycle-based applications, particularly for companies operating across multiple jurisdictions and asset types (ICMM 2025a).

A fourth insight is that progressive closure should be understood not only as a rehabilitation activity but also as a learning and risk-reduction mechanism. Progressive works reduce deferred liabilities, test design assumptions, improve cost confidence, build implementation evidence and strengthen readiness for final closure. Closely related to this is the need for planning-to-cost traceability. Closure cost estimates are only as reliable as the technical assumptions, design basis, implementation logic and risk treatment that underpin them. The framework development process reinforced that financial provisioning becomes more meaningful when costs are transparently linked to the approved scope, land use assumptions, closure activities, risk and implementation planning. In industry practice, this underscores the importance of treating closure cost estimation as a strategic governance issue, not merely a downstream finance exercise (Botes et al. 2025).

A fifth insight is that social transition and post-closure land use should be treated as core closure issues rather than peripheral community relations matters. Workforce transition, community transition, land use change, infrastructure handover and residual social obligations all influence whether closure outcomes are sustainable and credible. Embedding these elements more explicitly within the framework strengthened the link between closure objectives, stakeholder engagement, long-term land use and transition planning. The broader implication is that integrated closure frameworks need to incorporate workforce and community transition, land use planning, residual obligations and stewardship pathways directly into closure planning rather than leaving them outside the core closure system.

A final insight is that evidence and assurance requirements need to be designed into the framework from the outset. Monitoring, information management, success criteria, verification pathways and assurance mechanisms cannot be left until late-stage closure or relinquishment planning. Assets are more likely to generate usable, defensible closure evidence when monitoring logic, data retention, verification expectations and review pathways are built into the framework early. This also reinforces that implementation is inherently iterative; closure frameworks do not become effective simply because they are issued or approved but through application, review, monitoring, feedback and continuous improvement. For broader industry practice this suggests that the most effective integrated closure frameworks are those that combine governance clarity, life cycle integration, proportionality, planning-to-cost traceability, social transition and evidence-based assurance within a single coherent operating model.

10 Conclusion

Mine closure increasingly requires a more integrated and disciplined approach than has traditionally been applied in many mining contexts. This paper has outlined the development and operationalisation of an integrated closure framework intended to translate current good practice into a practical model for portfolio-wide application. In doing so, it has shown how governance, life cycle planning, knowledge development, progressive closure, implementation planning, financial provisioning, stakeholder engagement, monitoring, assurance and relinquishment readiness can be brought together within a single coherent framework.

The work indicates that effective integrated closure depends less on procedural expansion and more on the quality of the operating system that connects closure governance, asset-level planning, cost traceability, social transition, implementation evidence and assurance. The contribution of the framework is that it brings these elements together in a single portfolio-wide model that is structured enough to support consistency but flexible enough to scale according to asset maturity, risk profile and closure context.

Although the framework was developed for a specific corporate context, the broader approach is transferable. Its value lies in translating closure guidance into governance mechanisms, planning interfaces and verification pathways that can be used in day-to-day business processes rather than remaining as standalone closure guidance. In that respect the framework offers one practical model for moving mine closure from guidance to governance.

References

Anglo American 2019, *Mine Closure Toolbox Examples Version 3*, London, https://www.angloamerican.com/~/media/Files/A/Anglo-American-Group/PLC/sustainability/mine-closure-toolbox-examples-version-3-2019.pdf

Bainton, N & Holcombe, S 2018, 'A critical review of the social aspects of mine closure', *Resources Policy*, vol. 59, pp. 468–478, https://doi.org/10.1016/j.resourpol.2018.08.020

Botes, A, Sheridan, C & Steyn, C 2025, 'A probabilistic framework for mine closure financial liability assessment', in S Knutsson, AB Fourie & M Tibbett (eds), *Mine Closure 2025: Proceedings of the 18th International Conference on Mine Closure*, Australian Centre for Geomechanics, Perth, https://doi.org/10.36487/ACG_repo/2515_29

Boggs, G, Measham, T, D'Urso, J & Kelley, B 2025, 'Enabling change in mine closure: six key challenges and strategies to enable transition planning, management and execution', in S Knutsson, AB Fourie & M Tibbett (eds), *Mine Closure 2025: Proceedings of the 18th International Conference on Mine Closure*, Australian Centre for Geomechanics, Perth, https://doi.org/10.36487/ACG_repo/2515_12

Commonwealth of Australia 2016, *Mine Closure: Leading Practice Sustainable Development Program for the Mining Industry*, Department of Industry, Innovation and Science, Canberra, https://www.industry.gov.au/sites/default/files/2019-05/lpsdp-mine-closure-handbook-english.pdf

Global Tailings Review, ICMM, PRI & UNEP 2020, *Global Industry Standard on Tailings Management*, https://globaltailingsreview.org/wp-content/uploads/2020/08/global-industry-standard-on-tailings-management.pdf

International Council on Mining and Metals (ICMM) 2025a, *Integrated Mine Closure: Good Practice Guide*, London, https://pimcore.icmm.com/website/publications/pdfs/environmental-stewardship/2025/guidance_mine-closure_update.pdf

International Council on Mining and Metals (ICMM) 2025b, *Tailings Management Good Practice Guide*, London.

International Finance Corporation (IFC) 2007, *Environmental, Health, and Safety Guidelines for Mining*, Washington DC, https://www.ifc.org/content/dam/ifc/doc/2000/2007-mining-ehs-guidelines-en.pdf

International Financial Reporting Standards (IFRS) Foundation 2023, *IAS 37 Provisions, Contingent Liabilities and Contingent Assets: Discount Rates*, London, https://www.ifrs.org/content/dam/ifrs/meetings/2023/november/iasb/ap22-provisions-targeted-improvements-discount-rates.pdf

Pérez Gómez, D, Munita Ortíz, D & Curotto Berruezo, M 2025, 'Mine closure plan transition: from a document to a management tool during mine operation', in S Knutsson, AB Fourie & M Tibbett (eds), *Mine Closure 2025: Proceedings of the 18th International Conference on Mine Closure*, Australian Centre for Geomechanics, Perth, https://doi.org/10.36487/ACG_repo/2515_55

Santos, CS, de Lima, HM, Flores, JC & Maldonado, CB 2025, 'Integrated mine closure planning adherence index: a new approach for evaluating mine closure plans', *Resources Policy*, vol. 105, https://doi.org/10.1016/j.resourpol.2025.105604

Svobodova, K, Everingham, JA, Mackenzie, S & Witt, K 2025, 'Designing community participation for mine closure and social transition', *Sustainable Development*, https://doi.org/10.1002/sd.70176

Worden, S, Svobodova, K, Côte, C & Bolz, P 2024, 'Regional post-mining land use assessment: an interdisciplinary and multi-stakeholder approach', *Resources Policy*, vol. 89, https://doi.org/10.1016/j.resourpol.2024.104680

World Bank 2021, *Mine Closure: A Toolbox for Governments*, Washington DC, https://openknowledge.worldbank.org/entities/publication/0b1b1ae2-2945-53c0-8758-d6b3e502766f