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Bringing the future of ground control to life: an integrated systems approach

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Abstract

Despite executive-level attention and increased investments in technology, ground control-related incidents continue to occur in both underground and surface mining environments. Incident investigations reveal that technology investment is required, although this alone is insufficient to prevent incidents; implementation, maintenance and support programs are also often neglected. To remedy this, the authors advocate a multi-pronged approach where technology is one part of a broader prevention strategy that includes effective deployment, sustained upkeep and non-technology-related endeavours.

Successful technology implementation is not just selecting the right technology: a key challenge and common failure point is ensuring that sites are engaged throughout the process. Bringing sites along on the journey means involving them in decision-making, identifying and mitigating risks early in the process, and fostering adoption in daily operations. Drawing on work across multiple mining companies, including Vale Base Metals, this paper presents an integrated approach to technology scanning, prioritisation and needs-based site assessment, resulting in operating-level technology roadmaps that mitigate critical risks. This approach, though new to the mining industry, is derived from learnings in other industries. We will share a model for the future that will impact how mines are managed, including advancements in reducing worker exposure, monitoring, modelling, ground support and characterisation, coupled with our approach to engaging entire organisations through a program that sets a foundation for the future.

Keywords: *geotechnical, ground control, technology, roadmap, future*

1 Introduction

Vale Base Metals (VBM) currently operates seven underground mines and four surface mines in Canada, Brazil and Indonesia. A critical risk that must be managed at these mines is the impact of rockbursts and falls of ground on people, infrastructure and equipment. Unfortunately, as underground mining depths and extraction ratios (proportion of ore removed compared to the total amount of ore available) have increased over time, so too has the frequency of seismic events, thereby increasing the risk of rockbursts in these mines. Additionally, as surface mines have expanded, the amount of exposed rock that must be managed by ground control teams has increased, posing unique challenges. Consequently, in addition to sound engineering principles, there has been a focus on utilising technology to assist in rock mass support, characterisation, monitoring and modelling, as well as to reduce worker exposure. This focus led to multiple initiatives driven by various teams throughout the organisation. Although these initiatives were progressing with the best of intentions, several challenges emerged, including:

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- no single unifying vision
- lack of visibility at the leadership level regarding ongoing projects and their benefits
- unclear roles and responsibilities concerning technology project prioritisation and implementation
- insufficient budget and resources to implement all technology projects in a timely manner.

To address these challenges, VBM developed a technology framework designed to guide innovation and implementation efforts across the organisation. This framework began by establishing a clear ambition, articulated through well-defined problem statements, thematic focus areas and strategic goals. It enabled the creation of a portfolio of technology options informed by systematic scans and detailed profiling.

The framework also encouraged innovative thinking by challenging conventional assumptions and exploring feasibility through structured assessments. Collaboration was central to its success, with clearly defined roles and responsibilities helping to align efforts and overcome organisational barriers. Ultimately, the framework provided a unified direction for the company, culminating in the development of collaboratively built technology roadmaps that support long-term strategic alignment.

Though this paper primarily focuses on the technology framework developed, this area is but one piece of a larger management system. Recognising that technology alone is insufficient for a holistic approach to managing geotechnical risks, a ground control management system (GCMS) was defined to link not only the technology framework to a future vision, but also people, decision-making, project assurance and operation assurance frameworks to create a unified system.

2 Ground control management system

The VBM GCMS is applied to all company assets and is composed of five frameworks: people, decision-making, technology, project assurance and operation assurance. These frameworks were built on a foundation of standards, procedures and guidelines, underpinned by leadership commitment and a culture driven by key behaviours, as illustrated in Figure 1. By integrating these frameworks, the GCMS aims to create a cohesive and effective approach to managing geotechnical risks, ensuring that all aspects of the business are aligned and working towards common goals.

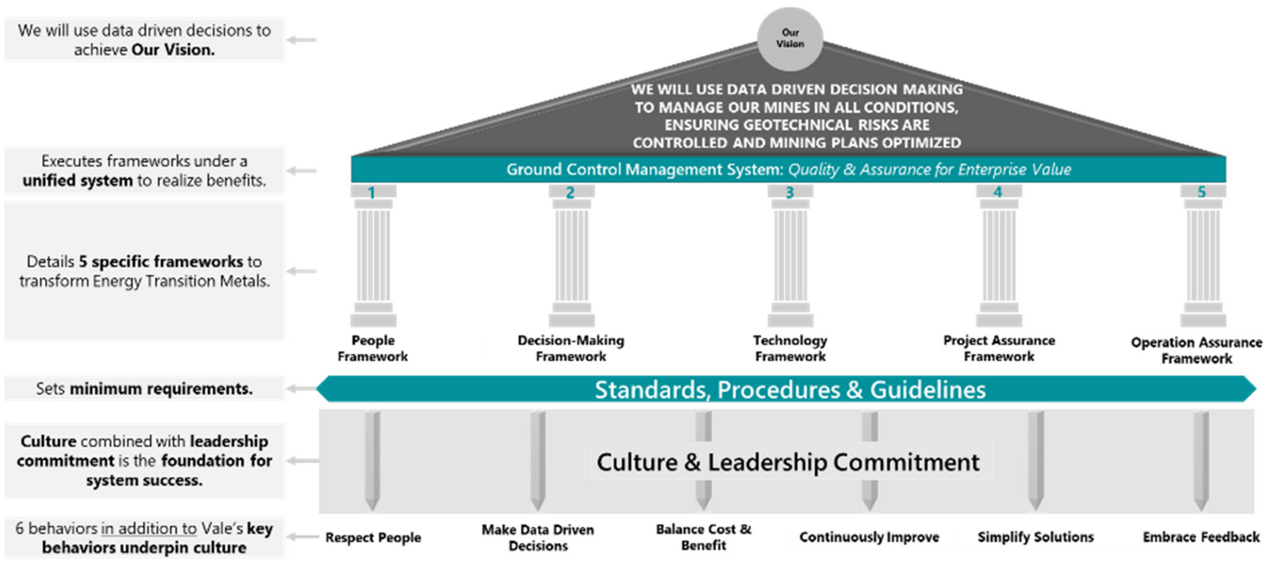


Figure 1 The Vale Base Metals' ground control management system

3 Technology framework

Integral to the GCMS is the technology framework, which was developed primarily to assist with the management of geotechnical-related risks. The objectives of the framework are not only to address immediate safety concerns but also enhance overall operational efficiency and profitability, as shown in Figures 2 and 3.

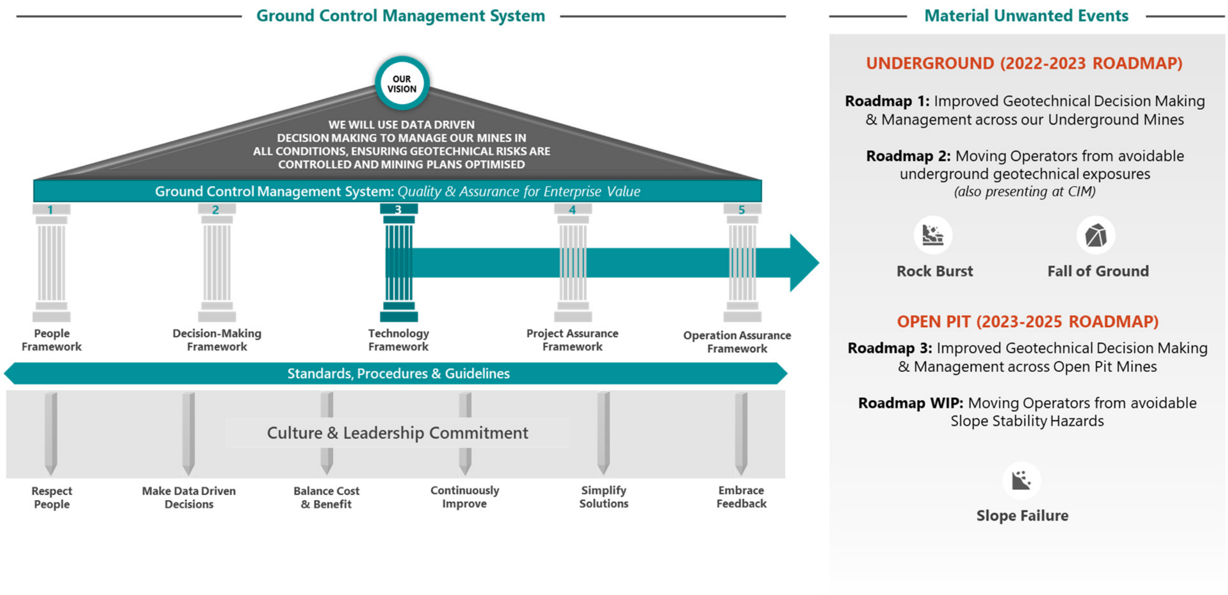


Figure 2 Vale Base Metals' technology framework

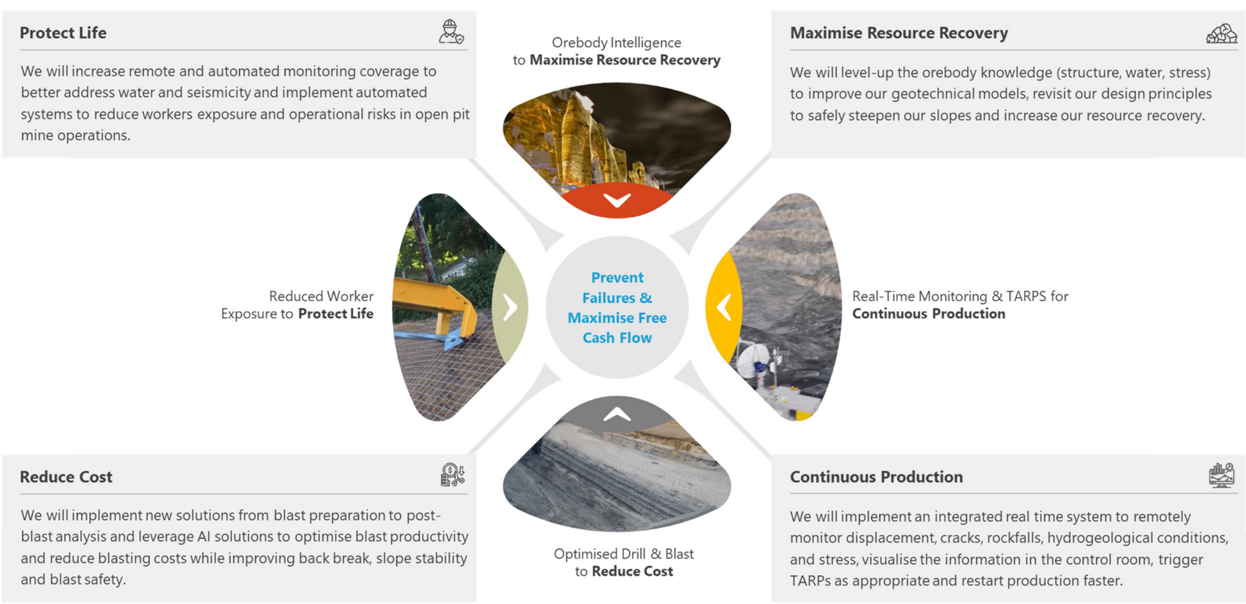


Figure 3 Vale Base Metals' technology value equation for slope management

The technology framework at VBM ensures that technological innovation is systematically integrated into mining operations in alignment with the overarching goals of the GCMS. This integration is achieved through the development and implementation of technology roadmaps which align with corporate priorities, address specific operational needs, foster collaboration and secure stakeholder commitment.

Before developing a technology roadmap, it is essential to define the criteria that make it effective. A strong roadmap should be anchored in a clear vision and address well-defined challenges. Each technology initiative must respond to prioritised needs that are validated through diagnostics, workshops and leadership engagement.

A roadmap should outline the technologies selected to address a specific challenge and organise them across multiple time horizons. For the VBM roadmaps, technologies were organised across time horizons. Horizon 1 included mature technologies with low uncertainty; Horizon 2 covered emerging technologies with a clear development path; and Horizon 3 encompassed high-uncertainty technologies with unresolved questions around readiness, supply or implementation. In addition to guiding implementation, roadmaps should serve as a visual communication tool, clearly presenting key themes, initiatives and responsibilities, and enabling factors over time.

To ensure a technology roadmap is grounded in operational reality, the scope and relevant activities must be clearly defined. For VBM, this began with the development of a geotechnical life cycle, as shown in Figure 4, which categorised the critical activities geotechnical teams undertake to manage rockbursts and falls of ground. From this foundation, focus areas were identified. These included reducing personnel exposure to slope and seismic hazards, enhancing protection through improved ground support and monitoring, and enabling safer mine planning through better rock mass characterisation, modelling and predictive analysis.

Figure 4 Vale Base Metals' geotechnical life cycle

4 Exposure definitions

From the outset it was crucial to define exposure zones for both underground and surface operations. These exposure zones were essential for qualifying the benefits associated with technologies aimed at reducing worker exposure.

For underground mines at VBM, the exposure zone was defined as the area of the floor adjacent to an unsupported or partially supported face that extends a distance equal to the height of the back at the face (1:1 ratio). The following exposure levels were defined for workers in these zones:

- personnel outside of the exposure zone within a cab were considered to have low exposure
- personnel inside of the exposure zone within a cab were considered to have moderate exposure
- personnel on foot or on equipment without a cab and within the exposure zone were considered to have high exposure.

For surface mines, the exposure zones were defined as follows:

- at the toe of the slope, the zone was 1.5 times the height of the wall
- at the crest of the slope, the zone was 0.5 times the height of the wall.

The following exposure levels were defined for operators working in these zones (refer to Figure 5):

- personnel working outside of these exposure zones were considered to have low exposure
- personnel working in a cab within these exposure zones were considered to have moderate exposure
- personnel working on foot or on equipment without a cab and within these exposure zones were considered to have high exposure.

Although the definitions above for both underground and surface mines at VBM could be considered simplistic as they do not consider local ground conditions, they were deemed fit for purpose by a multi-disciplinary team spanning multiple assets.

By clearly defining these exposure zones and levels, the impact of new technologies on worker safety could be more accurately assessed, ensuring that the implemented solutions effectively reduce exposure and enhance overall safety in both underground and surface mining environments.

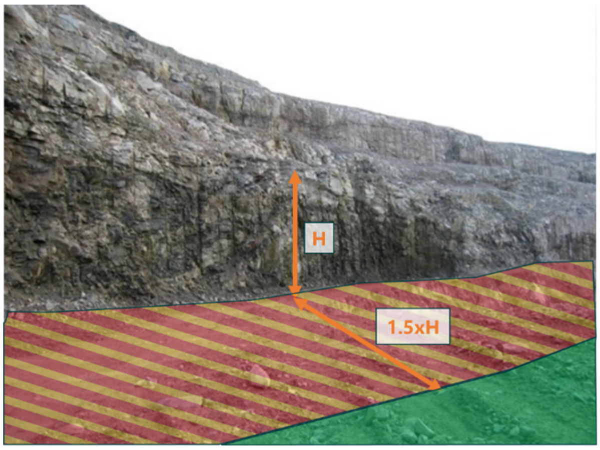


Figure 5 Exposure zone defined at the toe of slopes for Vale Base Metals' surface mines

5 Activity definition, exposure time and exposure rating

Building on the defined exposure zones it was then essential to identify and evaluate activities that constitute the development and production cycles for both underground and surface mines at VBM. This evaluation aims to determine the total exposure time and rating for workers during each activity, ensuring that the business focuses on technologies that offer the greatest benefits.

To achieve this, multi-disciplinary teams were formed, representing both underground and surface mining operations. For underground mines, 45 activities were identified within the typical development and production cycles that could potentially be improved through technology and process enhancements from an exposure perspective. For surface mines at VBM, production and support activities were categorised into 68 hard rock activities and 43 soft rock activities (refer to Figure 6).

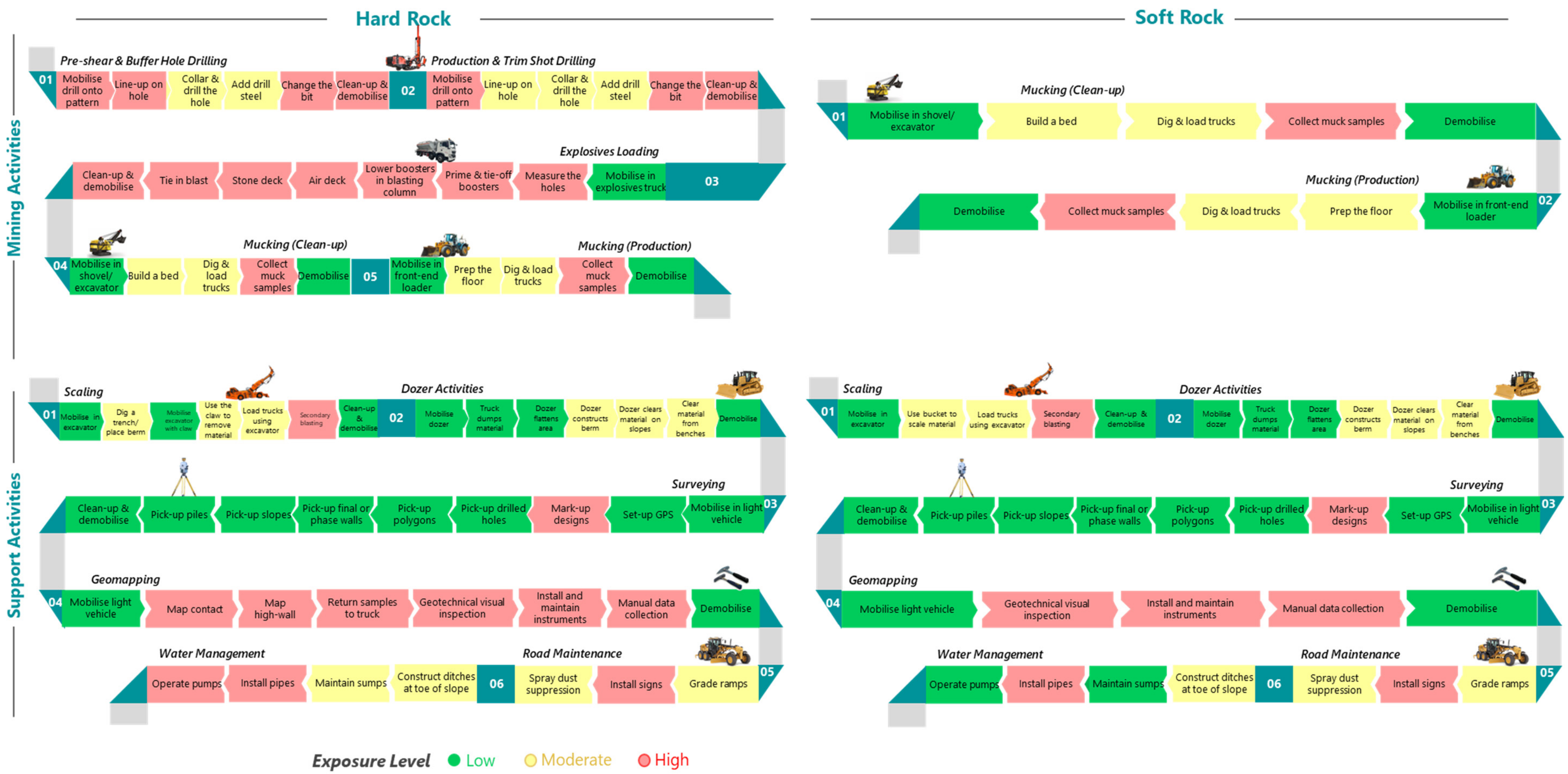


Figure 6 Production and support activities mapped for surface mines at Vale Base Metals

Once the exposure zones and activities were defined, the exposure time and rating for each activity was determined using a first principles-based approach. This analysis was conducted for both underground and surface mining activities. Figure 7 illustrates the mapped exposures for surface mining activities at VBM.

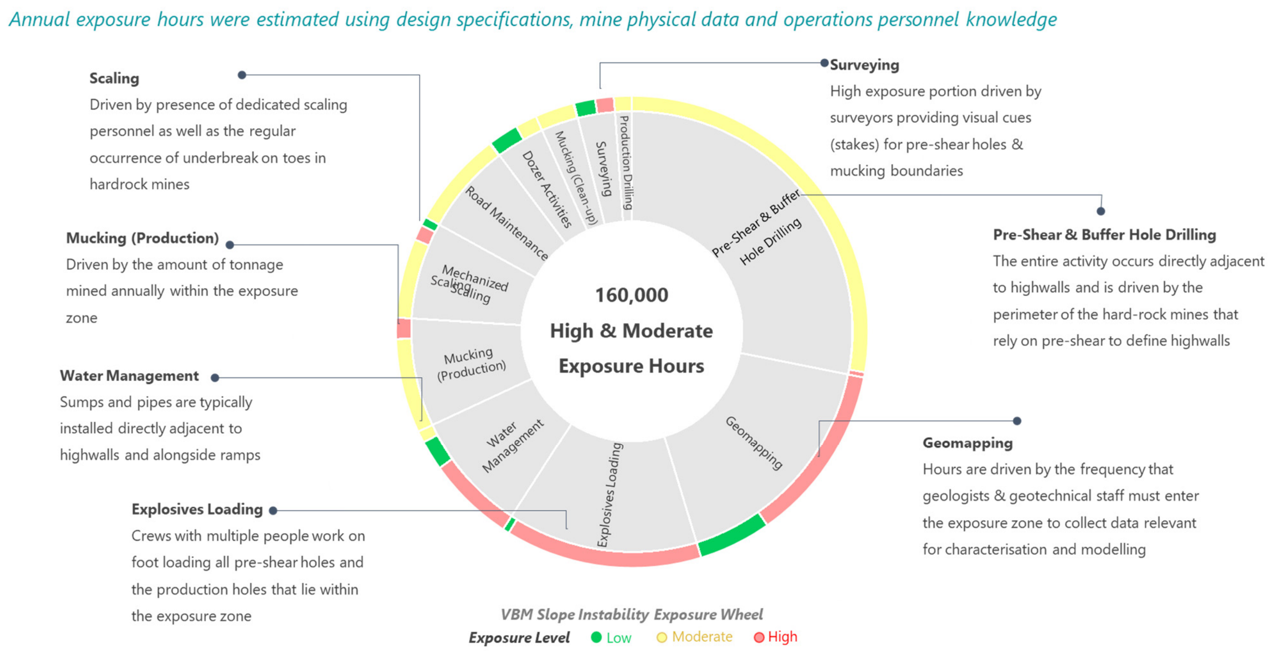


Figure 7 Activity exposure map for surface mining at Vale Base Metals

By systematically defining and evaluating these activities, the key steps in the development and production process were identified and prioritised for technological improvements, ensuring maximum business benefits.

6 Technology scanning

Following the identification of activities, definition of exposure times and specification of exposure ratings, a comprehensive technology scan was conducted to identify technologies that could address operational needs. The industries explored for potential technology solutions included, but were not limited to, aerospace, defence, mining, medical, oil and gas, and information technology.

To facilitate the technology scanning process a series of structured sessions was organised, including the kick-off meeting, and needs, vision, options and planning workshops. The kick-off meeting was aimed to develop a digital diagnostic tool to capture and prioritise needs across various sites. This tool was distributed to site representatives to ensure a comprehensive understanding of the operational requirements. The needs workshop served to reconfirm the needs identified through the digital diagnostic, uncover any additional requirements and identify existing initiatives at the sites that could be leveraged. The vision workshop was designed to establish the guiding principles, metrics and operating model that VBM aspired to achieve. This workshop also informed the selection of technology options by aligning them with the company's strategic vision. During the options workshop, the identified needs and requirements were matched with known technologies. These technologies were then prioritised based on their potential impact and feasibility, ensuring that the most promising solutions were selected. Finally, the planning workshop was focused on developing the final technology roadmap, which involved assigning roles and responsibilities, setting timelines and outlining the steps required for successful implementation.

By conducting these workshops VBM could ensure a thorough and collaborative approach to technology scanning, enabling the identification and prioritisation of technologies that would deliver the greatest benefits to the organisation.

6.1 Characterisation, modelling, monitoring, ground support and mitigation

Based on the results of the digital diagnostics, technology scans and workshops, thousands of technologies were identified for application in both underground and surface mining operations. Figures 8 and 9 illustrate the results of the technology scans for both underground and surface mines at VBM, respectively.

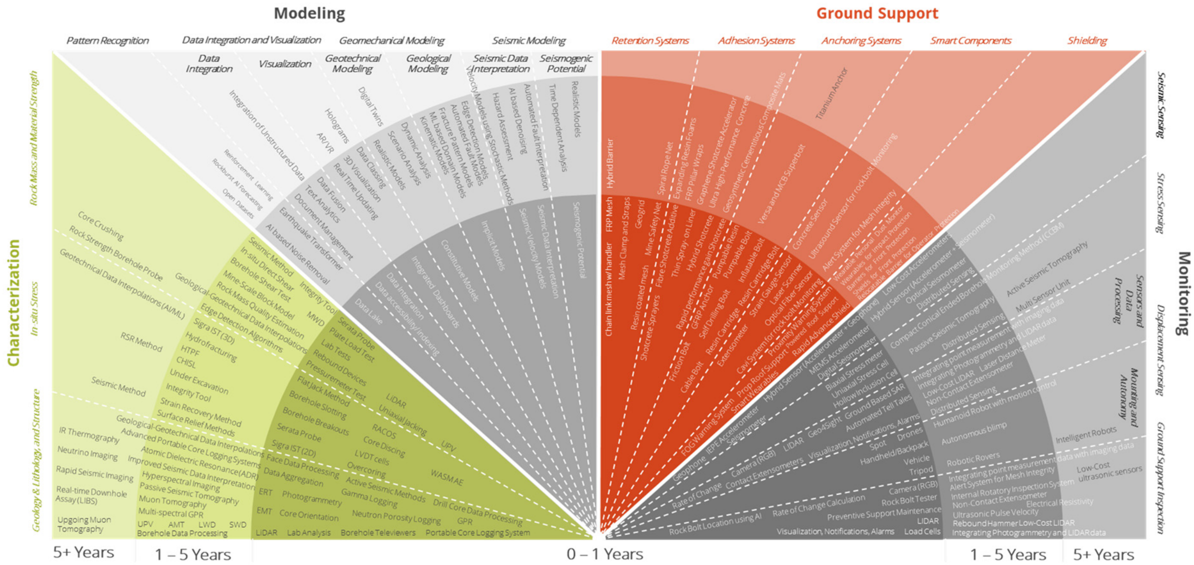


Figure 8 Final results of the technology scan for underground mines at Vale Base Metals (Stratalis 2023)

Figure 9 Final results of the technology scan for surface mines at Vale Base Metals (Stratalis 2024)

The comprehensive technology scans conducted at VBM enabled a structured classification of technologies, supporting a strategic approach to implementation across both surface and underground mining operations.

For surface mines, technologies were grouped based on their primary function. Monitoring technologies were identified for their role in detecting geotechnical risks, including displacement sensors to track rock mass movement, hydrogeological instruments to monitor groundwater behaviour, and stress sensors to detect changes within the rock mass. Complementing these were mitigation technologies which included slope reinforcement systems, physical barriers, water management infrastructure and controlled blasting techniques, all aimed at enhancing slope stability and reducing operational hazards.

Characterisation technologies played a critical role in understanding geological and geotechnical conditions. These included methods for geological mapping, rock mass strength assessment, hydrogeological characterisation and stress regime analysis. To support decision-making, modelling technologies were also identified, offering capabilities for simulating rock mass behaviour, integrating and visualising complex datasets, and forecasting potential geotechnical issues through advanced analytics.

In underground mining environments a similar classification framework was applied. Monitoring technologies focused on real-time sensing of seismic activity, stress variations and rock displacement, along with tools for inspecting ground support systems. Ground support technologies included advanced reinforcement materials and sensor-equipped elements designed to monitor performance and structural integrity.

Characterisation efforts in underground settings emphasised detailed geological and structural analysis, stress measurement and mechanical property evaluation. These insights were further enhanced by modelling technologies capable of simulating underground conditions, analysing seismic events and integrating geotechnical data for predictive insights.

This structured categorisation allowed VBM to align technology solutions with operational needs, ensuring that implementation efforts were both targeted and effective in enhancing safety, performance and long-term resilience.

6.2 Exposure reduction

In addition to technologies associated with protecting workers, characterising, modelling, monitoring and supporting the rock mass, a wide array of technologies were identified as having the potential to reduce worker exposure to geotechnical hazards. These technologies were aimed at enhancing safety in both underground and surface mining operations.

At the time of the scan many of the technologies were market-ready, indicating their immediate applicability and potential for rapid deployment. However, it was also noted that several promising solutions required further development to achieve full operational success. This development phase was seen as crucial for refining these technologies to meet the specific needs and challenges of the mining environment.

Figure 10 shows the technologies that could reduce worker exposure to slope hazards, while Figure 11 shows a non-exhaustive list of identified technologies that could reduce worker exposure to seismic and fall of ground hazards in underground mines.

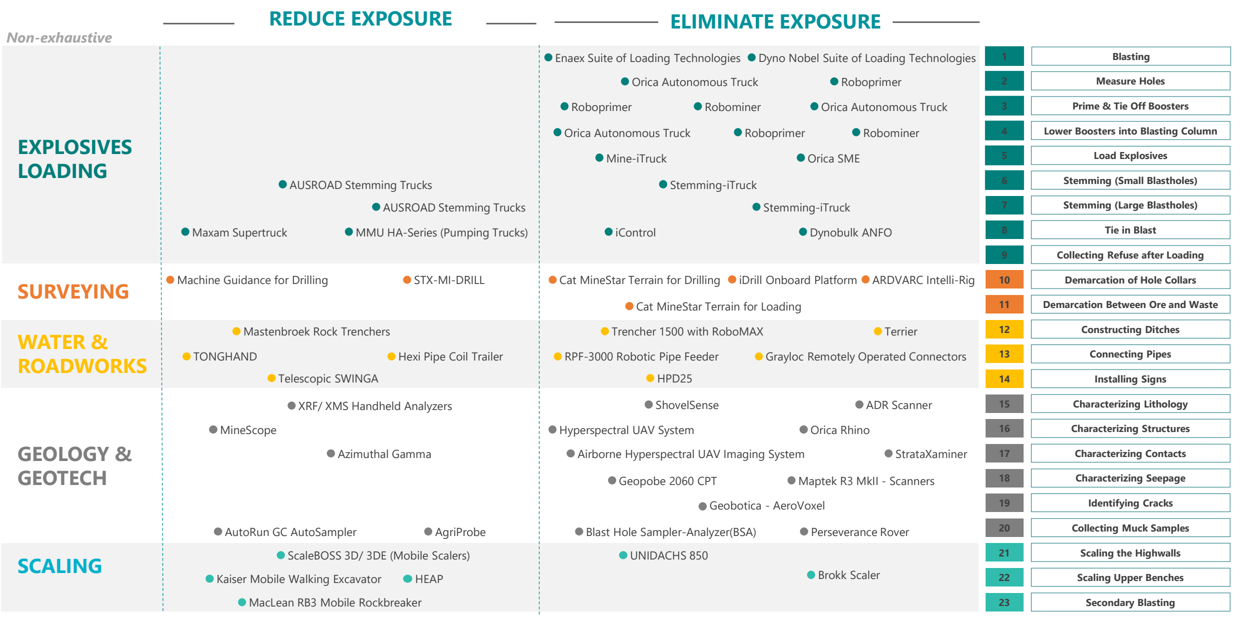


Figure 10 Technology scan results that may reduce worker exposure to slope hazards

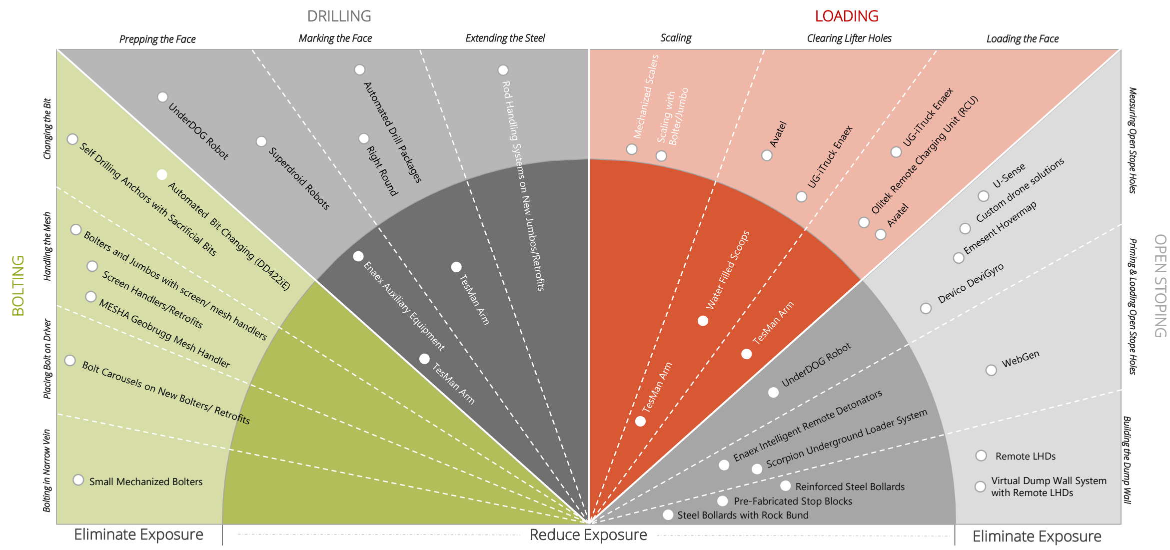


Figure 11 Technology scan results that may reduce underground hazard exposure (Stratalis 2023)

The categories shown in Figures 10 and 11 were based on activities mapped as part of the activity definition, exposure time and exposure rating assessment.

Explosive loading technologies were common elements to both underground and surface mining environments, while surveying, water management, geology and geotechnical activities were associated with reducing worker exposure to slope hazards. Drilling, bolting and open stoping were focused on reducing worker exposure in underground mining environments.

7 Needs-based approach to technology prioritisation

Upon completion of the technology scan it became imperative to prioritise the identified technologies. This was achieved via a thorough assessment of the mines which encompassed an evaluation of reports generated from biennial geotechnical audits as well as reviews carried out by the company's Geotechnical Review Board. Additionally, interviews with key stakeholders and the facilitation of workshops were integral to this process. For a detailed overview of the needs-based approach employed to prioritise technology projects across the business refer to Figure 12

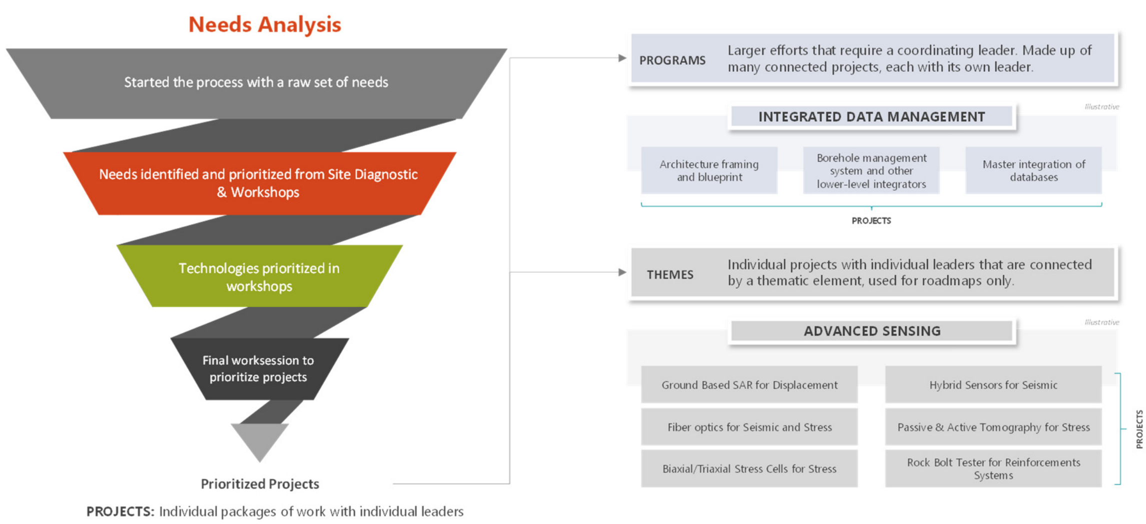


Figure 12 Needs-based approach employed at Vale Base Metals to prioritise the implementation of technologies

7.1 Benefits

During the technology scan the potential benefits of each solution were qualitatively assessed to inform prioritisation decisions. This evaluation considered a range of value drivers relevant to both operational performance and strategic outcomes.

Health and safety was a key focus, with technologies evaluated for their ability to enhance the wellbeing of employees, contractors and surrounding communities. The potential to reduce business interruptions was also considered, particularly in terms of minimising operational downtime or mitigating the impact of unforeseen events. Technologies that could strengthen the company's reputation, by improving stakeholder relations, regulatory standing or investor confidence, were also prioritised.

Financial implications were assessed based on both immediate and long-term cost impacts. In parallel, the potential to prevent or mitigate catastrophic events, particularly those that could lead to material unwanted events, was carefully reviewed. finally, environmental performance was evaluated, with emphasis on technologies that could reduce ecological harm or support sustainability objectives.

The following criteria were used to assess the aforementioned elements:

- Extreme: an extreme and certain impact
- Very high: a very high likelihood of significant impact on key performance indicators (KPIs), the company or the impact area
- High: a significant direct impact or avoidance of an impact on KPIs that, by itself, merits consideration
- Significant: a moderate or noticeable impact contributing to the overall benefit
- Low: a low impact on KPIs, either directly or through avoidance.

The results of the benefit assessment for the VBM Seismicity Management Technology Roadmap are illustrated in Figure 13. In this case, it is evident that the majority of benefits were associated with reducing costs and the likelihood of catastrophic events. This structured assessment enabled a balanced view of each technology's value, supporting informed and strategic implementation decisions.

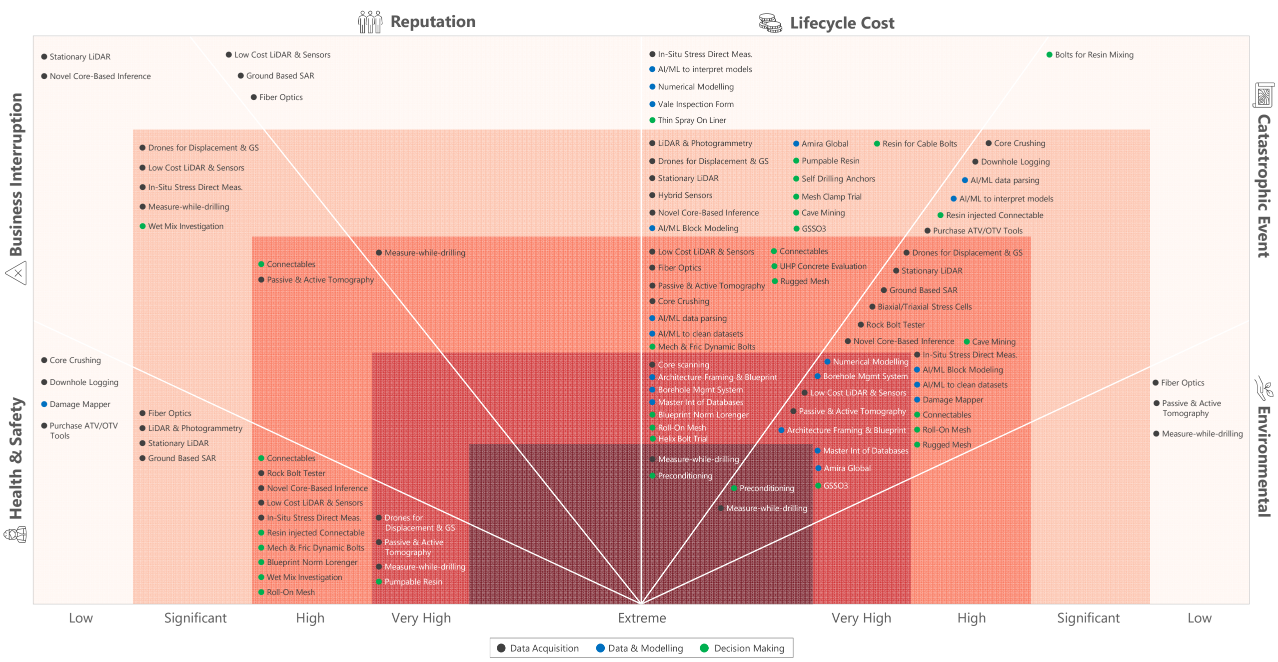


Figure 13 Estimated benefits of each project on the Vale Base Metals' Seismicity Management Technology Roadmap

7.2 Company readiness and uncertainty

As part of the technology prioritisation process it was essential to evaluate the uncertainties associated with each proposed solution. This evaluation considered several dimensions that influence the feasibility and success of implementation. The stability, maturity and availability of the supply ecosystem were examined to understand potential sourcing risks. Internally and externally driven factors that could support or hinder implementation were also assessed to gauge operational readiness. The technological maturity of each solution was reviewed, including its feasibility and integration within existing systems.

Financial and strategic viability was analysed through the lens of funding availability, business case strength and alignment with corporate objectives. Broader macro-level risks such as political, regulatory, economic, social, legal and environmental factors were also considered to understand external pressures that could impact deployment. Finally, potential showstoppers, both internal and external, were identified to anticipate and mitigate critical barriers before they materialise.

8 Project plan one-pagers

Upon completion of the technology scan and the confirmation of site needs, as well as the understanding of technology benefits and uncertainties to determine priorities, potential projects were defined around a technology or technologies. Worksheets or one-page summaries were developed for each project to serve as the foundation for the future management of each technology. They provided a concise description of the project, identified the project owner, specified the business needs, presented technology options along with enabling technologies and teams, outlined a high-level timeline for implementation, and detailed the required budget and support. Additionally, they highlighted the anticipated benefits of the project. For an example of a technology project one-pager, please refer to Figure 14.

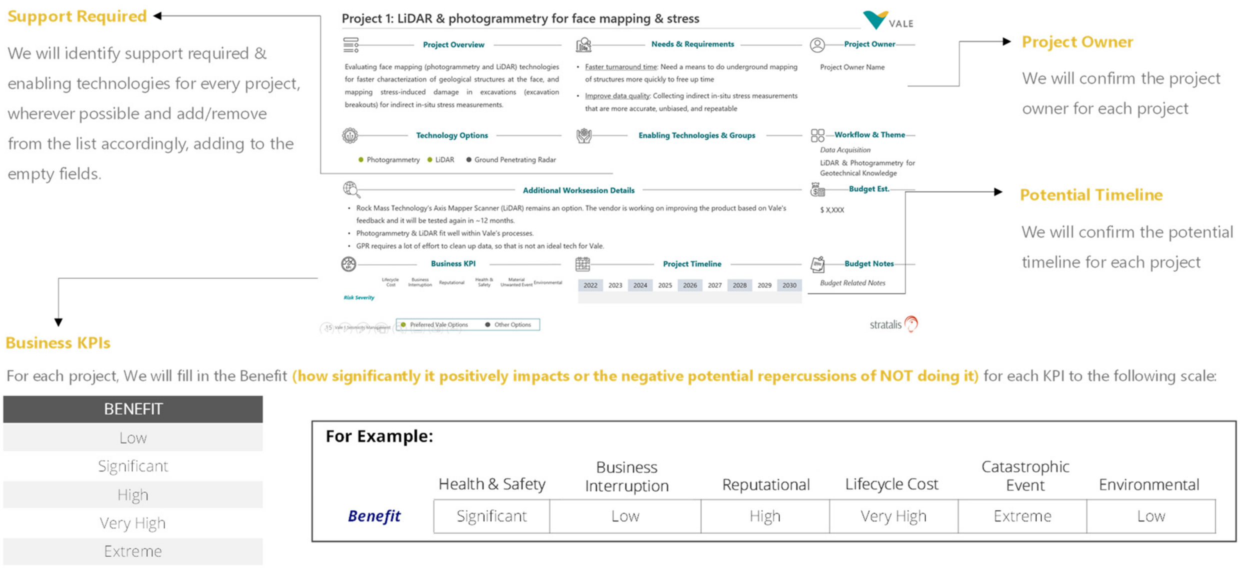


Figure 14 Example of a Technology Project Plan one-pager

9 Technology roadmap

To organise projects in a multi-time-horizon roadmap, key themes and programs of projects were delineated. A program is defined as a larger effort that necessitates a coordinating leader and comprises multiple interconnected projects, each with a designated project owner. Conversely, a theme consists of numerous individual projects, each with an owner, connected by a thematic element used solely for roadmap purposes.

For the VBM Seismicity Management Technology Roadmap approximately 50 projects were defined, then categorised into three programs and 10 themes. The programs and themes established for the roadmap are illustrated in Figure 15, while individual projects are depicted in Figure 16.

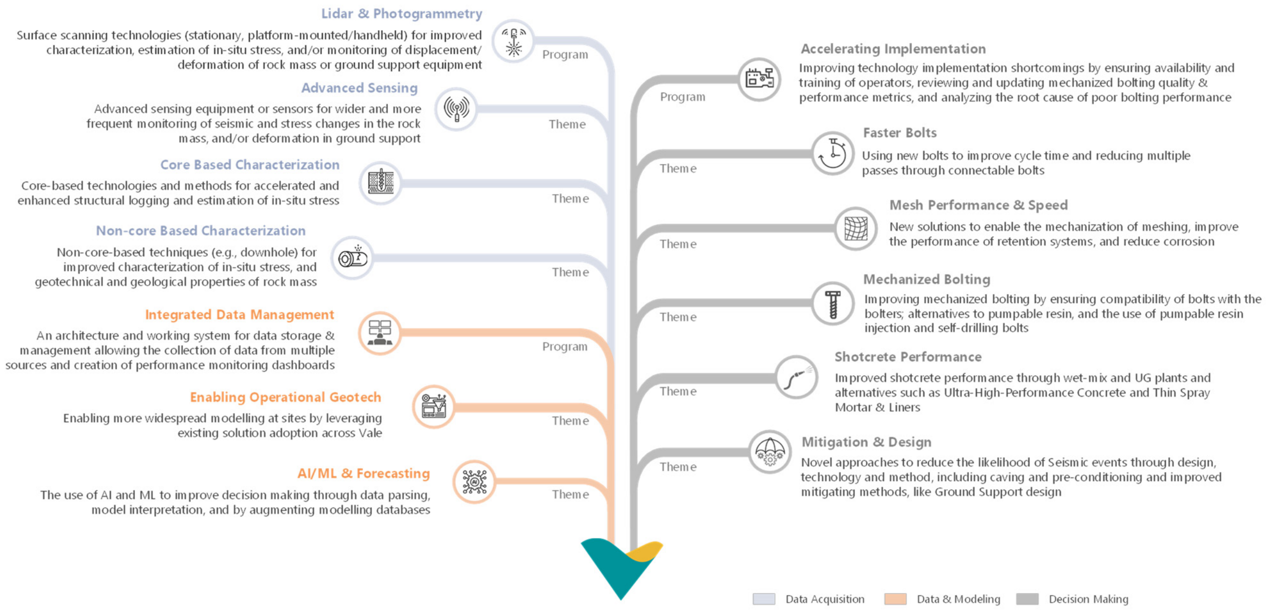


Figure 15 Programs and themes that form the Seismicity Management Technology Roadmap for Vale Base Metals

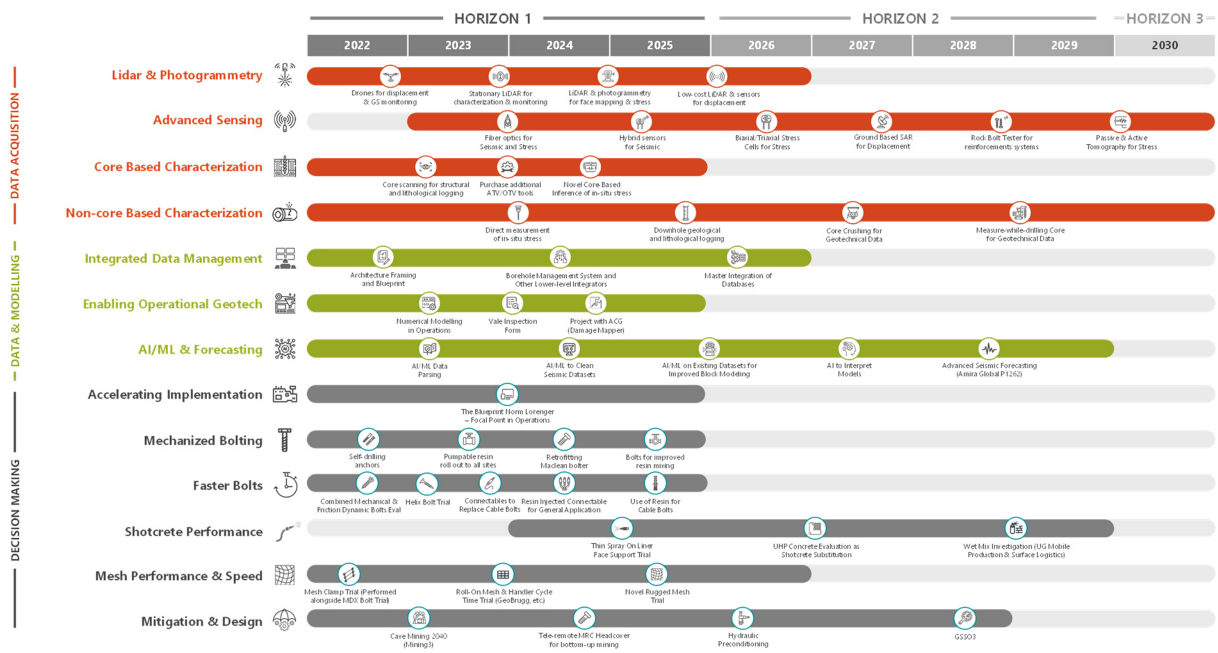
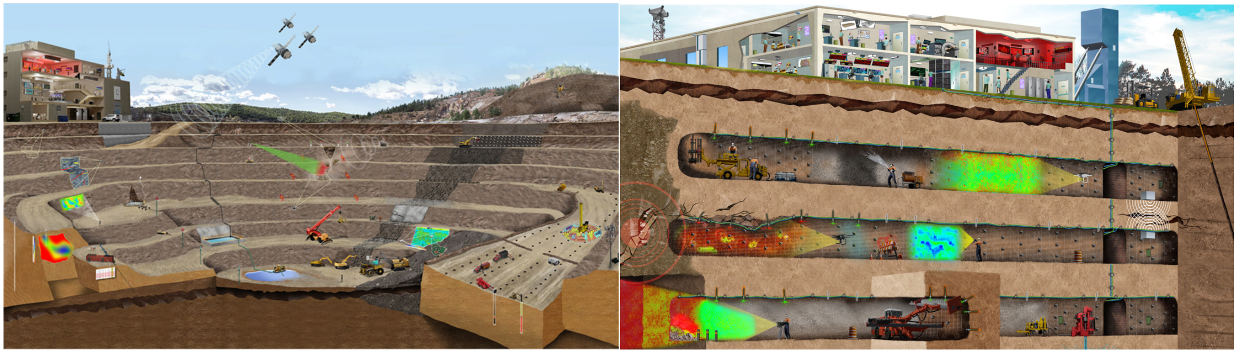


Figure 16 All projects that make up the Seismicity Management Technology Roadmap for Vale Base Metals

To facilitate the communication of Technology Roadmaps across the business, visualisations were created for both the Seismicity and Slope Management Technology Roadmaps. Refer to Figure 17 for these visual representations.



(a) (b)

Figure 17 Technology roadmap illustrations for: (a) surface mines and (b) underground mines at Vale Base Metals

10 Technology implementation

After developing Technology Roadmaps, the next crucial step is implementing the technologies specified. This implementation process presents several challenges that must be effectively addressed to ensure success.

At VBM, a phased implementation approach has been adopted across the business for each technology to manage risks and facilitate the smooth integration of new technologies into operations. This strategy involves breaking down the implementation process into manageable stages.

The initial stage involves conducting small-scale trials at select sites to test the effectiveness of the new technology in a controlled environment and are instrumental in identifying potential issues and gathering performance data.

Following the success of a small-scale trial, the implementation of a new technology would be gradually expanded to additional mining operations. This phased approach allows for necessary adjustments and refinements to be made at each site, with the ultimate objective of full-scale deployment at all assets.

Throughout each phase the performance of a new technology is continuously monitored to ensure it meets the desired objectives. This supports making informed decisions and addressing any challenges promptly.

In addition to the aforementioned steps, several critical elements were deemed essential for the successful implementation of new technologies at VBM, including but not limited to:

- Communication: ensure clear and consistent communication with all stakeholders to facilitate collaboration and address concerns.
- Scope of work: define a clear scope of work to establish expectations and responsibilities.
- Performance criteria: set specific performance criteria to measure the success of the technology.
- Management of change: implement a structured approach to manage changes and mitigate associated risks.
- Project monitoring and data collection: systematically collect data to monitor progress and inform decision-making.
- Close-out: carry out a thorough close-out process to ensure all objectives have been met and to document lessons learned.

10.1 Communication

Stakeholder engagement is critical for the successful introduction of any new technology. At VBM, engaging stakeholders effectively ensured alignment with expectations, reduced resistance and supported smooth implementation. This engagement was driven by clear communication, collaboration and continuous feedback.

Objectives, benefits and potential impacts of each technology were communicated transparently to all relevant stakeholders. Senior leaders received quarterly updates to maintain visibility and alignment throughout the implementation process. Meetings were held as needed to gather input, address concerns and collaboratively resolve challenges, ensuring that implementation plans were both comprehensive and inclusive.

Stakeholders were also actively involved in decision-making, fostering ownership and commitment at the site level. Feedback was regularly solicited and discussed, providing valuable insights that informed adjustments to the implementation strategy. Importantly, this feedback was acted upon promptly, reinforcing trust and demonstrating that stakeholder input was both valued and impactful.

10.2 Scope of work

For each technology implemented as part of a Technology Roadmap at VBM, a scope of work (SoW) was created. This document provided a comprehensive overview of the technology, including its purpose, objectives and deliverables. The objectives for each technology were designed to be specific, measurable, achievable, relevant and time bound.

Each SoW outlined a detailed timeline for the implementation of the technology, encompassing key milestones and deadlines that covered all phases from trial to evaluation and full implementation. Additionally, the SoW specified the budget, detailing costs for equipment, materials, labour, training and any other associated expenses.

Furthermore, the roles and responsibilities of key stakeholders were clearly delineated within the SoW, ensuring accountability and clarity throughout the implementation process.

10.3 Performance criteria

Establishing clear performance criteria within the SoW was crucial for evaluating the effectiveness and efficiency of a new technology. The key performance criteria that should be established when writing a SoW depend on the type of technology being implemented, however, when implementing new technologies at VBM it was discovered that all performance criteria could be grouped into safety, cost and productivity categories.

These categories provided a framework for evaluating a technology's effectiveness, ensuring it met safety, financial and operational requirements. By specifying clear performance criteria, the implementation process could be managed more effectively, leading to improved outcomes and greater overall success.

10.4 Management of change

Implementing new technologies at VBM often necessitated significant changes to existing processes and workflows. Consequently, it was essential to adhere to the established management of change (MoC) process to address potential resistance and ensure a smooth transition.

The MoC process was employed not only to manage the risks associated with the introduction of new technologies at an operation but also as an effective communication tool with the broader workforce. This process enabled key stakeholders to actively participate in the implementation process, fostering important discussions, trust and collaboration.

Additionally, the MoC process encompassed various aspects such as technical training, safety procedures and support systems. These elements were crucial in ensuring that all personnel were adequately prepared and supported throughout the transition.

10.5 Project monitoring and data collection

During the trial phase of a new technology at VBM, data was systematically collected and analysed to assess performance and determine its suitability for broader deployment. While the specific data points vary depending on the technology, they generally fall into key categories: technical performance (including accuracy, availability and system integration), operational efficiency (such as productivity and workflow alignment), safety and compliance (covering exposure, ergonomics and regulatory adherence), financial outcomes (including cost savings and return on investment), environmental impact (such as sustainability metrics and compliance), stakeholder feedback (from employees, communities and other stakeholders), data management (focusing on quality, integration and reporting), and training and support (evaluating program effectiveness and knowledge transfer). This structured approach enabled informed decision-making regarding the scalability and long-term value of the technology.

10.6 Close-out

At the completion of every geotechnical technology project at VBM the project manager would complete a Technology Completion Form. This form was vital for capturing performance information on the technology and whether a project was endorsed for broader rollout across the business. The VBM Technology Project Completion Form is shown in Figure 18.

VALE

TECHNOLOGY PROJECT FORM
Vale Base Metals Geotechnical Office

This form shall be completed for all ground control related technology projects by the Project Manager.

PROJECT SUMMARY		
TITLE		
OWNER		
SITE		
PARTNERS	Name	Company
START DATE	Planned	Actual
FINISH DATE	Planned	Actual
COST	Planned	Actual
OVERVIEW		
BUSINESS BENEFIT		
SUCCESS CRITERIA	•	☒ Achieved ☒ Not Achieved
	•	☒ Achieved ☒ Not Achieved
	•	☒ Achieved ☒ Not Achieved
	•	☒ Achieved ☒ Not Achieved
	•	☒ Achieved ☒ Not Achieved
LESSONS LEARNED		
Key findings	•	
Follow-up actions	•	
Rollout	☐ Rollout ☒ Rollout with additional actions ☐ Do not rollout	
Sign-off by Project Manager		
Name:	Title:	Date:
Phone:	E-Mail:	

Created on September 1st, 2023

Figure 18 The Technology Project Completion Form used at Vale Base Metals (Hossack 2023)

11 Conclusion

The development of multi-time-horizon technology roadmaps, supported by sites and guided by a holistic Ground Control Management System (GCMS), has demonstrated significant benefits in addressing geotechnical challenges.

The unified effort of the GCMS integrates people, decision-making, technology, project assurance and operation assurance frameworks, creating a system to address ground control challenges. This unified approach not only enhances an organisation's ability to characterise, monitor, model and mitigate ground control-related hazards, but also ensures that efforts align with business needs and aspirations. The result is an innovative business with empowered sites that take ownership of their technology roadmaps, which ultimately deliver measurable business benefits.

Developing a Technology Roadmap and implementing identified technologies is a strategic approach to improving business performance. By following a structured process, establishing a clear ambition, defining problem statements and leveraging collaborative processes, mining operations can achieve significant improvements in safety, productivity and cost. The approach to Technology Roadmap development and implementation outlined in this paper significantly increases the likelihood that new, effective technologies can be identified for a mining operation, and that these technologies can be efficiently integrated into workflows, leading to enhanced business performance and long-term success.

Acknowledgement

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