

Performance tools to assess maturity in mine closure

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Abstract

Mine closure represents a complex challenge for the mining industry, requiring structured planning and clear governance to ensure compliance and mitigate environmental and social risks. This article presents the Mine Closure Management Performance Assessment Tool and the Sustainability Criteria Assessment Tool for Mine Closure, made available in Brazil in 2024 by Brazilian Mining Institute (IBRAM) in the Indicators Guide for Mine Closure Planning and the Sustainability Criteria Guide for Mine Closure, respectively. The mentioned guides are considered national references in the Brazilian mining sector and are consulted by the Brazilian National Mining Agency in regulatory mine closure processes.

With indicators organised into maturity levels and supported by detailed checklists and action plans, the tools enable a consistent and transparent approach to closure planning. Their practical design also allows visual applications, such as dashboards or process flow diagrams, which facilitate integration into corporate systems and support more effective decision-making across organisational levels.

Keywords: performance tools for mine closure, mine closure maturity model, ESG in mine closure, mine closure indicators, IBRAM indicators

1 Introduction

Mine closure represents one of the most complex stages in the mining life cycle, particularly in countries like Brazil where vast territorial extensions, diverse biomes and strong community dependencies on mining activity intensify the challenge. In addition to requiring advanced technical planning and coordination, mine closure demands sensitivity to the socio-economic and environmental transitions that impact local populations. One example is the difficulty of repurposing large post-mining areas in regions with low economic diversification, often resulting in abandoned infrastructure and social disengagement.

Over the last few decades, the strengthening of regulatory requirements and the evolution of society's expectations regarding the socio-environmental responsibility of companies have driven debate on the need for a new paradigm for the closure of mining activities. Inadequate closure planning can result in long-term environmental liabilities such as acid mine drainage, and social issues including unemployment and loss of local infrastructure, as seen in several post-mining regions in Brazil. In this context, advance planning and the use of structured tools that promote sustainability and continuous improvement have become essential elements of good governance in the sector.

Aiming to support this movement, the Brazilian Mining Institute (IBRAM), in partnership with Alvarez & Marsal, developed two documents in 2024 that seek to contribute to the improvement of closure practices in the Brazilian mining sector: the Indicators Guide for Mine Closure Planning and the Sustainability Criteria Guide for Mine Closure. The publications present practical and guiding tools that enable companies to assess their management standards, identify weaknesses and promote corrective actions in a structured, anticipated and integrated manner.

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The Indicators Guide for Mine Closure Planning (IBRAM & Alvarez & Marsal 2024a) aims to provide a self-assessment tool for performance in closure management and is structured around seven fundamental guidelines that cover everything from the early start of planning to monitoring the socio-economic and environmental impacts of a mine. The 38 indicators presented in the document allow for measuring the level of adherence of companies to good closure practices, promoting a culture of continuous improvement and operational excellence.

The Sustainability Criteria Guide for Mine Closure (IBRAM & Alvarez & Marsal 2024b) expands the traditional approach by incorporating environmental, social and governance (ESG) principles into closure processes. By presenting six sustainability best practices applicable throughout the entire life cycle of the project, the guide reinforces the need for holistic management focusing on governance, risk assessment, stakeholder engagement and value generation for society.

Both guides were developed collaboratively, with technical workshops and public consultations, ensuring the participation of industry experts, academic representatives and mining companies. The participatory approach based on practical experiences gave robustness to the tools developed, which have been recognised as national technical references and used by the Brazilian National Mining Agency (ANM) as a subsidy in regulatory processes in Brazil.

This article presents the methodological and conceptual foundations that guided the development of both tools, as well as their structures, forms of application and expected benefits for the sector. By promoting more strategic, integrated and sustainable closure management, the guides contribute to consolidating a new model for mine closure — more transparent, collaborative and aligned with the contemporary challenges of responsible mining. While the tools were developed for the Brazilian mining sector, their underlying principles and practices can offer valuable insights to international stakeholders seeking to improve their own mine closure strategies.

2 Assessment tools

The development of the tools presented in this article – the Mine Closure Management Performance Assessment Tool and the Sustainability Criteria Assessment Tool for Mine Closure – followed a participatory and evidence-based methodology. The tools are aligned with international references, including frameworks from the International Council on Mining and Metals (ICMM), the Initiative for Responsible Mining Assurance (IRMA) and the Towards Sustainable Mining (TSM) protocol. Both are the result of an initiative by the Environmental Impact Mitigation Working Group within the scope of the Brazilian Mining ESG Agenda, coordinated by the IBRAM with technical support from Alvarez & Marsal.

2.1 Methodological foundations

The development of the tools followed a methodology structured around three main pillars:

1. the survey and systematisation of good practices already recognised in the mining sector, including international frameworks such as the Integrated Mine Closure: Good Practice Guide (ICMM 2019), the Standard for Responsible Mining (IRMA 2006) and TSM Guiding Principles (Mining Association of Canada 2004), besides national references such as the Guide to Mine Closure Planning (Sánchez & Brazilian Mining Institute 2013)
2. active listening and engagement of over 100 stakeholders, including representatives from mining companies, academia, consulting firms, and regulatory agencies such as the ANM and state environmental bodies
3. technical validation through collaborative workshops, public consultations and targeted interviews with subject-matter experts in environmental, legal and operational areas.

In addition, the tools were developed to ensure compliance with current Brazilian regulatory requirements, such as ANM Resolution No. 68/2021, and applicable federal and state environmental legislation.

2.2 Tool structure

2.2.1 Performance assessment tool for mine closure management

The first tool, presented in the Indicators Guide for Mine Closure Planning (IBRAM & Alvarez & Marsal 2024a), is organised around seven fundamental guidelines, based on the Guide to Mine Closure Planning (Sánchez & Brazilian Mining Institute 2013):

1. Closure planning should begin at the conception of a new mine project.
2. The company should plan the closure of active mines.
3. Closure planning should involve engaging internal and external stakeholders.
4. The results of the planning should be recorded in closure plans and other related documents.
5. The company must estimate all costs associated with the closure of a mine.
6. The company must follow local socio-economic development.
7. The closure plan must be updated whenever there are substantial changes in the mine project.

Table 1 presents the seven guidelines, detailing their technical purpose and examples of associated good practices. The guidelines provide guidance from the early initiation of planning to its continuous updating, promoting an integrated, preventive and participatory approach to mine closure. This framework supports companies in conducting a responsible process aligned with legislation and best practices in the minerals sector.

Table 1 Mine closure planning guidelines and good practices

Guideline	Importance	Objective	Main associated good practices
1. Closure planning should begin at the conception of a new mine project.	Ensures that closure is technically and economically viable from the start, avoiding long-term liabilities and costly retroactive measures	Incorporate closure into feasibility studies and mine design to reduce future risks and facilitate rehabilitation	• Include closure in strategic planning • Design considering future use • Assess impacts from the environmental impact study
2. The company should plan the closure of active mines.	Enables proactive risk management and gradual reduction of environmental liabilities during mine operation	Develop planning based on technical diagnostics, mine history and current socio-environmental context	• Survey the mine's technical history • Assess structural risks • Carry out progressive recovery
3. Closure planning should involve engaging internal and external stakeholders.	Builds trust, improves decision-making and strengthens the social licence to operate through participatory processes	Carry out identification, consultation, communication with and participation of stakeholders throughout the planning process	• Consult stakeholders • Establish channels of dialogue • Involve stakeholders in monitoring
4. The results of the planning should be recorded in closure plans and other related documents.	Ensures clarity, traceability and alignment with regulatory expectations by formalising the closure strategy	Formalise planning through documents that detail actions, programs and closing objectives	• Develop mine closure plan • Prepare decommissioning plans • Assess risks of planned actions
5. The company must estimate all costs associated	Provides financial security for closure execution and protects	Include detailed and up-to-date costs for all closure	• Detail costs for each program • Update estimates periodically

Guideline	Importance	Objective	Main associated good practices
with the closure of a mine.	stakeholders from unplanned burdens	actions and ensure financial provision mechanisms	• Make financial provisions
6. The company must follow local socio-economic development.	Helps mitigate social and economic disruption and supports a positive post-mining legacy	Monitor and support local development to promote sustainability after closure	• Monitor socio-economic indicators • Promote economic diversification • Develop community programs
7. The closure plan must be updated whenever there are substantial changes in the mine project.	Ensures that the closure plan remains current, effective and responsive to evolving risks and contexts	Review the plan considering operational, legal or social and environmental changes	• Update the closure plan as regulations change • Incorporate innovations • Consider uncertainties

These guidelines and good practices are broken down into 38 performance indicators, with criteria graded into five maturity levels (C, B, A, AA and AAA), which assess practices ranging from the absence of practices to excellence in their implementation, as shown in Table 2. While level C typically reflects minimal or incipient practices, often limited to basic legal compliance, level AAA represents excellence, characterised by a fully integrated, strategic and continuously improved approach that goes beyond compliance. The application process occurs through guided self-assessment using detailed checklists, action plan models and classification by level of adherence.

Table 2 Criteria for meeting indicators and maturity level

Level	General description	Characterisation of maturity level
C	Initial or non-existent	The company does not have structured practices for the indicator evaluated or only meets the minimum legal requirements
B	Emerging	There are specific initiatives or action plans being developed but the practice has not yet been consolidated or widely implemented
A	Implemented	The practice is implemented and operationalised, being applied consistently in the company's processes
AA	Advanced	The practice is consolidated, has formal responsibilities, is monitored with indicators and is integrated into the organisational strategy.
AAA	Excellence	The practice is at a level of excellence, with continuous training programs, embedded organisational culture and continuous improvement

This scale allows companies to perform a graduated self-assessment, identifying their current stage in each indicator and defining goals for improvement. The differentiation between levels also provides clarity for prioritising actions and monitoring progress over time.

The tool enables structured and standardised assessments which facilitate external audits, regulatory reviews and internal performance monitoring.

2.2.2 Sustainability criteria assessment tool for mine closure

The second tool, available in the Sustainability Criteria Guide for Mine Closure, helps companies integrate ESG principles into closure planning. While the first tool focuses on performance and compliance, this one emphasises strategic alignment with sustainability goals. It is structured around six best practices:

1. Implement governance for mine closure, including ESG aspects.
2. Identify socio-environmental impacts in the mine closure process.
3. Establish a socio-environmental risk management plan for mine closure.
4. Implement TSM as a best practice for the mining sector and for mine closure.
5. Structure the ESG strategy for mine closure using materiality aspects.
6. Obtain economic gains by implementing sustainability criteria in mine closure processes.

The six best practices are essential for guiding responsible and transparent mine closures aligned with ESG principles, as shown in Table 3. They support strong governance, risk management, stakeholder engagement and legacy planning. For example, applying materiality helps companies prioritise sustainability themes based on stakeholder input, aligning closure with local expectations. These practices also promote economic value creation, positioning mine closure as the start of a new development cycle rather than simply the end of operations.

Table 3 Good sustainable mine closure practices

Good practice	Recommendation	Main objective
1. Implement governance for mine closure, including environmental, social and governance (ESG) aspects.	Structure committees, processes and indicators to integrate closing into the company's strategy and management	Establish solid, transparent governance that is integrated with sustainability issues
2. Identify socio-environmental impacts in the mine closure process.	Diagnose the impacts of closure in an early and participatory manner	Understanding the risks and impacts to support mitigation and rehabilitation actions
3. Establish a socio-environmental risk management plan for mine closure	Map, classify and treat socio-environmental risks related to closure	Reduce exposure to critical events and strengthen preventive and corrective management
4. Implement Towards Sustainable Mining (TSM) as a best practice for the mining sector and for mine closure	Adopt TSM protocol modules in the mine closure process	Ensure alignment with global standards, promoting transparency, continuous improvement and independent verification
5. Structure the ESG strategy for mine closure using materiality aspects	Apply the concept of materiality to define priority themes with stakeholders	Connect the closure strategy to the company's social expectations and sustainable goals
6. Obtain economic gains by implementing sustainability criteria in mine closure processes	Demonstrate the economic viability of sustainable actions, such as area appreciation, future use and investment attraction	Transforming sustainability into a source of value and economic return post-closing

Good practices range from structuring governance for closure, with a clear definition of responsibilities and decision-making processes, to identifying and managing socio-environmental impacts and risks. They also guide companies in adopting the TSM protocol, promoting alignment with international standards and applying materiality, connecting closure to stakeholder expectations and the most relevant ESG themes for each context.

In addition, the importance of demonstrating economic viability in adopting sustainability criteria is highlighted, encouraging solutions that not only reduce impacts but also generate value for the affected territories – such as the productive re-use of mined areas, attracting investments and strengthening the social licence to operate. For instance, post-closure redevelopment can lead to land value appreciation,

especially when former mining sites are converted into renewable energy hubs, industrial parks or ecotourism areas.

This structure guides mining companies to transform mine closure into an opportunity for a positive legacy, economic diversification and social innovation, expanding the impact of closure actions beyond regulatory compliance.

These good practices are accompanied by specific indicators, structured with criteria graded into five maturity levels (C, B, A, AA and AAA) which can be applied throughout the mine's life cycle and focus on risk mitigation, value creation and stakeholder engagement. Aligned with international frameworks such as TSM and IRMA, the tool also includes a self-assessment form and an action plan template to support practical implementation and adaptation to project-specific contexts.

2.3 Application methods

The two tools were designed to be used in a complementary manner. The first, aimed at closure management, focuses on compliance, technical performance and continuous monitoring. The second, focused on sustainability, broadens the company's strategic approach by including governance issues, socio-environmental risks and legacy potential.

Table 4 highlights the differences and similarities between the tools, facilitating an understanding of how the tools complement each other and how they can be applied together to promote more effective, strategic and sustainable closure management.

Table 4 Comparison between tools

Aspect	Performance assessment tool	Sustainability criteria tool
Related guide	Indicators Guide for Mine Closure Planning	Sustainability Criteria Guide for Mine Closure
Focus	Compliance, technical performance, monitoring	Governance, environmental, social and governance (ESG) risks, long-term value creation
Objective	Assess the closure management standard and its regulatory compliance	Assess the integration of ESG criteria in mine closure
Structure	Seven guidelines 38 performance indicators	Six good practices with associated indicators
Classification	Five levels: C, B, A, AA, AAA	Five levels: C, B, A, AA, AAA
Support instruments	Self-assessment checklist, action plan template and glossary	Self-assessment checklist, action plan template and glossary
Expected application	Self-diagnosis and continuous improvement of closing processes	Self-diagnosis and strategic direction with a focus on shared value

The tools can be applied through periodic assessment cycles conducted by multidisciplinary teams with technical knowledge on the subject. Annual reassessments are recommended, especially when aligned with major closure planning milestones such as plan updates, feasibility reviews or licence renewals. Senior leadership should be directly involved in analysing the results to ensure institutional engagement and prioritisation of improvement actions. Action plan templates help address identified gaps and ensure traceability of corrective initiatives.

The flowchart shown in Figure 1 represents the structured cycle for applying performance assessment tools and sustainability criteria during mine closure. The process begins with formalising the evaluation cycle and defining focal points, followed by the application of the Performance Assessment Tool and diagnosis of

the maturity level. Based on this, a correction plan is prepared and complemented by the Sustainability Criteria Assessment Tool for Mine Closure. The final stages involve executing improvement actions, updating the assessment periodically and communicating results to stakeholders. This integrated approach strengthens management, increases sustainability and promotes a positive legacy after closure.

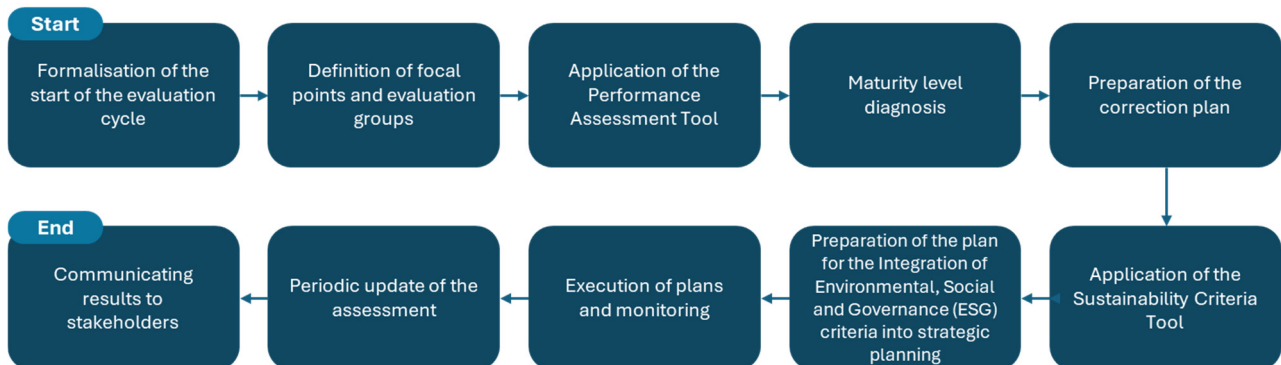


Figure 1 Flowchart of the integrated application of tools

2.4 Expected benefits for the mineral sector

The systematic adoption of tools promotes several tangible benefits for companies and the sector as a whole:

- strengthens internal governance, supported by the Sustainability Criteria Assessment Tool for Mine Closure, by clarifying responsibilities and aligning closure with ESG priorities
- reduces regulatory, environmental and reputational risks, addressed by the Mine Closure Management Performance Assessment Tool through early diagnosis and adherence to good practice
- improves operational efficiency, enabled by both tools through action planning, resource optimisation and risk mitigation
- provides greater transparency and credibility, enhanced by the Mine Closure Management Performance Assessment Tool via standardised processes and stakeholder reporting
- generates a positive legacy and shared value, guided by the Sustainability Criteria Assessment Tool for Mine Closure, by aligning closure with the sustainable development goals of affected territories.

By consolidating these instruments, IBRAM and Alvarez & Marsal offer the Brazilian mineral sector a reference framework for the responsible and sustainable management of mine closure, promoting a paradigm shift from merely technical closure to an integrated, participatory and future-oriented process.

3 Conclusion

Mine closure, due to its critical and multidimensional nature, has become a central issue in contemporary mining, driven by increasing regulatory demands, investor scrutiny and societal expectations for long-term environmental and social responsibility. The topic has gone from being at a low-visibility stage to becoming a strategic component of organisations, directly associated with corporate reputation, business sustainability and its contribution to the sustainable development of territories

In this scenario, the two guides launched by the Brazilian Mining Institute, in partnership with Alvarez & Marsal, represent a concrete response to the demands of the mining sector for practical, applicable methodologies aligned with regulatory requirements, international best practices and environmental, social and governance principles. The Mine Closure Management Performance Assessment Tool contributes to the professionalisation of closure management by offering a robust technical instrument, based on structured indicators, to diagnose, monitor and continuously improve companies' internal processes. The Sustainability Criteria Assessment Tool for Mine Closure broadens the perspective of mining companies by positioning closure as an opportunity to

generate socio-environmental value and a positive legacy, incorporating criteria that strengthen governance, transparency and stakeholder engagement. Both tools are conceptually aligned with global frameworks such as the ICM Mine Closure Good Practice Guide, the Initiative for Responsible Mining Assurance and the Towards Sustainable Mining protocol, making them adaptable to international contexts.

The tools were developed collaboratively, involving a wide range of stakeholders from the Brazilian mining ecosystem – including companies, regulatory bodies, academia and civil society – which reinforces their legitimacy and practical applicability. By promoting self-assessment, the standardisation of criteria and the internalisation of good practices, the guides have become national references and position Brazil among the countries advancing responsible mine closure. Their participatory development process adds a complementary perspective to existing international frameworks, fostering broader alignment and practical value.

It is expected that their adoption by mining companies will favour a more coherent and predictable regulatory environment, foster the continuous improvement of risk management and enhance the positive impacts of mining beyond the useful life of the projects. Mine closure, when well conducted, can and should be part of the solution – and not just a liability – on the path towards more ethical, transparent and sustainable mining.

Acknowledgement

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