

# Thinking of the future, acting today: building post-mining legacies through innovation, technology, and engagement

Jussara Januário <sup>a,\*</sup>, Ana Paula Silva Della Torre <sup>a</sup>, Eduardo Duffles <sup>a</sup>, Gustavo Roque <sup>a</sup>, Eliane Almeida <sup>a</sup>

<sup>a</sup> Vale, Brazil

## Abstract

*Planning the future use of mining sites is increasingly complex in modern society, requiring a careful balance between transparency and execution. With extractive industries facing stricter regulations, increased societal scrutiny and growing expectations for sustainable transitions, transparent disclosure of post-mining transition plans is essential for maintaining stakeholder trust. However, fulfilling these commitments poses technical, financial, social, and environmental challenges; requiring innovative and collaborative approaches. These challenges are particularly pressing due to the already planned mine closures in the coming years and the growing demand for sustainable mining of critical minerals in the green economy.*

*Given the unpredictable nature of the future, envisioning future scenarios and developing aligned strategies must go hand in hand. This includes identifying moments to anticipate likely outcomes based on past trends and current dynamics (forecasting) and envisioning the desired future and how to achieve it (foresight).*

*At the same time, addressing critical societal questions is essential, especially regarding how behavioural and macro forces shape solutions, while fostering critical thinking. Balancing present expectations with the uncertainties of future outcomes remains a significant challenge, especially in an uncertain and complex world.*

*Thus, building future readiness, rather than attempting to provide definitive answers, is key to shaping the trajectory of these areas. It is important to consider a variety of potential outcomes and their impacts. As opportunities arise, the ability to manage uncertainty must also grow to effectively respond to changing conditions.*

*This paper examines the importance of managing both transparency and practical steps in mine repurposing, reflecting on key perspectives such as uncertainty management; human factors; digital transformation; and decision-making. It also highlights strategies and initiatives by Vale S.A. to address challenges in planning for future use of mining sites, emphasising continuous evolution, optimisation, and the integration of emerging technologies, agile methodologies and design thinking approaches.*

**Keywords:** *post-mining planning, mine repurposing, sustainable transitions, post-closure vision, stakeholder partnerships, collaborative engagement*

## 1 Introduction

Planning for the future use of mined areas is evolving in response to new social, regulatory, and sustainability demands. Companies in the extractive sector now face a dual challenge: to clearly communicate their plans for transitioning these areas and to ensure these plans are effectively implemented.

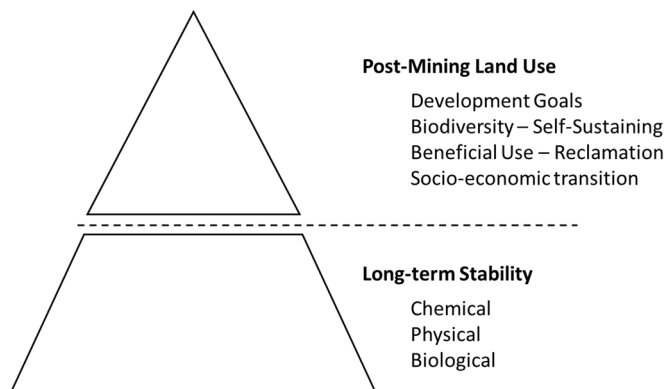
Balancing disclosure and delivery involves technical, financial, human, and institutional challenges that go beyond having solid plans. Companies need future-oriented strategies, adaptability, and the ability to navigate uncertainty.

---

\* Corresponding author. Email address: [jussara.januario@vale.com](mailto:jussara.januario@vale.com)

*“Rather than focusing on a single end point of relinquishment, companies need to recognise closure as a dynamic, progressive and uncertain process and take a long-term vision of post-closure scenarios” (ICMM 2025).*

Planning the future use of post-mining areas goes beyond defining new purposes or projects. Above all, it is an exercise in strategic imagination, seeking to reconnect these areas to the social, economic, and ecological dynamics of their regions. Instead of focusing only on traditional closure plans aimed at physical, chemical, and biological stability, post-mining land use seeks to create new values, functions, and connections (Figure 1).



**Figure 1 The hierarchy of closure needs (Adapted from Asia-Pacific Economic Cooperation 2018)**

In recent years, regulatory demands related to legal compliance, transparency, sustainability, and environmental, social and governance (ESG) criteria in the mining sector have grown significantly (Table 1). International guidelines, technical standards, and legal frameworks now require mining companies to clearly and consistently report their closure plans and future land use intentions. These instruments not only promote best practices but also set criteria for external evaluation, audits, reporting, and, increasingly, for obtaining and maintaining the social license to operate and close.

In this context, as disclosures and expectations increase, so does responsibility for what is communicated and promised. How can long-term commitments be balanced with the actual capacity for delivery in an increasingly uncertain and complex world?

Transparency now goes beyond regulatory compliance. It plays a crucial role in building trust and reputation and attracting lasting partnerships, and this requires clear, realistic, and consistent actions.

Thus, future land use planning must consider three fundamental dimensions:

- What is desirable from a social, cultural, and environmental perspective?
- What is necessary in terms of quality of life, infrastructure, and resources?
- What is technically, legally, and economically feasible?

A fourth dimension must be added to these: What effectively generates value, not only from a financial standpoint, but also symbolic, ecological, and social value?

In recent years, the topic of ‘mine closure and future use’ has gained increasing prominence in the annual *Top 10 Business Risks and Opportunities for Mining and Metals* report published by Ernst & Young (EY), reflecting a structural shift in how the sector views the end of the mining asset lifecycle.

In 2021 and 2022, the topic appeared under the categories ‘Green Agenda’ and ‘Environmental and Social’, respectively (EY 2020, 2021). However, from 2023 onwards, it gained greater visibility, being categorised under ESG – which ranked first in that year and the following one (EY 2022, 2023). For 2025, the topic maintained its relevance, being cited under the categories ‘License to Operate’ and ‘New Business’, emphasising the potential of future use as an opportunity to leave a legacy and long-term value (EY 2024).

**Table 1 Organisations and instruments defining standards or requirements influencing decisions on mining, mine closure, and future land use**

No.	Acronym	Name	Description
1	GRI Index	Global reporting initiative	International standard for sustainability reporting, covering economic, social, and environmental impacts.
2	IRMA	Initiative for Responsible Mining Assurance	Voluntary standard establishing criteria for responsible mining with independent verification.
3	RMI	Responsible mining index	Index that assesses the transparency and performance of the world's largest mining companies.
4	ICMM	International Council on Mining and Metals	International support organisation promoting the sustainable development of the mining and metals industry. Established the Mining Principles to evaluate members performance in sustainability and responsible mining.
5	TCFD	Task Force on Climate-related Financial Disclosures	Framework for disclosing financial risks and opportunities related to climate change.
6	TNFD	Task Force on Nature-related Financial Disclosures	Framework for disclosing financial risks and opportunities related to nature.
7	ODS	Sustainable development goals	The United Nations global agenda with 17 goals to end poverty, protect the planet, and promote prosperity.
8	SASB	Sustainability accounting standards board	Defines ESG disclosure standards specific to each economic sector.
9	ISO	International Organization for Standardization	Standardises environmental, social, and governance aspects of mine closure and reclamation and mining legacies, such as ISO 21795, ISO 20305, and ISO 24419.
10	TSM	Towards sustainable mining	Set of practices and protocols to promote more responsible and sustainable mining.
11	CSMI	Consolidated mining standards initiative	Unified global standard for responsible mining, integrating best practices and requirements from various organisations.
12	CSRD	Corporate sustainability reporting directive	European Union directive mandating enhanced sustainability reporting for companies, including mining operations in Europe.
13	ESRS	European sustainability reporting standards	Standards that support the CSRD, providing a framework for companies to report on ESG performance.
14	ISSB	International sustainability standards board	Global standards for sustainability-related disclosures, with a focus on financial reports related to sustainability and climate change, including those relevant to mining.
15	EITI	Extractive industries transparency initiative	Global standard for assessing the transparency of extractive industries (oil, gas, and mining).

## 1.1 Vale Brazil experience

The development of future use projects led by the Vale Brazil team, has been built on an essentially collaborative process, developed iteratively and often intuitively.

Initially, solutions were shaped by practical experience, active listening to the territories, and the integration of diverse perspectives. Over time, as the team aligned with conceptual and methodological frameworks consolidated in both academic literature and national and international experiences, it became clear that many of the practices in use resonated with established approaches. These include design thinking, foresight, the Double Diamond model, and other tools for innovation, territorial planning, and stakeholder engagement.

Mapping and systematising these practices were essential to refining our solutions. By adopting proven methodologies and best practices, the team gained structure while maintaining flexibility and experimental mindset essential to future use projects. What began as a conceptual approach is now part of daily operations, supporting continuous and adaptive improvement.

A key strength of this process is the team's multidisciplinary composition. With experts in architecture, engineering, geography, sociology, communications, management, and economics, we bring together technical, strategic, and social perspectives, enriched by systems thinking and local awareness. This diversity goes beyond technical knowledge, it is a strategic advantage. It sparks creativity, broadens solution pathways, and supports integrated approaches.

## 2 Envisioning futures

The increasing complexity of contemporary challenges requires that future land use planning for mined areas move beyond linear and prescriptive approaches. Uncertainty about economic, social, and environmental outcomes, combined with pressure for coherent and sustainable solutions, calls for integrating diverse methodologies that connect the past, present, and possible futures, across different scales, from individuals to entire communities.

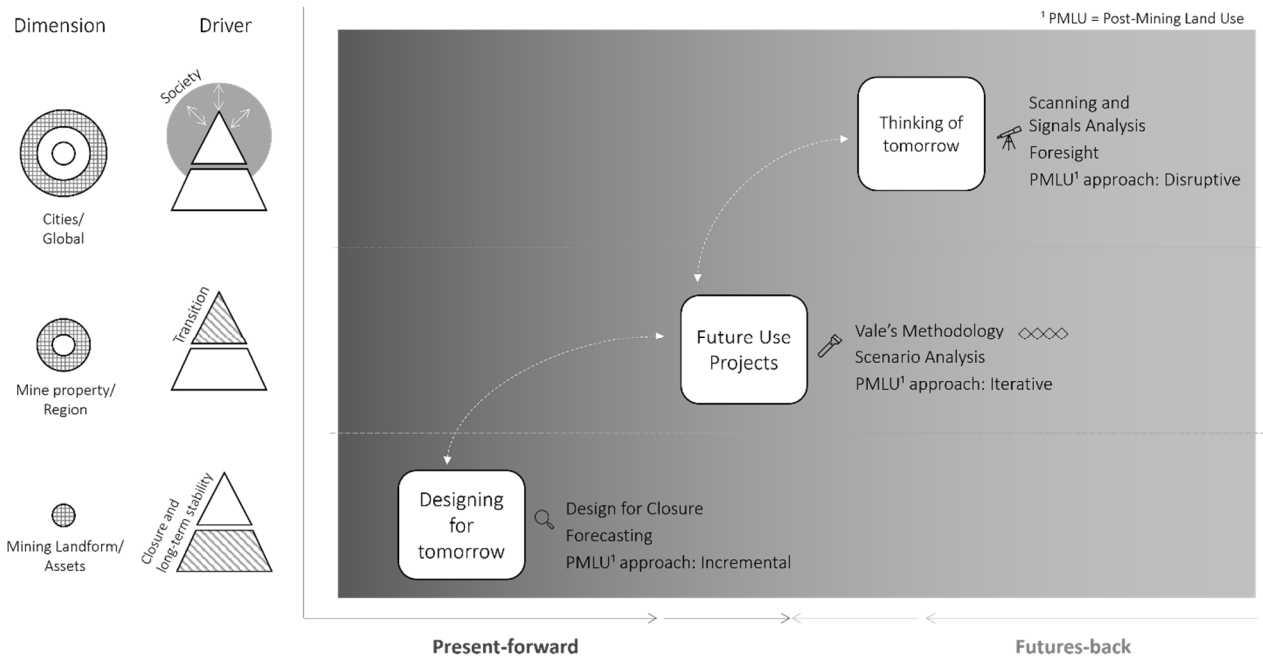
Two complementary methodological approaches stand out when thinking about and preparing for the future: forecasting and foresight. Forecasting relies on analysing trends and historical data to predict likely developments based on current conditions. Foresight takes a broader, more exploratory view, considering emerging signals, behavioural changes, generational shifts, technological advances, and systemic transformations that could shape future pathways.

For example, in mine closure planning, forecasting helps guide decisions based on proven solutions, validated technologies, and established benchmarks. This approach emphasises control, predictability, and risk mitigation, especially in the early project stages when ensuring technical feasibility, long-term stability, and environmental recovery is critical. In short, it focuses on a future with a high degree of certainty.

In contrast, foresight expands the range of possibilities by identifying alternative scenarios, unforeseen risks, and new opportunities. This approach is especially valuable for driving innovation and creating shared value, as it helps organisations prepare for structural changes and emerging future demands.

At Vale Brazil, when working with future use, we envision a hybrid model. This combines moments of anticipating likely outcomes based on past trends and current conditions (as in design for closure) with moments focused on exploring future possibilities. This includes monitoring signals that may indicate shifts and discussing scenarios at different scales, including the global level.

This framework (Figure 2) incorporates different spatial and temporal dimensions, and key drivers spanning technical, social, environmental, and economic domains. Future use projects aim to balance short-term and long-term perspectives, combining current limitations and capabilities with future trends and local aspirations to design scenarios for each area. It is a dynamic and iterative process, that continuously evolves incorporating best practices, new technologies, and emerging approaches to build sustainable alternatives aligned with societal expectations and needs.

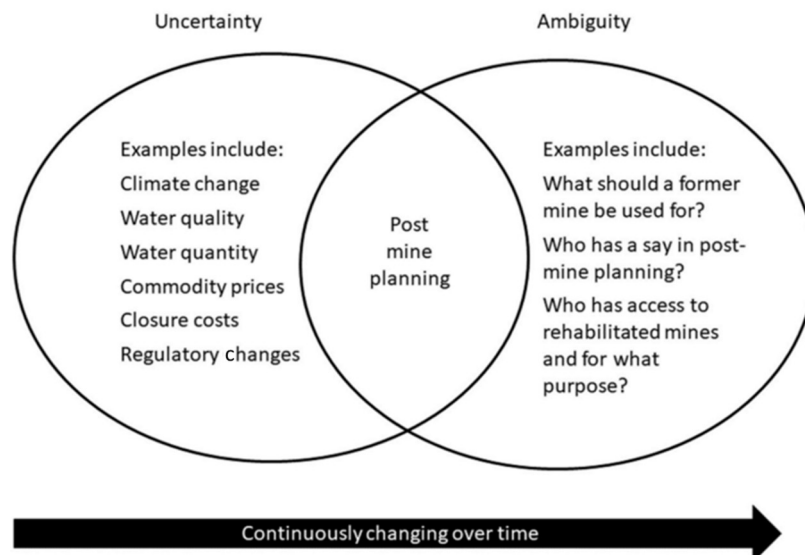


**Figure 2** Illustrative framework of the different planning approaches applied to future use projects for post-mining areas, according to their temporal orientation, spatial dimension, and primary driver

### 3 Reflecting on modern era challenges

#### 3.1 Uncertainty in your favour

Planning the transition of mined territories to new uses involves managing several interconnected factors. According to Measham et al. (2023), these factors can be grouped into two main categories: uncertainty and ambiguity (Figure 3).



**Figure 3** Role of uncertainty in post-mine planning (Measham et al. 2024)

Uncertainty refers to the variability of environmental, regulatory, and market factors. These are often unpredictable, non-linear, and interconnected. Ambiguity refers to the lack of clarity about the meanings, values, and goals linked to the future use of a territory, such as who decides, for what purpose, and at what

scale. These two dimensions coexist and reinforce one another over time, challenging traditional planning approaches.

Typically, in response to this scenario, organisations adopt strategies that focus on reducing risk, stabilising systems, and controlling variables. However, this approach may not be enough to deal with the increasing complexity and instability of today's world.

As an alternative, the concept of antifragility (proposed by Taleb [2012]) offers a new perspective; to view territories not as fragile or static systems, but as living organisms capable of learning from instability and evolving through it.

According to Taleb (2012), antifragile systems do not merely resist chaos (like the robust), but improves because of it. While the fragile breaks under stress and the robust remains the same, the antifragile systems adapt, strengthen, and use volatility as a source of growth. In territorial planning, this means shifting the narrative: it is not the most stable territory that thrives, but the one continuously reinventing itself in the face of adversity.

When applied to mine repurposing, this perspective promotes open, experimental, decentralised, and iterative approaches that embrace error as part of the process and see unpredictability as a source of innovation. Instead of aiming for rigid, fully controlled solutions, this approach supports flexible models where uncertainty becomes a learning opportunity.

This mindset is especially relevant today, in a world of global instability, climate change, and shifting social agreements. Thriving territories are those that do not cling to stability at all costs, but instead learn from disruption, redefine their purpose, and cultivate new possible futures, despite uncertainty and ambiguity.

### 3.2 Manage what matters

The execution of complex projects in contexts of territorial transition demands approaches that combine careful planning, flexible implementation, and continuous learning. According to Flyvbjerg (2023), evidence accumulated from large-scale projects, shows that the best results are achieved when time is invested upfront – in conceptual structuring, strategic alignment, and clear definition of objectives – enabling more agile, cohesive, and resilient implementation. As the Flyvbjerg (2023) states, “projects usually don't go wrong, they start wrong”. That is, the most common issues do not arise during execution but stem from flaws in initial design.

*“In this complex world, we can and must move the probabilities in our favour, but we can never achieve certainty. Good risk managers know this in their bones and are prepared for it” (Flyvbjerg 2023).*

According to him, it is crucial to be aware of the risks that come with premature commitment to specific solutions, timelines, or budgets, especially when working under high uncertainty. Making decisions too soon can reduce a project's flexibility over time and weaken its ability to adapt to changing contexts.

*“Don't assume you know all there is to know. (...) That sort of premature commitment puts you at risk of missing not only glaring flaws but also opportunities that could make your project much better than what you have in mind now. (...) At first, commit to having an open mind; that is, commit to not committing” (Flyvbjerg 2023).*

Another critical aspect is acknowledging that many challenges in future use projects are actually similar and can be repeated. Although each territory has its unique features, assuming the project is exceptional can limit the use of valuable historical data and lessons learned from previous experiences. By comparing projects and referring to similar cases, what Flyvbjerg (2023) calls the 'outside view' decision-making becomes more based on evidence and less prone to bias.

Lastly, Flyvbjerg (2023) argues that modularity is an powerful strategy to increase scalability, reduce risks, and speed up delivery. Projects built around repeatable modules, both physical and conceptual, allow for small-scale testing, continuous improvement, and faster adaptation to different territorial contexts. In future

use processes this can mean, for example, zoning areas for phased occupation, developing prototypes of territorial uses, temporarily testing productive arrangements or governance models, and gradually scaling them as they prove successful.

The author also poses a thought-provoking question for project manager: ‘What’s your Lego?’ He suggests shifting the mindset from ‘one big thing’ to ‘many small things’. According to Flyvbjerg (2023), modularity helps make projects faster, cheaper, and less risky, without losing their transformative potential.

These approaches, with focus on iterative strategic planning, flexible decision-making, and evidence-based learning, are especially valuable in projects that aim to combine innovation, sustainability, and positive territorial impact.

### 3.3 Engage to transform

Change management is a great challenge in projects set in complex and transformative contexts, such as those involving post-mining land uses. In these initiatives, change goes beyond physical or technical aspects of the territory; it requires reshaping narratives, expectations, institutional roles, and forms of collective action.

It is therefore useful to reflect on the factors influencing the adoption, alignment, and sustainability of structural transformations. For example, the Awareness, Desire, Knowledge, Ability, and Reinforcement (ADKAR) model (Hiatt 2006), a well-known change management framework, is based on the premise that effective change only occurs when individuals and organisations go through five dimensions: ‘awareness’ of the need for change; ‘desire’ to participate and support it; ‘knowledge’ on how to change; ‘ability’ to implement it; and ‘reinforcement’ to sustain the change over time.

Often, initiatives jump straight to the implementation without first ensuring a clear understanding of why the change is necessary (awareness) or without actively involving key stakeholders (desire). Sometimes, initiatives are technically sound but face resistance or low engagement due to a lack of shared knowledge (knowledge) or institutional support and capacity (ability).

In future use projects, where there are multiple scales of interest, long-term visions, and diverse stakeholders, it is essential to pay closer attention to the human factors that shape transitions. These aspects are often overlooked in traditional planning. A more sensitive approach to change management strengthens the legitimacy of projects and encourages collaboration, helping initiatives move forward consistently.

Still within the human dimension, decision-making requires more than technical knowledge; it also requires awareness of how we think, feel, and judge under conditions of uncertainty. The way we perceive risks, evaluate alternatives, and project scenarios are influenced by cognitive biases; systematic patterns of thinking that can shape judgment, as stated by Kahneman (2011).

Some of the most common biases in projects include: confirmation bias (the tendency to seek information that supports pre-existing ideas), availability bias (giving undue weight to easily recalled information, even if it’s not the most representative), anchoring effect (overreliance on an initial reference point), and loss aversion (the emotional impact of losses is perceived as greater than that of equivalent gains) (Kahneman 2011).

Recognising that invisible mental structures shape our decisions helps improve the quality of the projects we plan and deliver. This becomes a strategic competence in territorial transition environments, marked by high uncertainty, multiple interests, and longtime horizons.

## 4 Vale Case Studies

The transition of mined areas to new uses is a living process shaped by strategic decisions, active listening, and continuous learning. This section presents experiences from different territories where Vale has led such initiatives.

The cases presented here vary in their maturity levels and territorial contexts. Yet, they share a common purpose: to transform former mining assets by balancing social, environmental, and economic sustainability.

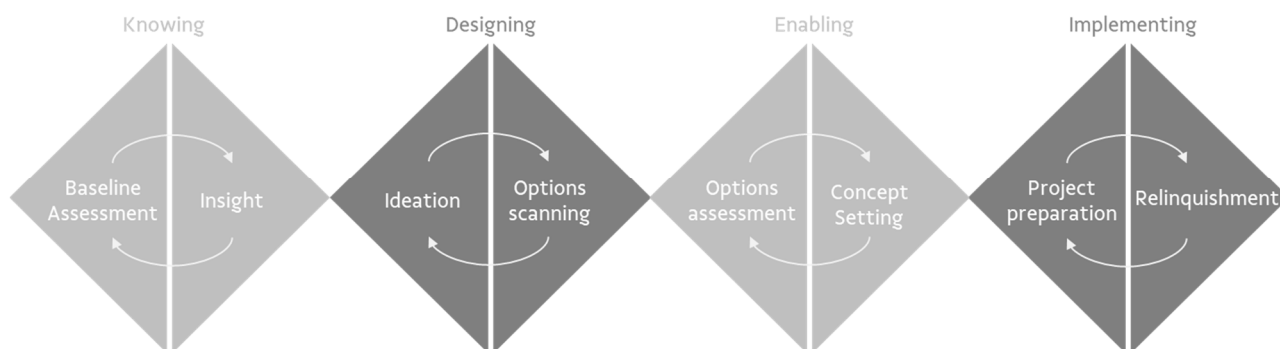
These projects aim to create spaces that generate shared value, respect local context and history, and expand future possibilities. Rather than offering ready-made solutions, each example provides insights and lessons about real-world implementation challenges and potential pathways to enable sustainable, adaptable, and collaborative projects.

#### 4.1 Design thinking-based approach

Vale's planning model is designed to connect different timeframes and territorial scales. This is achieved through a methodology based on design thinking, particularly the Double Diamond framework, which structures the process into phases of divergence and convergence. It starts with a deep understanding of the problem to develop effective solutions (Figure 4).

Although still in the consolidation process, this model has already guided the search for best practices in territorial transition projects. It serves as a reference for combining technical assessments, active listening, and the creation of alternatives based on evidence and local values. As mining operations near closure, the opportunity for co-creation with stakeholders grows, allowing for the refinement of narratives; alignment of future visions; and validation of proposals (Januário et al. 2023). A zoning approach has been adopted to support cycles of experimentation and learning, aligned with the progressive closure of areas.

As the process moves forward, more precise diagnostics and stronger engagement with local stakeholders becomes possible, along with better alignment of project timelines. Seen as a continuously evolving model, this methodological approach seeks to balance probable and desirable futures, offering solutions that consider both technical and legal constraints and the aspirations of communities and potential of each territory.



**Figure 4 Vale Brazil's revised future land use project methodology from a design thinking perspective (Adapted from Januário et al. 2023)**

#### 4.2 Minecraft education: gamification for youth engagement

In partnership with Microsoft, Vale implemented an engagement initiative with young people and children from communities near its mining operations, using Minecraft Education; the educational version of the world's most popular game. The initiative aims to introduce students to the mining world and encourage the collective construction of sustainable scenarios for the future of mined areas.

Through a gamified and collaborative approach, the project promotes environmental education, pedagogical innovation, and structured listening; strengthening the relationship between the company, the territory, and the new generations. Among the main benefits observed for Vale are closer ties with the community through a structured educational program, the launch of territorial listening focused on future land use, and integrated action with local governments, such as those in Canaã dos Carajás (Pará) and Nova Lima (Minas Gerais).

From the community's perspective, the benefits include access to new tools and learning methodologies, and the development of skills in innovation and sustainability, especially among students with limited access to educational technologies.

In its first edition, the project involved four schools (two in Pará and two in Minas Gerais), with the participation of 26 teachers and more than 1,750 students. Within the game platform, replicas of three Vale mines were built and used to stimulate reflection on the challenges and possibilities for transforming these territories in the post-mining context. Figure 5 illustrates a structure from the SD11 Mine, in Canaã dos Carajás, recreated within the Minecraft platform.



**Figure 5** Minecraft-based representation of a structure from the SD11 Mine, located in Canaã dos Carajás

### 4.3 Future use house: a living space for listening and co-creation

The Future Use House is a physical space located at Águas Claras Mine, occupying an area of 320 m<sup>2</sup>, intended for structured listening to stakeholders. The aim is for the house to become a space for genuine, continuous, participatory and broad engagement; contributing to the reframing of Águas Claras Mine.

The Future Use House serves as a platform to preserve and share stories, supporting the mine closure process while exploring opportunities for implementation across various regions to foster co-creation of future land use. Inspired by international best practices in engagement and activation, the space integrates both physical and digital resources. Its primary purpose is to function as a dynamic living environment encouraging stakeholder involvement through organised visits, discussions and workshops (Vale 2024). Experiences like the Future Use House (Figure 6) reinforce that engagement is not an event; it is a process, and an integral part of the overall strategy. By June 2025, the space had received approximately 600 visitors.



**Figure 6 Panel featuring information about the Águas Claras Mine, currently on display at the Future Use House exhibition**

#### 4.4 Digital twin for nature

The Green Cubes Project is being piloted at Águas Claras Mine, serving as a case study for the application of Green Cubes technology, in collaboration with R-evolution – Hexagon’s green tech subsidiary. The aim is to develop a multidimensional model of the mine’s environmental assets, facilitating a better understanding of opportunities related to natural capital. The project will assess data collection and generation through the combination of various technologies, the integration of key indicators, compliance with international standards and the feasibility of a digital asset sponsorship model for generating resources through environmental conservation (Vale 2024).

The partnership aims to enhance forest monitoring in Vale’s areas using advanced technologies that enable a deeper understanding of ecosystem biodiversity, by creating a digital twin of nature.

The initial efforts of the Green Cubes Project, at the Águas Claras Mine unit (MAC), focus on activating four distinct experience points, with the goal of generating comparisons and lessons learned to guide the project’s next phases. The initiative is located within the Mata do Jambreiro, a private preservation area covering 9,120,000 m<sup>2</sup>, and an additional 4,000,000 m<sup>2</sup> of legal reserve. The site hosts a rare ecological transition zone between the Atlantic Forest and Cerrado biomes.

In this context, the project seeks to evaluate and discuss methodologies for measuring, monitoring, and managing natural capital; considering the site’s transition towards future use. The objective is to support more informed, integrated, and sustainability-oriented decision-making.

#### 4.5 Digital twin for legacy

The concept of a digital twin has become a strategic solution for the monitoring and managing assets throughout their lifecycle. In the context of mine infrastructure and industrial heritage, its application enables the creation of high-precision digital representations that integrate technical, historical, and contextual data.

This approach expands the possibilities for preserving and repurposing existing structures, enhancing the use of buildings with historical, technical, or symbolic value, and enabling their integration into new uses. By capturing not only the material aspects of the structure but also its meanings and contexts, the digital twin becomes a powerful tool for preserving memory and telling the story of a transforming territory.

As a pilot project, a digital twin was developed for one of the structures at the Córrego do Feijão Mine in Brumadinho (Minas Gerais), scheduled for decommissioning as part of the environmental recovery process initiated after the dam collapse in 2019. The initiative aims to capture, with a high degree of fidelity, the technical and visual record of the facility before its decommission (Figure 7).

More than an archival resource, the model supports projects for industrial repurposing, heritage education, community engagement, and applied engineering innovation. By combining digitisation technologies with territorial sensitivity, the initiative contributes to the construction of a technical and narrative legacy.



**Figure 7** Laser scan representation of an industrial structure at the Córrego do Feijão Mine, developed as part of a digital twin model

#### 4.6 GenIA: signs of the future with artificial Intelligence

To make the process of building future land use scenarios more agile, scalable, and continuous, Vale developed a Proof of Concept in partnership with A3Data and AWS (Amazon), using a generative artificial intelligence application. The initiative aims to overcome the cost and time limitations of traditional studies by enabling more frequent updates and internalising analytical steps that previously depended heavily on specialised consultants.

The solution was initially tested in six pilot territories and structured around four main dimensions:

1. Objects of tomorrow (OdAs): identification of technologies, startups, behaviours, and emerging trends that could influence or inspire possible futures for each territory.
2. Territories: analysis of characteristics such as economy, geography, population, climate, industry, and services.
3. Reflections: automated generation of interpretations and future use possibilities linked to the identified signals.
4. Interaction: use an artificial intelligence-powered chat to engage with data, propose scenarios, and visualise ideas through images and simulations.

A total of 551 OdAs were identified, organised into four types (science, technology, business, and process) and grouped into eight major themes such as circularity, energy, habitat, and entrepreneurship. The outcome was the generation of over 950 strategic insights, tailored to the specific attributes of each territory.

Key benefits of this solution include increased scale and frequency of updates, reduced operational costs, strengthened internal intelligence, and the potential to expand the tool's use beyond Vale; contributing to more inclusive planning processes that are better connected to tomorrow's challenges.

## 5 Conclusion

Planning for the future use of post-mining areas imposes a new imperative on organisations: balancing transparency with delivery, vision with action, and aspiration with coherence. More than offering definitive answers, it is about demonstrating the ability to navigate uncertainty, foster genuine engagement, and build flexible yet intentional pathways.

This paper discussed how the integration of forecasting and foresight, combined with approaches such as design thinking, stakeholder engagement, and the use of emerging technologies, can turn plans into legitimate and contextually viable commitments. It also explored how regulatory evolution, international indicators, and innovative pilot projects are shaping new transition practices in the mining sector.

Planning for the future is not about accurately predicting what is to come, but about being prepared to act responsibly in the present, even in the face of the unknown. It is within this commitment, between imagination and execution, that the strength of post-mining land use projects lies: not simply processing data or forecasting trends, but orchestrating possibilities with empathy, creativity, and collaboration.

Therefore, a successful post-mining transition is not just about handing over assets, it is about generating legacies. Legacies that are built not only through what is seen, but also through what is felt and sustained over time.

## Acknowledgement

We thank Vale for the institutional support and trust in leading the initiatives presented in this paper. We extend our appreciation to all professionals involved, whose contributions were essential to the technical and methodological development of the projects. We also thank our external partners, who collaborated strategically in the joint construction of innovative solutions for the future of post-mining territories.

## References

- Asia-Pacific Economic Cooperation 2018, *Mine Closure Checklist for Governments*, Singapore.
- EY 2024, *Top 10 Risks and Opportunities for Mining and Metals Companies in 2025*, Perth.
- EY 2023, *Top 10 Risks and Opportunities for Mining and Metals Companies in 2024*, Perth.
- EY 2022, *Top 10 Risks and Opportunities for Mining and Metals Companies in 2023*, Perth.
- EY 2021, *Top 10 Risks and Opportunities for Mining and Metals Companies in 2022*, Perth.
- EY 2020, *Top 10 Risks and Opportunities for Mining and Metals Companies in 2021*, Perth.
- Flyvbjerg, B & D Gardner 2023, *How Big Things Get Done: The Surprising Factors That Determine the Fate of Every Project, from Home Renovations to Space Exploration and Everything in Between*, Pan Macmillan, London.
- Hiatt, J 2006, *ADKAR: A Model for Change in Business, Government and Our Community*, Prosci Research, Fort Collins.
- ICMM 2025, *Handbook on Multistakeholder Approaches to Socio-Economic Transitions in Mining*, London.
- Januário, J, Muniz, A, Silva, A, Roque, G, Duffles, E, Almeida, A 2023, 'Developing an incremental and strategic approach for postmining land use identification and planning', in L Coudert, I Demers, P Hernandez, J Ordonez, D Priscu, F Rivero, D Serra, P Valenzuela, J Wiertz (eds), *8th International Congress on Environment and Social Responsibility in Mining*, Gecamin, Santiago, <https://www.gecaminpublications.com/sustainable-mining-2023/>
- Kahneman, D 2011, *Thinking, Fast and Slow*, Farrar, Straus and Giroux, New York.
- Measham, T, Walker, J, Haslam McKenzie, F, Kirby, J, Williams, C, D'Urso, J, ... Boggs, G 2024, 'Beyond closure: a literature review and research agenda for post-mining transitions', *Resources Policy*, vol. 90, 104859, <https://doi.org/10.1016/j.resourpol.2024.104859>
- Taleb, N 2012, *Antifragile: Things That Gain from Disorder*, Random House, New York.
- Vale 2025, *Integrated Report 2024*, Rio de Janeiro, <https://vale.com/esg/document-library>