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# Risk, lessons and opportunities: a unified knowledge management approach for mass mining

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## Abstract

*How companies operate caving mines can differ, often extensively, from what was originally envisioned during planning stages. Realities change as the project shifts from a paper design through construction, the first encounter with actual conditions, to cave establishment and steady state production. Much is learned along the way, including how an organisation functions and responds to change, how the rock mass itself responds to caving, the robustness of the original plan against actual conditions, and whether the cost and schedule estimates were reasonable or achievable. Once a mine is operational, strategy and tactics continue to evolve from initial plans as changes are made to deal with the realities of ground conditions, project logistics and market pressures. Invariably, such changes tend to result in schedule delays and cost increases. The intent of risk analysis is to capture the likelihood and consequence of such changes and to have mitigation processes in place to deal with the new conditions. As a planning and operational necessity, risk management at larger operations is typically established and maintained to at least a basic level. However, the systematic capture and application of lessons learned and opportunities (i.e. the feedback loop), tends to be less formally implemented. Critical institutional knowledge can be lost with staff departures or poor records capture. Case examples are provided to illustrate the benefits of risk, lessons learned and opportunity registries across multiple disciplines in large panel caves. Experience is shared on the linked utilisation of these tools, which has led to stronger organisational collaboration with more desirable safety and production outcomes.*

**Keywords:** *risk, lessons learned, opportunities, mine planning, operations, strategy*

## 1 Introduction

Large mining organisations often struggle with the capture, retention, and application of institutional knowledge. Organisations similarly struggle to capitalise on retained knowledge. Work is redone, mistakes remade, and opportunities lost more often than operators would wish to admit. Despite an extensive amount of published work on the technical and operational practices of underground mass mining, knowledge can remain on the pages rather than in the minds and practice of a workforce. Such factors are particularly pronounced in complex, underground mining environments such as sublevel, block, and panel caves where staff may turn over several times throughout the life an operation. Even for organisations with stronger record keeping, the sheer amount of retained knowledge may not allow new and growing teams to keep pace with learnings of the past.

In such environments, individuals or groups may lean on heuristics and bias when it comes to technical and operational decision-making. Groupthink practice can also drive dysfunction through the desire for cohesiveness without a true understanding of the problem and likely result of applied solutions. Consultants may be excessively relied upon to patch knowledge gaps which do not necessarily exist. Scenarios like this can lead to adverse safety and production results in addition to overspending and schedule loss. Without organisational buy-in to effective knowledge management, teams cannot get ahead of pitfalls, and the cycle continues to repeat.

Three key knowledge sources are identified in terms of preserving and exploiting institutional knowledge: risk, lessons learned and opportunities. A simple approach, rooted in modern project management practice, is presented which unifies and captures the connected value of these knowledge sources. Advances

previously gained in fields such as medicine and aerospace are borrowed and applied to knowledge management for underground mass mining.

To illustrate the practical benefits of this approach to knowledge management, a case example is provided from PT Freeport Indonesia's (PTFI) Grasberg operation. PTFI is well-suited for this approach given the vastness of the operation and rapid expansion projects, which have been ongoing over the past several decades. The case example illustrates why off-the-shelf solutions simply do not replace the customised knowledge gained from the operation.

# 2 Knowledge management: pitfalls and modern solutions

Risk management is now a common theme in the mining industry as organisations shift from vulnerable and reactive to proactive and resilient (Read & Stacey 2009; Hadjigeorgiou 2019). Risk management platforms are increasingly geared to improving safety and production performance while quantifying exposure to well established hazards associated with underground mass mining (Flores-Gonzalez 2019). Beyond risk, other aspects of institutional knowledge management have not yet reached such a status despite this improving culture around safety and production efficiency.

## 2.1 Knowledge management pitfalls

The main contributors to poor knowledge management are not unique to mining. Contributors that can do the most damage often relate to risk, lessons learned and opportunities. Examples of knowledge pitfalls experienced in recent years at PTFI are summarised in Table 1.

**Table 1 Knowledge management pitfalls experienced at PTFI**

| Pitfall | Result |
|---|---|
| Inadequate understanding or incorporation of previous work | Previous knowledge lost, scope rework, overspending |
| Insufficient benchmarking | Available solutions may be missed without benchmarking; mistakes, made previously by others, may be missed and repeated |
| Insufficient knowledge management training | Staff not aware of platforms available to record and apply institutional knowledge |
| Lack of inter-organisational sharing and/or cataloguing | Experience of industry peers not exploited; without letting go of your data, others not likely to share |
| Disorganised record keeping | Without organised people and organised practice, knowledge retention suffers |
| Qualitative knowledge not quantified | Without recording and communicating knowledge in a semi-quantitative format, key messages can be lost |
| Poor knowledge communication | Inadequate knowledge management platforms (e.g. text heavy databases) bury valuable information, making extraction difficult |
| Too many or not enough knowledge management tools | Too many tools or not enough of the right tools can cloud knowledge management efforts |
| Dropped consulting/academia relationships | Knowledge is lost where consulting and academia relationships are dropped and learnings not properly recorded |
| Staff surveys not routinely conducted/captured | The lack of current or departing staff surveys limit ability to collect valuable information (i.e. no repository for ideas, concerns, etc.) |

Dülgerler & Negri (2016) issue a clear summary of common practices, traps and remedies associated with the collection of organisational knowledge. Their example focuses on lessons learned through five phases: collection, prioritisation, documentation, communication, and assimilation (Table 2). Additional work by other project management specialists (Rowe & Sikes 2006; Walker 2008), has also been considered in developing the knowledge management framework applied at PTFI.

**Table 2 Traps and remedies for managing lessons learned (modified after Dülgerler & Negri 2016)**

| Stage | Common practice | Trap | Remedy |
|---|---|---|---|
| Collection | Lessons are usually gathered directly from project stakeholders through workshops and meetings | Gathering lessons can be difficult as individuals or groups are normally reluctant to admit failures | Collect lessons anonymously prior to moderated sessions |
| Prioritisation | Lessons are commonly documented and stored independent of the participants role or contribution to the project | Stakeholders and stakeholder groups can be biased in prioritising lessons; especially for aspects in which they are directly involved | Restrict the prioritisation process only to the key project team members, using a scoring system to identify the most effective lessons |
| Documentation | It is a common practice to describe the lessons in a textual format, linking each lesson to the problem it should prevent | Often lessons are documented in a 'not-actionable' format, with no practical instruction on how to implement the lesson | Clear descriptions should be provided to accompany each recorded lesson learned such that the lesson can be practically applied |
| Communication | Lessons are typically communicated via publishing from a lessons learned database | When the next project begins, extracting the task-relevant lessons can be ineffective and time consuming | Link each lesson learned to a specific category so that retrieval of relevant lessons is easier |
| Assimilation | Consult the lessons learned database to recover applicable knowledge | Without a simple and repeatable process, this step is often skipped, rendering the overall process ineffective | Create a formalised extraction process to incorporate relevant lessons learned to the appropriate scope items |

## 2.2 Modern solutions in knowledge management

Knowledge can be worthless if not within reach to the right people at the right time; particularly for operations experiencing change. Valuable lessons learned and opportunities often languish in spreadsheets, SWOT assessments, and other 'one off' exercises without being properly recorded, indexed, and later applied. The recent pandemic has not only improved digital collaboration platforms, but it has also significantly driven up usership of such platforms. This broader adoption has made such centralised tools viable as collaboration options for both mine site and corporate teams, from new hires to upper management.

PTFI has leveraged experience and momentum gained from an in-house risk management platform (Llewelyn et al. 2022) to develop a joint lessons learned and opportunities registry. In constructing the platform, PTFI representatives interviewed staff and industry peers to gain insight into what would make such an effort most effective.

The following key findings were established:

- Develop a simple, one-form data entry sheet backed up by a centralised database.
- Utilise an online platform such that specialised software is not required.
- Create simple drop downs and checklists to ensure consistency (where possible).
- Limit descriptive verbiage and rather rely on linked documentation to provide detail (e.g. reports, presentations).
- Ensure the database is easily sortable and searchable.
- Focus on visualisation wherever possible (e.g. dashboards, charts).
- Cross reference knowledge sources (lessons learned, opportunities, and risks) via hyperlinks.
- Define departmental champions within the organisation to promote ownership and cooperation.
- Establish a per-entry application, review, and approval process.
- Create a regular review cycle to promote and maintain the process.

# 3 Knowledge sources

Risk, lessons learned, and opportunities are considered critical knowledge sources at PTFI. Table 3 provides PTFI definitions of these specific sources followed by further description in following sections.

**Table 3 PTFI definitions associated with risk, lessons learned and opportunity management**

| Knowledge source | PTFI description |
|---|---|
| Hazard | An action, situation or behaviour that has the potential to cause injury, damage to property or the environment, interruptions to production, legal non-compliance or loss of social license and stakeholder support |
| Risk | A situation where action can be taken to make more or less likely to occur but is ultimately outside of an organisations direct control. Initial, current, and residual risk is determined, and risk is calculated for each hazard using defined likelihood of occurrence and consequence ratings |
| Lesson Learned | An experience from which useful knowledge or principles can be learned. A lesson learned is a record of learning associated with a specific lesson or group of related lessons |
| Opportunity | A favourable or advantageous circumstance or combination of circumstances that can be viewed as favourable to the project. To realise an opportunity, action must be taken which tends to have an associated cost and time (to realise) component |

## 3.1 Risk

PTFI's approach to risk assessment enables stakeholders to understand the divisional risk across multiple departments and focus their efforts on practical scope definition, manpower and budget allocation to promote safety and achieve stated production targets. The approach focuses on identifying hazards, managing those hazards, and communicating risk from early planning through operational phases. The risk management process is administered through a database-supported online platform known as the Risk Register. PTFI's risk management process has been effective partly because all major project scopes are tied back to corresponding risk(s). Refer to Llewelyn et al. (2022) for a full description of PTFI's risk management process.

## 3.2 Lessons learned

Driven from project and operational experience, PTFI has been collecting lessons learned periodically since 2019. Each entry includes a description of the original driving event (i.e. lesson) along with a clear description of the lesson learned. Until the recent establishment of the online platform, lessons were previously collected via spreadsheet with an established template of drop downs, checklists, and text entry fields. The online platform, much like the pre-existing spreadsheet template, captures the following information:

- Lesson learned ID (automated).
- Lesson category and subcategory (drop down menus).
- Applicable mine(s) and level(s) (checklist).
- Description of lesson learned (text entry).
- Background on lesson learned (text entry).
- Area of greatest impact (checklist).
- Applicable fatal risk management (checklist).
- Applicable risks (hyperlink).
- Related opportunities (hyperlink).
- Related reporting (hyperlink).
- Author, date entered, date accepted, date of last revision.
- Keywords.

Cost and safety impacts are independently assessed based on historical, current, and ongoing experience related to the lesson learned (Figure 1). Although these ratings are summed to create the total lesson learned rating (0–10), safety and cost are considered in isolation. The cost rating is an estimate of the cost incurred based on learning the lesson (i.e. how much did learning that lesson cost the organisation). This amount can come in the form of direct capital or operational expenditure or production related impacts (e.g. reduced recovery, schedule loss). The rating for safety is a qualitative description on the criticality of the lesson learned to personnel safety. Safety ratings range from 'none' through 'mandatory' representing no impact and mandatory policy change scenarios, respectively.

| LESSON LEARNED COST | |
|---|---|
| LOOKUP | RATING |
| <0.25MM | 0 |
| 0.25-1.0MM | 1 |
| 1-5MM | 2 |
| 5-10MM | 3 |
| 10-50MM | 4 |
| >50MM | 5 |

| LESSON LEARNED SAFETY | |
|---|---|
| LOOKUP | RATING |
| MANDATORY | 5 |
| VERY HIGH | 4 |
| HIGH | 3 |
| MODERATE | 2 |
| MINOR | 1 |
| NONE | 0 |

**Figure 1 PTFI lessons learned scoring for safety and cost (MM, millions) impact**

## 3.3 Opportunities

Beyond the fields required for lesson learned, opportunities data entry requires the opportunity to be quantified such that prioritisation is straightforward to the stakeholder group (Figure 2). To transparently achieve this, PTFI has adopted a scoring system according to cost (to realise), time (to realise) and (potential) value (Figure 3). Ratings are then summarised to create a total opportunity value ranging (0–15). This scoring exercise permits a more rapid assessment of opportunity prioritisation.

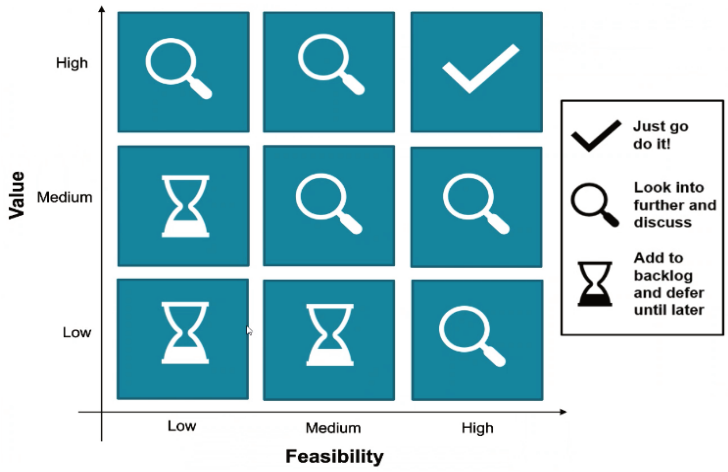


**Figure 2 PTFI opportunity prioritisation concept**

| OPPORTUNITY COST | |
|---|---|
| LOOKUP | RATING |
| <0.1MM | 5 |
| 0.1-0.5MM | 4 |
| 0.5-1MM | 3 |
| 1-3MM | 2 |
| 3-10MM | 1 |
| >10MM | 0 |

| OPPORTUNITY TIME | |
|---|---|
| LOOKUP | RATING |
| >3 MONTHS | 5 |
| 3-6 MONTHS | 4 |
| 6-12 MONTHS | 3 |
| 1-3 YEARS | 2 |
| 3-5 YEARS | 1 |
| >5 YEARS | 0 |

| OPPORTUNITY VALUE | |
|---|---|
| LOOKUP | RATING |
| <0.25MM | 0 |
| 0.25-1.0MM | 1 |
| 1-5MM | 2 |
| 5-10MM | 3 |
| 10-50MM | 4 |
| >50MM | 5 |

**Figure 3 PTFI opportunity scoring for cost (MM, millions), time (duration), and value (MM, millions)**

# 4 Knowledge capture, communication and application

In PTFI's experience, soliciting and gathering feedback on risk, lessons learned and opportunities is not a complex process. The difficulty comes in the consistent capture (i.e. format), effective communication and associated application of the knowledge itself. To address these challenges, PTFI has borrowed established practices, originating outside the mining industry, to develop a simple and effective framework designed to avoid typical pitfalls associated with knowledge management (e.g. Rowe & Sikes 2006; Walker 2008).

Figure 4 illustrates PTFI's adopted process for lessons and opportunities capture and communication. The nominated lessons learned and opportunities system approver(s) has responsibility for approving entries and maintaining the integrity of the registry. Approved lessons learned and opportunities submitted to the system are first indexed, thus allowing their quick retrieval by category and keywords.

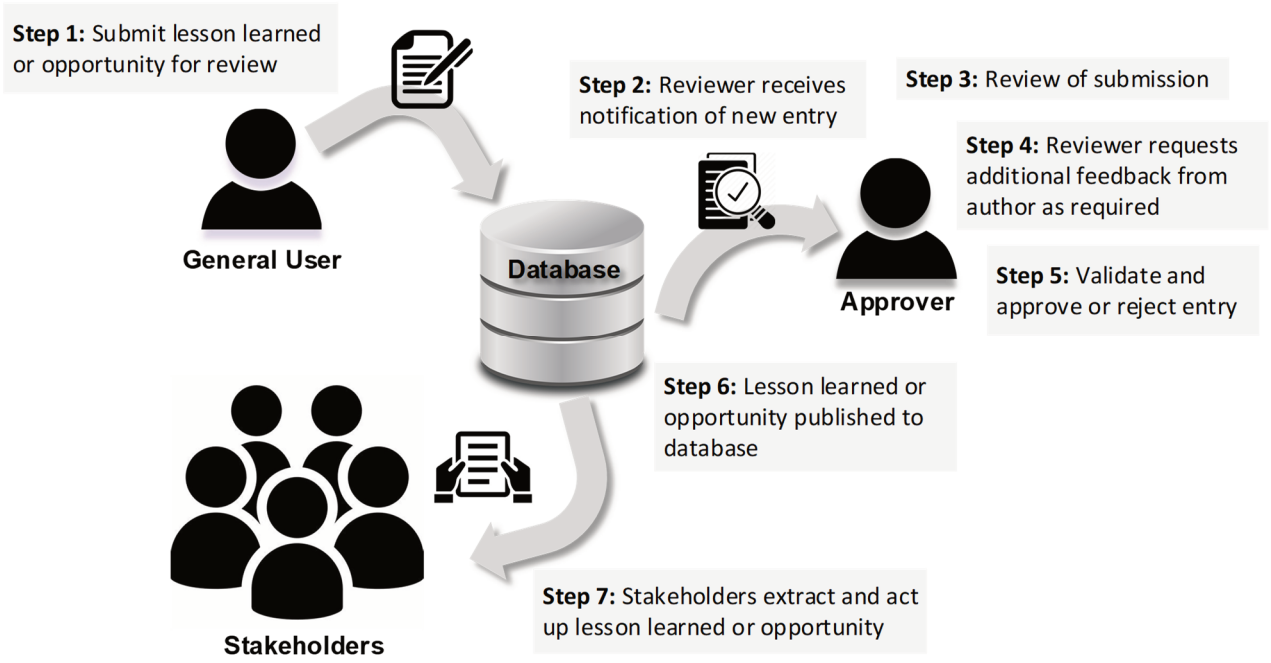


**Figure 4 PTFI knowledge capture and communication process**

## 4.1 Knowledge capture

PTFI's lessons learned and opportunities are captured using an intranet-based data entry form (Figure 5). Collection of lessons learned and opportunities can occur on an ad hoc basis, through facilitator-led meetings or dedicated surveys. Once approved, entries are indexed within the database allowing for quick retrieval by stakeholders using selected search criteria (e.g. specific mine, lesson category (Figure 6)). In addition to comprehensive search capabilities, user alerts can be issued by email as a relevant new lesson is entered and approved within the system.

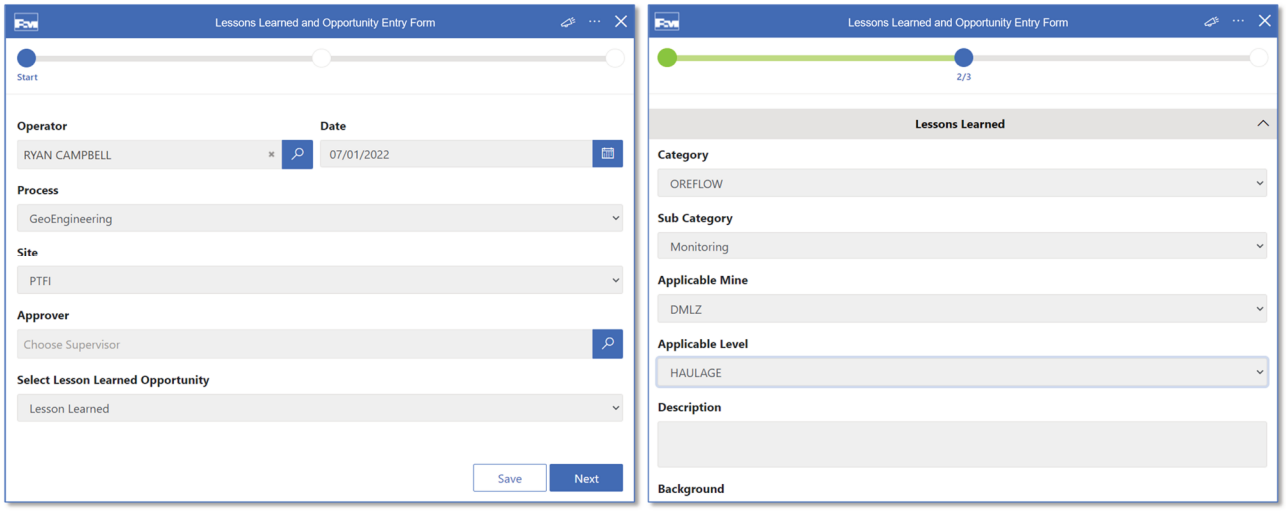


**Figure 5 PTFI lessons learned and opportunities data entry form (partial form only)**

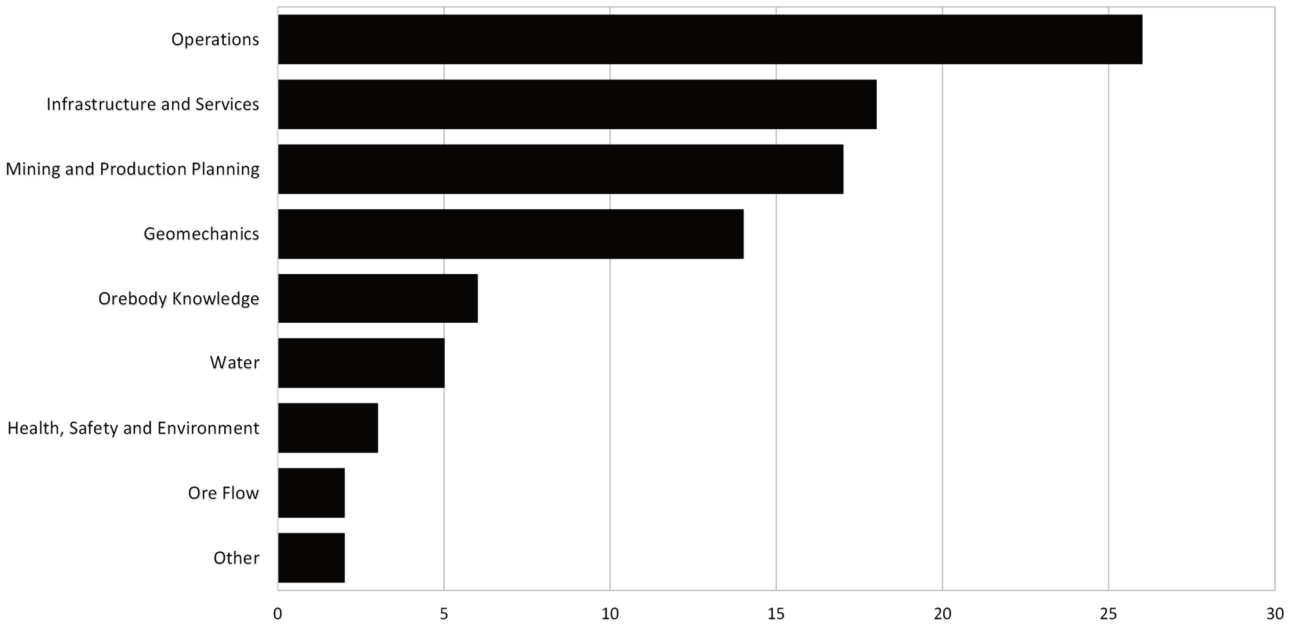


**Figure 6 PTFI lessons learned count by category (as of June 2022)**

## 4.2 Knowledge communication

Once knowledge is collected, it must be communicated to stakeholders. A key requirement, identified at the outset of process construction, was that captured knowledge must be easily accessible. With this requirement in mind, PTFI's knowledge registry has been set up to maximise visual aspects through a series of simple and graphic-focused reporting elements. Figure 7 illustrates an example opportunity cost-value with top rated opportunities from the PTFI Geoengineering division listed in Table 4. In addition to these visual aids, regular updates will also be issued through PTFI's quarterly forecast meetings.

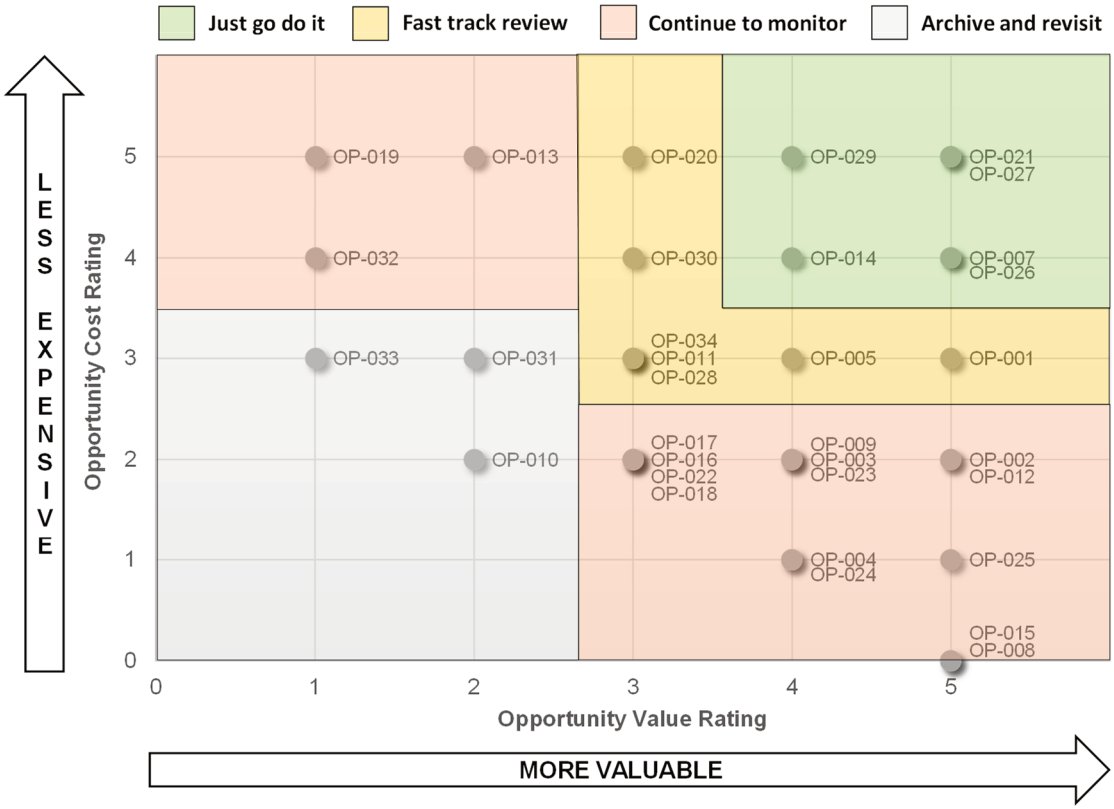


**Figure 7 Populated PTFI opportunity cost-value ranking matrix (as of June 2022)**

**Table 4 Top rated PTFI Geoengineering division opportunities (as of June 2022)**

| ID | Opportunity description | Cost to achieve ($) | Time to achieve | Potential value ($) | Total rating (0–15) |
|---|---|---|---|---|---|
| OP-027 | Establish and conduct advanced wet muck monitoring to increase drawpoint availability | <0.1 MM | 6–12 months | >50 MM | 13 |
| OP-021 | Intensify ground response monitoring in Grasberg Block Cave Poor ground areas to remove/reduce heavy support requirements in PB1N | <0.1 MM | 1–3 years | >50 MM | 12 |
| OP-026 | Evaluate increase of Big Gossan stope dimensions using actuals data | <0.1 MM | 6–12 months | 10–50 MM | 12 |
| OP-014 | Calibrate ground response monitoring versus numerical model results (global footprint scale) | 0.1–0.5 MM | 6–12 months | 10–50 MM | 11 |

## 4.3 Knowledge application

Once capture and communication is complete, application of lessons learned and opportunities must be undertaken. This is most often the stage where the process fails (Dülgerler & Negri 2016). As such, PTFI has combined clear communication tools with recurring knowledge management sessions to ensure the application process can succeed. The following approaches are either under development, trial or being actively implemented at the time of writing:

- Department-specific lessons learned and opportunity workshops (quarterly).
- Project-specific lessons learned and opportunity check-ups (ad hoc).
- Underground division summaries provided for all stakeholders (quarterly).
- Peer or external reviews of knowledge application (annually).
- External sharing sessions with industry partners (ad hoc).

For each mine, expansion project or new project, knowledge sources are individually reviewed and considered against what has been done, or not done to date. For lessons learned, cost and safety impacts are independently assessed based on historical, current, and ongoing experience related to the lesson. For opportunities, a similar process in undertaken on cost, time, and value.

To create a formal record of project-specific knowledge application, a lessons learned and opportunities scorecard has been developed. Application scoring is based on five potential responses following a one-by-one review of lessons learned and opportunities: complete, partial, none, not applicable, and rejected. Each lesson learned and opportunity must be scored in this manner during the scheduled or unscheduled working sessions. Completed scorecards are submitted to management for review.

# 5 Case study

PTFI is currently undertaking an optimisation of the Deep Mill Level Zone (DMLZ) mine. The expansion includes a repositioned production block, known as Production Block 4 (PB4), above the current 2590 mL DMLZ extraction level (Figure 8). This optimisation was driven by adverse stress conditions being encountered in the southern and eastern margins of the original DMLZ undercut and extraction level footprints.

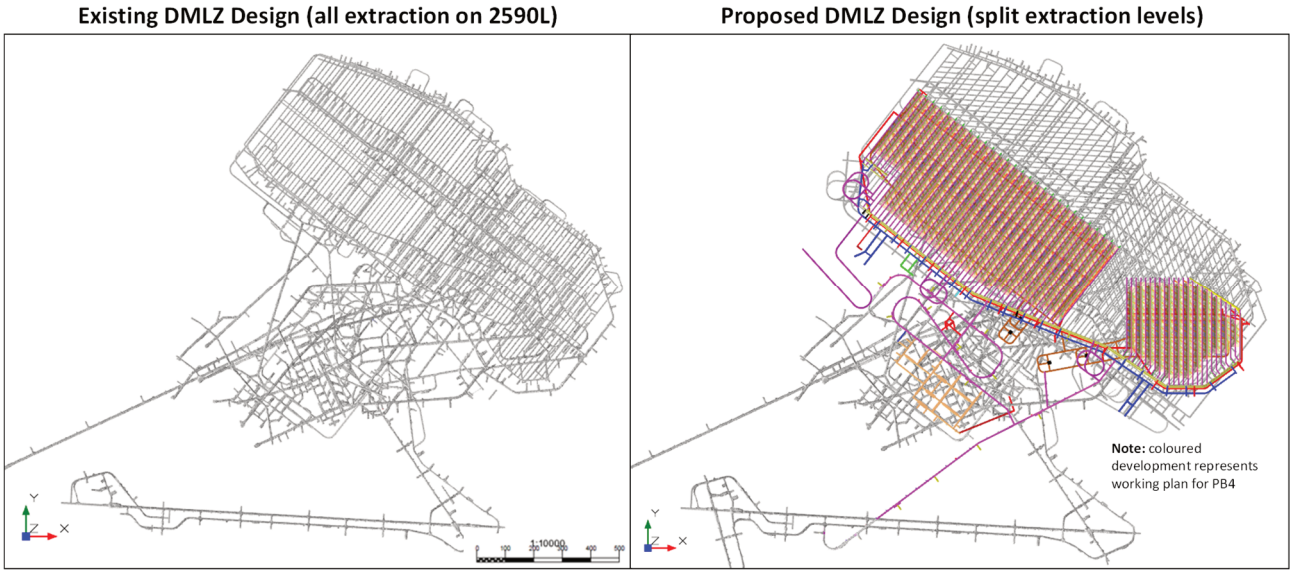


**Figure 8 DMLZ production block optimisation with the footprint reduction on 2590 mL and the adding of PB4 (2815 mL)**

The DMLZ PB4 project represented an early opportunity to apply the newly established knowledge database. Following a dedicated risk review, a scope of work was defined to advance the project to detailed design. Figure 9 illustrates the initial and residual geoengineering risk profiles defined at project kick-off. Table 5 provides example geoengineering risks defined at the outset of the project. In addition to the risk assessment, the lessons learned and opportunity knowledge database was consulted and adjustments were made to both the mine plan and associated workplan.

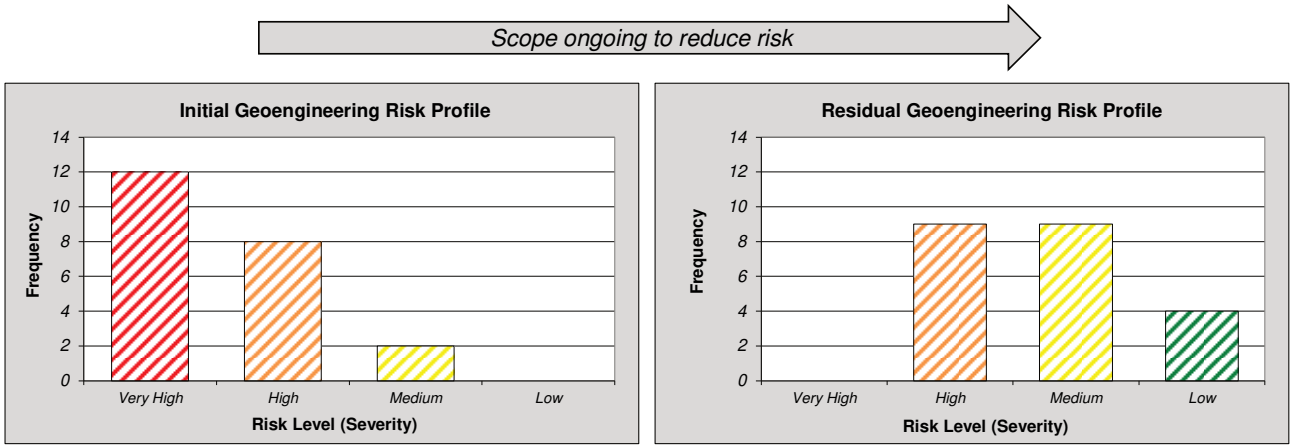


**Figure 9 Initial and residual geoengineering risk profile for the DMLZ PB4 project (initial risk defined at project kick-off, residual risk defined based on proposed risk mitigation)**

**Table 5 Example geoengineering initial (unmitigated) and residual (mitigated) risks identified for the DMLZ PB4 project**

| ID | Hazard description | Initial risk | Residual risk |
|---|---|---|---|
| A.1 | Failure to adequately estimate caveability and fragmentation (oversize and fines) | Medium | Low |
| C.3 | Designed undercutting sequence proves unstable, requiring a redesign of the sequence | Very high | Medium |
| C.11 | Lack of north fringe drift at the extraction and undercut level impedes secondary egress | Very high | Medium |
| D.11 | Fixed facilities, ramps, and south fringe location positioned too close to the cave resulting in heightened stress and burst risk | High | Low |
| D.13 | Subsidence related to DMLZ caving impacts PB4 infrastructure (vent, access/egress, etc) | High | Low |
| E.11 | High abutment stress can lead to seismic events resulting in shotcrete ejection in mine development and mass excavations | Very high | Medium |
| G.5 | Hydrofracturing not feasible to target sufficient PB4 reserve | High | Medium |

At a project review, a lessons learned (LL) and opportunity (OPP) scorecard was completed for the DMLZ PB4 study. Figure 10 includes a selected page of scorecard results

**Session Name: DMLZ PB4 Knowledge Application Workshop**
**Session Date: 05.30.2022**
**Project Description: DMLZ PB4 Expansion Study**

PT FREEPORT INDONESIA

| LL ID | LL Value Rating | LL Safety Rating | LL Total Rating | Project Relevance | Project Application |
|---|---|---|---|---|---|
| 001 | 5-10MM (3) | NONE (0) | 3 | HIGH | PARTIAL |
| 002 | 1-5MM (2) | NONE (0) | 2 | MODERATE | NOT STARTED |
| 003 | 5-10MM (3) | HIGH (3) | 6 | MODERATE | COMPLETE |
| 004 | 5-10MM (3) | HIGH (3) | 6 | HIGH | NOT STARTED |
| 005 | 1-5MM (2) | MODERATE (2) | 4 | LOW | COMPLETE |
| 006 | 10-50MM (4) | VERY HIGH (4) | 8 | HIGH | PARTIAL |
| 007 | 10-50MM (4) | MODERATE (2) | 6 | HIGH | COMPLETE |
| 008 | 10-50MM (4) | HIGH (3) | 7 | MODERATE | PARTIAL |
| 009 | 10-50MM (4) | MODERATE (2) | 6 | HIGH | PARTIAL |
| 010 | 10-50MM (4) | MODERATE (2) | 6 | LOW | PARTIAL |
| 011 | 10-50MM (4) | VERY HIGH (4) | 8 | VERY HIGH | PARTIAL |
| 012 | >50MM (5) | VERY HIGH (4) | 9 | MODERATE | PARTIAL |
| 013 | 5-10MM (3) | HIGH (3) | 6 | MODERATE | NOT STARTED |
| 014 | >50MM (5) | MANDATORY (5) | 10 | LOW | COMPLETE |
| 015 | 5-10MM (3) | MODERATE (2) | 5 | HIGH | PARTIAL |
| 016 | 1-5MM (2) | MANDATORY (5) | 7 | MODERATE | PARTIAL |

*Additional lessons learned scoring continued on next page*

| OPP ID | OPP Cost Rating | OPP Time Rating | OPP Value Rating | OPP Total Rating | Project Application |
|---|---|---|---|---|---|
| 001 | <0.1MM (5) | 6-12 MONTHS (3) | 5-10MM (3) | 11 | PARTIAL |
| 002 | <0.1MM (5) | 6-12 MONTHS (3) | 1-5MM (2) | 10 | COMPLETE |
| 003 | 0.1-0.5MM (4) | 1-3 YEARS (2) | 1-5MM (2) | 8 | COMPLETE |
| 004 | 0.1-0.5MM (4) | 1-3 YEARS (2) | 0.25-1.0MM (1) | 7 | PARTIAL |
| 005 | 0.1-0.5MM (4) | 1-3 YEARS (2) | 5-10MM (3) | 9 | NOT STARTED |
| 007 | <0.1MM (5) | 1-3 YEARS (2) | 10-50MM (4) | 11 | PARTIAL |
| 008 | <0.1MM (5) | 6-12 MONTHS (3) | <0.25MM (0) | 8 | PARTIAL |
| 009 | 0.1-0.5MM (4) | 6-12 MONTHS (3) | 1-5MM (2) | 9 | PARTIAL |
| 010 | 1-3MM (2) | 1-3 YEARS (2) | 1-5MM (2) | 6 | COMPLETE |
| 011 | 0.5-1MM (3) | 1-3 YEARS (2) | 5-10MM (3) | 8 | NOT STARTED |
| 012 | <0.1MM (5) | 6-12 MONTHS (3) | 1-5MM (2) | 10 | COMPLETE |
| 013 | 1-3MM (2) | 6-12 MONTHS (3) | >50MM (5) | 10 | PARTIAL |
| 014 | 0.1-0.5MM (4) | 6-12 MONTHS (3) | 10-50MM (4) | 11 | PARTIAL |
| 015 | <0.1MM (5) | 3-6 MONTHS (4) | <0.25MM (0) | 9 | NOT APPLICABLE |
| 016 | 0.5-1MM (3) | 6-12 MONTHS (3) | 1-5MM (2) | 8 | NOT APPLICABLE |

*Additional opportunity scoring continued on next page*

Participant List:
Notes:

**Figure 10 Session scorecard summary from the DMLZ PB4 project (project application cells highlighted where high total ratings are currently not completely applied to the project)**

Project owners and other stakeholders found this process to be both rapid and effective in terms of pulling in hard won knowledge from historical and current operations. A key outcome of the process included a refocusing of remaining scope as the project advances towards detailed design stage. In situations where high-scoring lessons learned and opportunities were given a 'project application' rating of 'partial' or 'not started', prioritisation was given to application of these knowledge sources to the relevant project scope (Figure 10). Stakeholders agreed that without this systematic review, key institutional knowledge may have been missed and never appropriately applied to the PB4 project.

# 6 Conclusion

PTFI's approach to knowledge management helps to keep risk, lessons learned and opportunities in the forefront of stakeholder minds. This inclusive and structured approach, coupled with consistent support from management, is resulting is more optimised studies with less rework and less repeated mistakes. This quantitative treatment of a qualitative dataset is currently aiding in the rapid and effective communication of institutional knowledge that may have otherwise been lost.

The process will fail without consistent support from project owners and management. The process will also be put at risk without scheduled refresh (i.e. database population, cleaning) and review periods. Stakeholders have also stressed the need for quick access and highly visual platform for viewing output from the knowledge database. In other words, the platform needs to be extremely easy to use and almost impossible to ignore captured knowledge.

The process will continue to evolve through its live application to the DMLZ PB4 and Kucing Liar expansion projects. Areas flagged for future process improvement include enhanced visualisation (e.g. dashboards) and automated alerts to users interested in a particular risk, lesson learned or opportunity category. An extension of this database to industry, vendor, consulting, and academic partners is also being explored, particularly on safety aspects within the knowledge registry.

# Acknowledgement

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