

Assessment of Sabetaung open pit general mine closure process

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Abstract

Unlike many other businesses, mining is only temporary and can cause positive and negative impacts on its surroundings. In the past, mine abandonment was the only option available. However, industry reputation is affected when mines are abandoned, or long-term detrimental environmental impacts emerge because they were not appropriately addressed during the life-of-mine. Hence, mine closure becomes important in the mining sector. Just like many other countries, Myanmar has been burdened with a legacy of unplanned mine closures, hazardous mine sites and abandoned mine sites. This paper assesses the effectiveness of the general mine closure process of the Sabetaung open pit in the Sabetaung and Kyisintaung (S&K) mine project by establishing the appropriate site-specific closure assessment framework. The closure assessment framework is divided into five dimensions (Legal, Community, Closure Preparation, Closure Planning, Closure Implementation and Monitoring) and they are then divided into themes and criteria. In addition to field observation, the assessment is carried out by interviewing the responsible persons from Myanmar Yang Tse Copper Limited (MYTCL) and from the Ministry of Natural Resources and Environmental Conservation (MONREC) to review the actual closure conditions. After obtaining the assessment results, the results are analysed, and a list of suggested prioritised improvements is generated. According to the results of the current assessment, it is observed that the following aspects of the Sabetaung closure process are required to be improved: Post-Mine Land Use, Closure Objectives and Completion Criteria, Post-Closure Planning and Financial Provisioning for Closure. Overall, the S&K mine follows several good mine closure practices in the Sabetaung closure process and has managed to establish an effective closure process.

Keywords: mine closure assessment, S&K mine, Sabetaung mine closure, MYTCL

1 Introduction

Mining is a finite economic activity that can provide socio-economic benefits to nearby communities. However, it leaves visible footprints in its surroundings. Interest in the mining sector's short- and long-term economic, environmental, and social effects have been largely increased due to the rapid expansion of the global mining sector. The integration of sustainability concepts in the mining sector and the need for sustainable mine closure systems have become important. Just like many other countries, Myanmar has been burdened with a legacy of unplanned mine closures, hazardous mine sites, and abandoned mine sites. Inadequate and inefficient mine closure policies, legislative controls, and past mining practices have resulted in a legacy of abandoned and derelict mine sites, which can have substantial impacts on environmental liabilities and mine rehabilitation costs in the absence of appropriate legislative frameworks and controls. In the past, mine decommissioning and mine closure planning were not a requirement or exclusively regulated within the mining industry and the environmental and socio-economic impacts were not identified or considered within the initial mine site development. Although the occupational safety and health provisions and labour affairs in the mining sector were well regulated, planned mine closure and completion is still at an early stage of development in Myanmar. Therefore, the need for sustainable mine closure practice becomes very important in Myanmar's mining sector.

The main purpose of this paper is to assess the effectiveness of the general mine closure process of the Sabetaung open pit, which is one of the open pits in the Sabetaung and Kyisintaung (S&K) mine project, by

establishing the appropriate site-specific closure assessment framework. Bearing this in mind, this research attempted to address the following key questions:

1. To what extent is the good practice of mine closure undertaken in the Sabetaung open pit mine closure process?
2. What is the current performance of a Sabetaung open pit mine closure process?
3. What are the shortcomings in practice in the Sabetaung open pit mine closure process and how can it be improved?

This research incorporated qualitative mine closure assessment with professionals from the Ministry of Natural Resources and Environmental Conservation (MONREC) and Myanmar Yang Tse Copper Limited (MYTCL). In this research paper, the authors discuss the detailed assessment methodology and results for the general mine closure process of Sabetaung open pit.

2 Research methodology

The proposed mine closure assessment framework is developed with the intention of dealing with the generalised mine closure process. It is also to be noted that this assessment is particularly developed for the Sabetaung open pit mine closure process and further improvements and modifications may be required for further research studies. Developing an assessment framework consists of four major steps: (1) Defining the scope for an assessment framework, (2) establishing the assessment framework, (3) developing weighting, evaluation, and priority, and (4) results interpretation and analysis.

2.1 Defining the scope for an assessment

There are three open pits in the S&K mine project: Sabetaung South, Sabetaung and Kyisintaung, with an overall estimated mine life of about 50 years. The project started its Sabetaung and Sabetaung South mining operation in 1985 by using traditional open pit truck loader technology and completed mining operation of Sabetaung South in late 2013 and Sabetaung in September 2014. Currently, the Sabetaung South pit has already been completely backfilled and the Sabetaung pit closure process is in progress. Therefore, Sabetaung open pit mine closure process was selected as the scope for this research process. Since the Sabetaung open pit closure process is part of the overall mine site closure and there will be no significant socio-economic impact on the local community due to Sabetaung open pit closure process, socio-economic factors are not considered in developing the current assessment framework.

2.1.1 *Establishing the assessment framework*

The assessment framework has been developed by adopting the general framework idea of the Sustainable Development Analytical Grid (Villeneuve et al. 2017), a sustainability assessment tool. The assessment framework is divided into the following five dimensions:

1. Legislations: To address the need for legal compliance in the mine closure process.
2. Community: To address the need for community involvement in the mine closure process.
3. Closure Preparation: To address the implementation of initial preparatory works required to ensure an effective closure process.
4. Closure Planning: To address the current mine closure process's consideration in the essential elements of the closure planning phase.
5. Closure Implementation and Monitoring: To address the effectiveness of the current closure process.

The dimensions are divided into themes and themes are then subdivided into specific good practice criteria, which will then be weighted and evaluated. Criteria are developed based on various mine closure guidelines

and handbooks (The Chamber of Mines of Namibia 2010; Department of Industry Tourism and Resources 2016; Department of Mines and Petroleum 2015; Heikkinen et al. 2008; Sánchez et al. 2014). The detailed mine closure assessment is provided in Table 1.

Table 1 General mine closure assessment framework detail

Dimension	Themes	Criteria
Legal	Legal obligations	1.1 Categorise obligations according to the entity to whom it attaches
		1.2 Categorise obligation to determine who bears the risk and how the obligation can be retired
	Review and update	1.3 Regular review and update as necessary (especially as changes in legislations occur)
Community	Legal compliance	1.4 Comply legally in all closure-related works
	Stakeholder identification	2.1 Identify external and internal stakeholders
		2.2 Identify key stakeholders
	Stakeholder management	2.3 Define roles and responsibilities for the engagement process
		2.4 Establish mechanism for submission of complaints and managing conflicts
		2.5 Provide adequate and appropriate resourcing (financial, human and materials) for the engagement process
	Stakeholder engagement	2.6 Encourage stakeholders to participate in the engagement process
		2.7 Establish stakeholder engagement strategy
		2.8 Regular engagement process
		2.9 Establish transparent closure information-sharing process for key stakeholders
		2.10 Allow key stakeholders to provide feedback on response and proposed action
		2.11 Take account of stakeholder interests and concerns in mine closure
		2.12 Keep record of stakeholder engagement (stakeholder engagement register)
Closure preparation	Closure-related study	3.1 Establish different closure domains that have the same aspects in closure process
		3.2 Learn from closure experience of similar mines
		3.3 Perform research, field trials and investigations
		3.4 Use recognised and acceptable methodologies and standards

Dimension	Themes	Criteria
Closure planning	Data analysis	3.5 Carry out baseline study, material characterisation, ESIA, etc.
		3.6 Carry out risk assessment and integrate into closure planning
		3.7 Develop detailed knowledge base
		3.8 Perform knowledge gap analysis (including the analysis of risk of not having certain kinds of information)
	Data management	3.9 Establish appropriate and easily accessible data management system for closure process (including cross-reference to all closure-related information)
		3.10 Ability to provide updated data and information regularly
	Post-mine land use	4.1 Engage with stakeholders for land use options
		4.2 Consider stakeholders' options
		4.3 Develop alternative post-mine land use options
		4.4 Perform analysis for each alternative option
		4.5 Acceptance and agreement by key stakeholders and regulators
		4.6 Develop detailed plan for proposed land use option (landform reconstruction, rehabilitation, etc.)
	Closure objectives and completion criteria	4.7 Develop based on proposed land use option
		4.8 Develop based on adequate up-to-date baseline information and data
		4.9 Stakeholder involvement in defining, refining of these objectives and criteria
		4.10 Realistic, achievable and site specific
		4.11 Set out for long-term goals for closure
		4.12 Periodic review, refine and update as necessary
	Site-specific closure issues	4.13 Acceptance and agreement by key stakeholders and regulators
		4.14 Closure issues identification
		4.15 Prioritisation of these closure issues by integrating risk assessment
		4.16 Develop detailed mitigation and management plans, including detailed technical design plan
	Post-closure	4.17 Periodic review and update
		4.18 Develop detailed decommissioning plan
		4.19 Develop post-closure management and monitoring plan
		4.20 Establish measurable performance indicator to prove the success of closure system

Dimension	Themes	Criteria
Closure implementation and monitoring	Closure cost	4.21 Develop relinquishment plan and strategy
		4.22 Periodic review and update
		4.23 Suitability and appropriateness of cost-modelling techniques and closure provisioning estimation process
		4.24 Based on reasonable, site-specific data and must be transparent and verifiable
		4.25 Regularly review and update
	Implementation and monitoring management	5.1 Establish clearly defined role and responsibilities for closure implementation and monitoring
		5.2 Establish clearly defined implementation and monitoring targets together with time frame
		5.3 Provide adequate resourcing (financial, human, materials) for closure implementation and monitoring
	Implementation performance	5.4 Establish implementation according to proposed plan and strategy
		5.5 Establish implementation according to predefined schedule
		5.6 Develop closure task register to keep track of closure progress
		5.7 Regular review and update of implementation programs to ensure effective closure implementation process has taken place
	Monitoring performance	5.8 Establish monitoring according to monitoring framework
		5.9 Use recognised or acceptable monitoring methodologies and standards
		5.10 Appropriate quality control systems and procedures in sampling, analysis, and reporting of results
		5.11 Develop referencing trends to ensure implementation takes place as expected
		5.12 Keep monitoring records to keep track of monitoring progress
		5.13 Regular review and update of monitoring programs to ensure effective monitoring process has taken place

2.1.2 *Developing weighting, evaluation, and priority*

Weighting reflects the importance of each criterion as assessed by a group, whereas evaluation indicates the performance of a given mine closure process for every criterion in the assessment, but it is the combination of both that establishes the priorities to attain effective mine closure process through corrective actions.

Weighting value 1, 2, and 3 are defined for each criterion in the assessment, as shown in Table 2. The following considerations shall be applied when weighting for each criterion:

1. Each criterion must be weighted according to their relevance and significance for a closure process in a given project at a particular moment.

2. Weighting must be based on the following question: 'Is achieving this criterion desirable, important or essential for the closure process?'

Table 2 Weightings for mine closure assessment

Weighting	Type	Description
1	Desirable	Achieving this criterion is deemed unimportant, or it has low value to fulfil identified needs.
2	Important	Achieving this criterion is deemed important but is not directly associated with identified needs regarding the closure.
3	Essential	Achieving this criterion is deemed essential and will contribute directly to the satisfaction of identified needs. It is considered essential to the success of the closure.

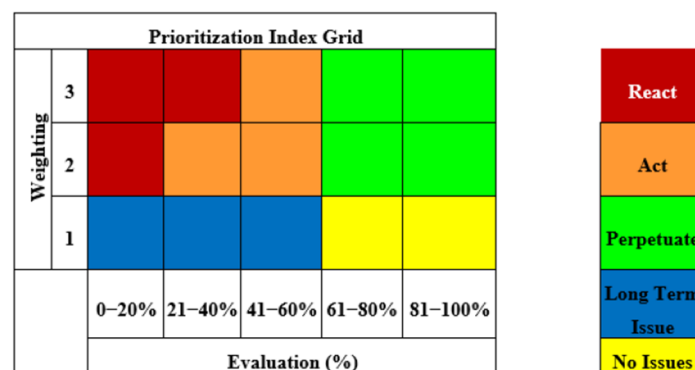
Percentage values will be used to determine a current closure performance regarding a given criterion, as shown in Table 3. The following considerations shall be applied:

1. Evaluation must be based on current and/or future actions documented in the material relating to the current closure process.
2. Evaluation must be based on the following question: 'How does the current closure process address this criterion?'

Table 3 Evaluations for mine closure assessment

Weighting	Description
0–20	The given criterion is ignored in the current closure process.
21–40	The given criterion is marginally addressed by the current closure process.
41–60	The given criterion is moderately addressed by the current closure process, mainly because of a certain amount of attention or applies regulatory compliance.
61–80	The given criterion is considered but still improvable.
81–100	The current closure process for this given criterion stands out by its innovations or effectiveness.

After weighting and evaluation, each criterion is prioritised in accordance with the prioritisation index grid, as shown in Figure 1.

**Figure 1 Prioritisation index grid**

Prioritising objectives maximises the efforts in the most relevant improvement avenues. The more significant an objective is deemed to be (high weight) and the poorer its performance (low evaluation), the more urgent

is the need to act and implement corrective actions. According to the result of the prioritisation index grid, the following actions are recommended:

- React: Immediate action is needed.
- Act: Improvements must be prioritised.
- Perpetuate: Ensure performance is maintained in the long term.
- Long-term issue: Revisit suggested improvements when priorities have been set.
- No priority: Suggested improvements will not significantly affect current closure performance.

2.1.3 Results interpretation and analysis

After conducting the assessment, the assessment results are interpreted in the following manner:

1. Generating average weight distributions among each dimension.
2. Constructing radar graphic for overall evaluation results.
3. Constructing priority pie charts for overall assessment.

Finally, assessment results will be analysed and a list of suggested prioritised improvements, the ones that address priority criteria ('React' and 'Act'), will be generated.

2.2 Procedures for mine closure assessment

The assessment is carried out by interviewing the responsible management person from the S&K mine site to reflect the actual condition of Sabetaung mine closure process. The assessment is conducted from two perspectives to avoid generating biased results and then results are compared. Step-by-step procedures for each stage of the assessment are provided in Table 4. Assessment is done by the following personnel relating to the current Sabetaung mine closure process:

1. MYTCL: Sabetaung Closure Committee.
2. MONREC.

Table 4 Detailed procedures for mine closure assessment

Stages	Procedures
Weighting stage	All criteria will be weighted individually Define average weight for each criterion based on individual weighting Develop weighting distributions for all dimensions
Evaluation stage	All criteria will be evaluated individually Define average evaluation for each criterion based on individual value Construct radar graphic for overall assessment (to find out strength and weakness in overall process) and for each dimension (to find out strength and weakness in each dimension)
Prioritisation stage	Assign priority among each criterion based on prioritisation index grid Construct priority pie chart for overall assessment
Result generation stage	Generate a list of suggested prioritised improvements (the ones that address priority 'React' and 'Act') Discussion and suggestions for improvement

3 Results

Final assessment results are interpreted in this manner: (1) Weighting, (2) Evaluation, and (3) Priority.

3.1 Final assessment result from MYTCL

Final assessment result from MYTCL is generated from the results of four individual personnel from the mine site: three from the Sabetaung Closure Committee and one from the Quality, Health, Safety and Environment (QHSE) department.

3.1.1 Weighting result

For the weighting step, the assessment members from MYTCL individually weighted the 64 criteria. Although the final weighting result should be generated as a consensus weighting for all 64 criteria through dialogue and meeting among the assessment members, the average final weighting method is selected in this research because of some constraints and limitations, such as participants' time constraints and short research time. The weighting distribution (Figure 2) shows that 67% of the criteria were deemed 'Essential', 33% 'Important' and 0% 'Desirable'. Although the weighting value '3' (Essential) is the one that is mostly attributed in all dimensions, the weighting distribution varies from one dimension to another.

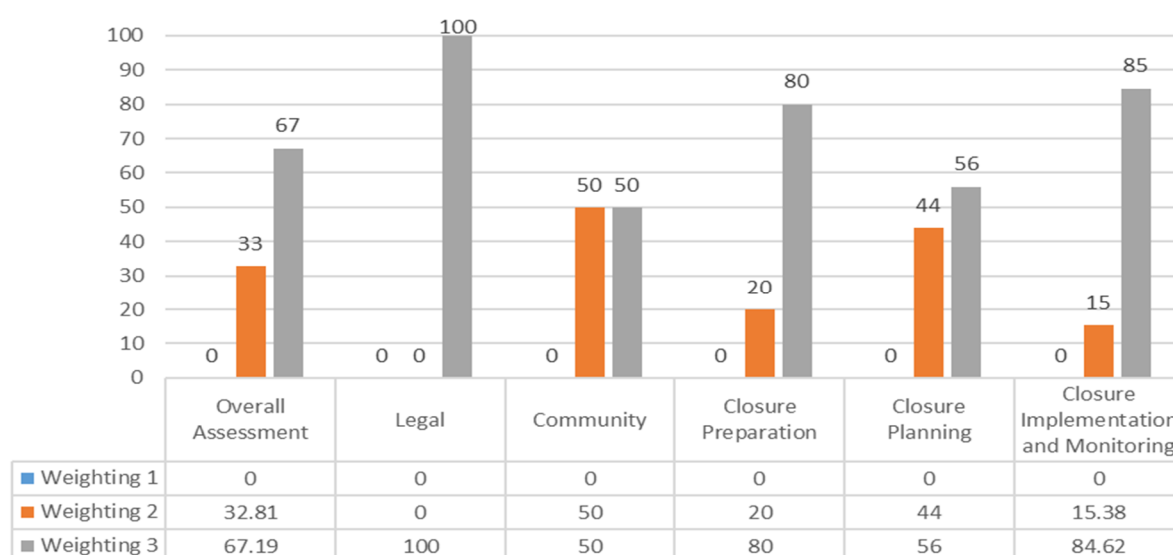


Figure 2 Overall assessment and individual dimension weighting distribution chart

3.1.2 Evaluation result

The same process as for the weighting was used for the evaluation of the criteria implementation. This time, instead of consensus, the value for each criterion was determined by averaging the evaluations of individual assessment members. It is assumed that the evaluations are based on actual and projected actions in the Sabetaung closure process. Figure 3 provides the evaluation results for overall assessment from MYTCL's perspective. According to the evaluation results, the Legal dimension obtained the highest score with 91%, while the Closure Planning dimension was the lowest with 73%. The results show that the closure process is balanced between dimensions with an average of 85% except for the Closure Planning dimension. There is no significant variation between the themes in Legal, Community, Closure Preparation, and Closure Monitoring and Implementation dimensions. The distributions of ratings in these dimensions are quite homogeneous, whereas in the Closure Planning dimension the distribution of rating is found to be more heterogeneous.

According to the evaluation results of Closure Planning dimension (Figure 4), the theme 'Post-Mine Land Use' is the weakest of the entire evaluation with 62% followed by the themes 'Post-Closure' and 'Closure Objectives and Completion Criteria', with 70% and 71% respectively. These values support the need to

implement improvements for the criteria in these themes. On the other hand, 'Site-Specific Closure Issues' stands out the most in that dimension.

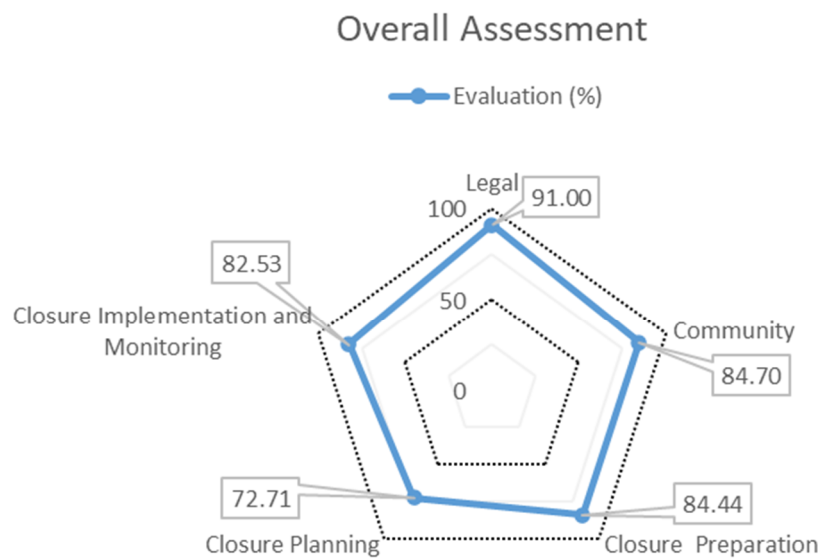


Figure 3 Evaluation result for overall assessment

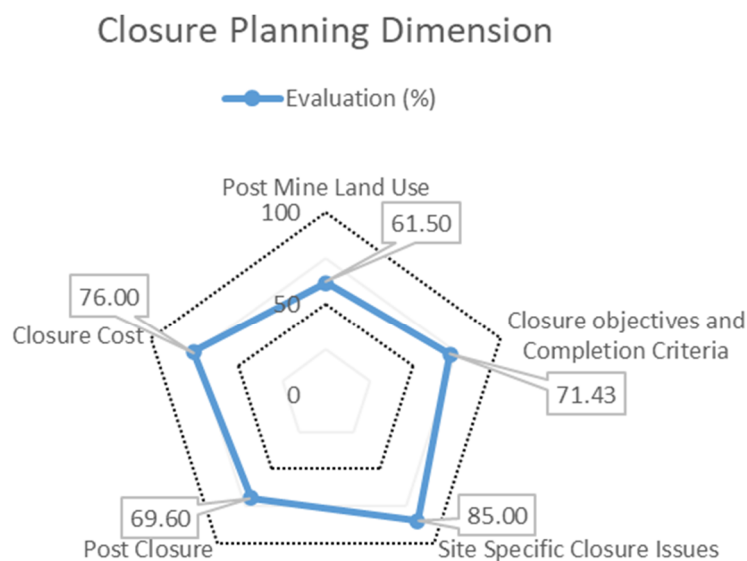


Figure 4 Evaluation result for closure planning dimension

3.1.3 Priority

Assigning priority among the objectives is essential. The juxtaposition of weight and performance of a criterion indicates the level of priority for implementation of corrective actions. Figure 5 shows the distribution of priorities for the overall assessment.

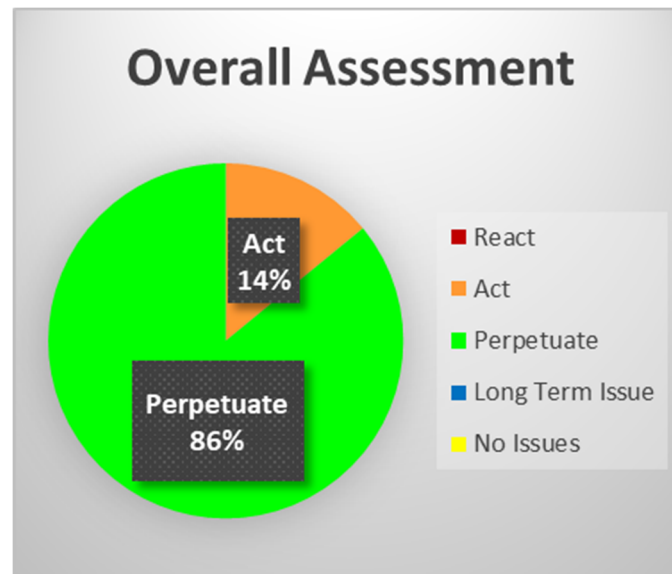


Figure 5 Priorities distribution among overall assessment

The overall distribution reveals that 14% of the overall criteria require prioritised improvements – priorities Act and React – and the remaining 86% are to be perpetuated, which means actual and projected measures are achieving the objectives and should maintain current performance in the long term.

3.2 Final assessment result from MONREC

The final assessment result from MONREC is generated from the result of authorised personnel from the Environmental Conservation Department.

3.2.1 Weighting result

The weighting distribution (Figure 6) shows that 52% of the criteria were assigned as 'Essential', 48% 'Important' and 0% 'Desirable'. Although the weighting value '3' (Essential) is attributed most in all dimensions, the weighting distribution fluctuates from one dimension to another.

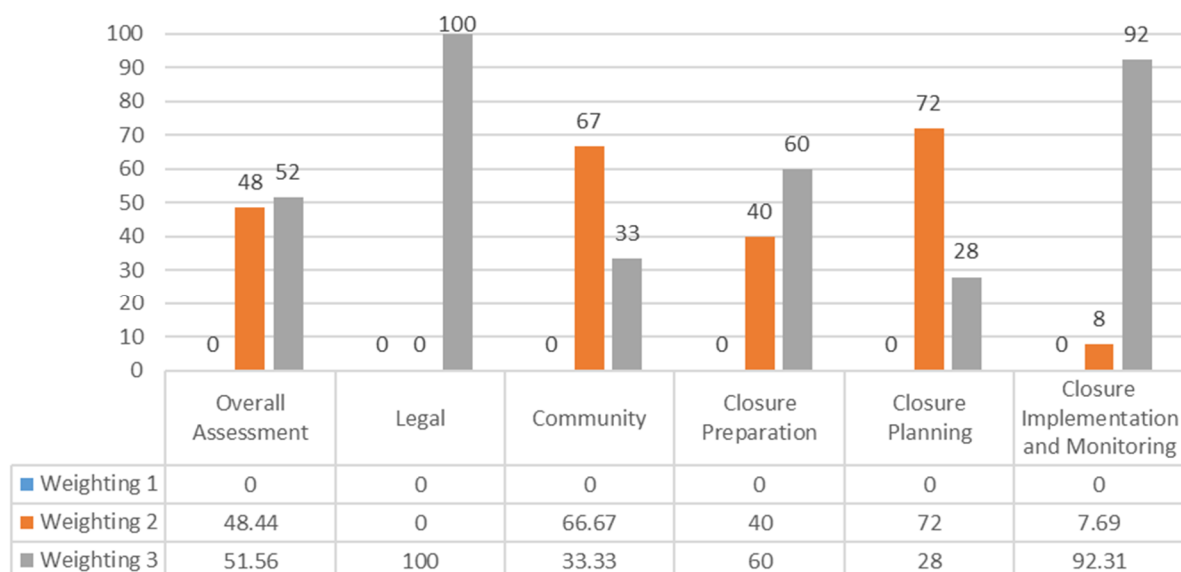


Figure 6 Overall assessment and individual dimension weighting distribution chart

3.2.2 Evaluation result

Figure 7 indicates the Sabetaung closure process evaluation according to MONREC.

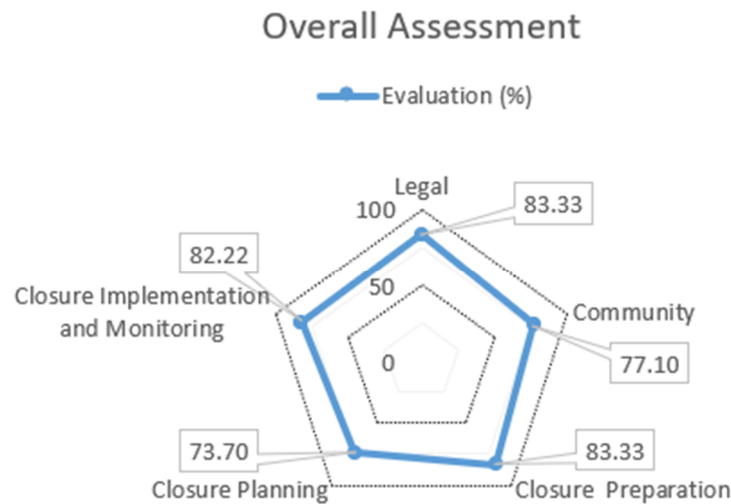


Figure 7 Evaluation result for overall assessment

The Legal and Closure Preparation dimensions stand out with the highest score of 83%, while the Closure Planning dimension was the lowest with 74%. The results show that the closure process is balanced between dimensions, with an average of 80%. There is no big difference between the themes in Legal, Closure Preparation and Closure Implementation and Monitoring dimensions, with an average of 83%. The distributions of rating in those dimensions are quite homogeneous, whereas in the Closure Planning dimension the average distribution is more heterogeneous.

As shown in Figure 8, the themes 'Post-Mine Land Use' and 'Post-Closure' are the weakest of the entire evaluation with 70% followed by the themes 'Closure Cost' with 73%. This indicates the need to implement improvements for those criteria in these themes. On the other hand, 'Site-Specific Closure Issues' stands out the most in the Closure Planning dimension with the rating of 79%.

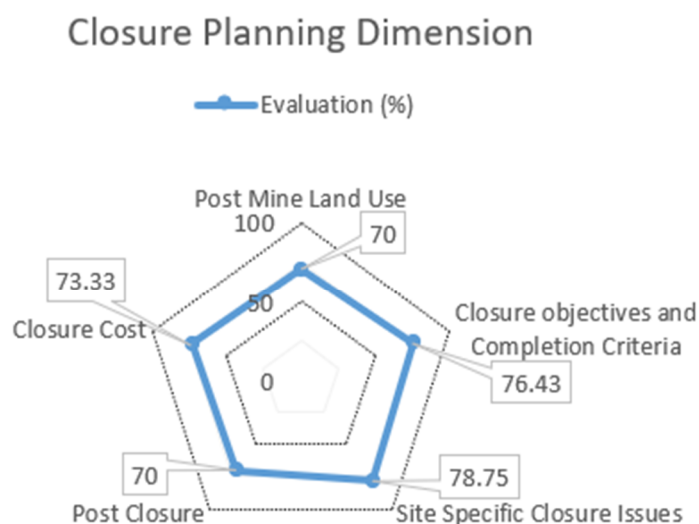


Figure 8 Evaluation result for closure planning dimension

3.2.3 Priority

Figure 9 shows the distribution of priorities for the overall assessment. The overall distribution reveals that all criteria are 'Perpetuate', which means actual and projected measures are achieving the objectives and should maintain current performance in the long term.

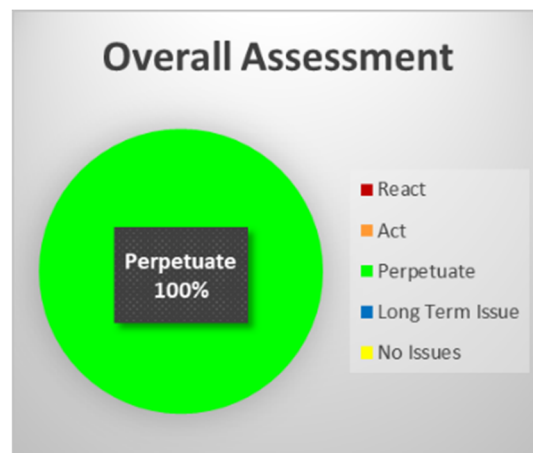


Figure 9 Priorities distribution among overall assessment

3.3 Results comparison

Comparison between the results not only reduces the possibility of generating biased results but also helps to identify the similarities and differences between MYTCL's and MONREC's perspective on the current Sabetaung closure process. The overall weighting distributions between two perspectives are nearly equal except for Community and Closure Planning dimensions where MYTCL gives higher weighting values than MONREC.

Figure 10 compares the overall evaluation results of MYTCL and MONREC for the Sabetaung closure process. It is observed that there is no significant variation between MYTCL and MONREC in three dimensions: Closure Preparation, Closure Planning and Closure Implementation and Monitoring. However, for Legal and Community dimensions, the results fluctuate where MYTCL assesses its own project's performance higher than that of MONREC by about 8%. Overall, it can be concluded that both MYTCL and MONREC share the same perspective on current closure process.

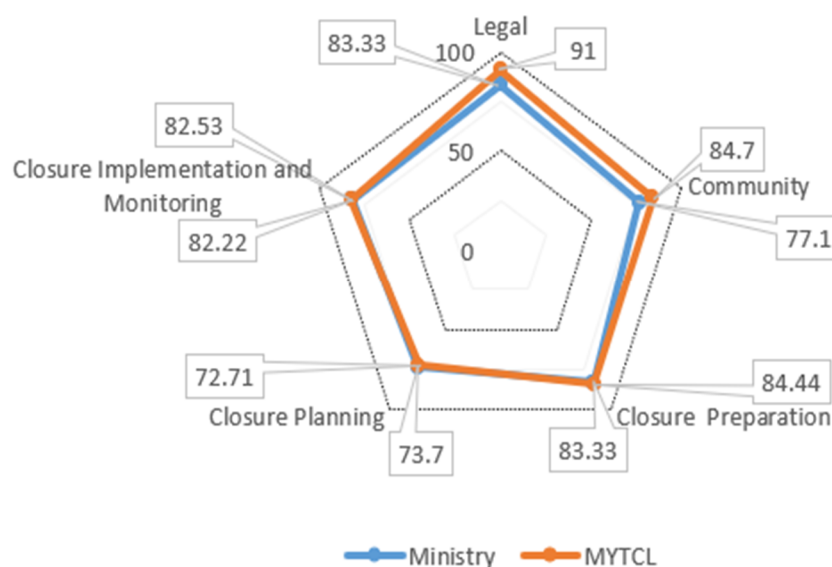


Figure 10 Overall evaluation results comparison between MYTCL and MONREC

3.4 Suggested prioritised improvements list generation

After analysing the overall final assessment results from MYTCL and MONREC, four main aspects of the Sabetaung pit closure are recommended to improve and promote its effectiveness. They are: (1) Post-Mine Land Use, (2) Closure Objectives and Completion Criteria, (3) Post-Closure Planning, and (4) Financial Provisioning for Mine Closure. A detailed list of suggested prioritised improvements is shown in Table 5.

Table 5 Detailed list of suggested prioritised improvements

Improvements	Dimensions	Themes	Criteria	Priority	
				React	Act
Establishment of final agreed post-mine land use	Closure Planning	Post-Mine Land Use	4.1, 4.2, 4.3, 4.4, 4.5, 4.6		4.1, 4.2 4.4, 4.5
Refine and update closure objectives and completion criteria	Closure Planning	Closure Objectives and Completion Criteria	4.7, 4.8, 4.9, 4.10, 4.11, 4.12, 4.13		4.7, 4.9
		Post-Closure	4.20		
Planning for post-closure	Closure Planning	Post-Closure	4.18, 4.19, 4.20, 4.21, 4.22		4.18, 4.21
Transparency in closure financial provisioning	Closure Planning	Closure Cost	4.23, 4.24, 4.25		4.24

According to Table 5, the following criteria are suggested as prioritised improvements: public consultation on post-mine land use, analysis of different land use options, establish agreed post-mine land use option, refine and update closure objectives and completion criteria based on proposed land use option, post-closure planning, and financial provisioning for mine closure.

4 Discussion

Before discussing the prioritised improvements, the Sabetaung conceptual mine closure plan is reviewed to make sure the discussion reflects the actual closure.

4.1 Post-mine land use

Public consultation for achieving final agreed post-mine land use must be developed and key stakeholders, including the neighbouring communities, must be informed transparently about the post-mine land use options to establish agreed upon post-mine land use for the Sabetaung pit. Although the Sabetaung conceptual mine closure plan considers the alternative post-mine land use options, which are viable and sustainable, it is observed that specific analysis for each alternative option has not been performed yet. Therefore, it is suggested to perform specific analysis for each of these proposed land use options to achieve the most viable final agreed post-mine land use for the Sabetaung pit. It is also suggested to take account of stakeholders' concerns and opinions on post-mine land use through continuous consultations when defining the final agreed post-mine land use.

4.2 Closure objectives and completion criteria

It is noted that closure objectives and completion criteria have already been developed in the conceptual mine closure plan. However, those closure objectives and completion criteria are broadly defined with little or no specific measurable standards and have not been based on final agreed upon post-mine land use

because agreed upon post-mine land use has not been established yet. Hence, it is suggested to refine and update these closure objectives and completion criteria, based on adequate up-to-date baseline data, after establishing final agreed upon post-mine land use to ensure they are site specific, realistic, and achievable for the proposed post-mine land use, and public consultation should also be carried out. It is also important to ensure that the Sabetaung closure objectives and completion criteria reflect the overall mine site closure objectives.

4.3 Post-closure planning

It is found that plans and strategies for post-closure, suggested in current closure plan, have not been prepared yet. It is recognised that the Sabetaung pit closure process is a part of the overall mine site closure system and there will be no need to implement a relinquishment plan immediately as the S&K mine site still has a relatively long remaining life. However, it is suggested to prepare for post-closure (relinquishment, community, etc.) as part of the overall mine site closure system so that there will be no significant liability issue in the relinquishment stage.

4.4 Financial provisioning for mine closure

Although closure expenditures have been described in the Sustainability Report developed by MYTCL, the financial provisioning process and methodology for closure are not described clearly in the current closure plan and are still confidential elements to most company staff and local communities. According to the Guidelines for Preparing Mine Closure Plans (Department of Mines and Petroleum 2015) developed by the Western Australian Government, the financial provisioning process and methodology has to be transparent and verifiable, assumptions and uncertainties have to be clearly documented, and they have to be based on reasonable, site-specific information and data throughout the life of the project. Hence, it is suggested that a more transparent and verifiable financial provisioning process is established for mine closure.

5 Conclusion

The research work is mainly based on assessing the current Sabetaung closure by developing a suitable closure assessment framework. In this research, the assessment is done by onsite management persons from MYTCL and responsible personnel from MONREC to reflect the actual closure condition. There are some difficulties in obtaining assessment results as mine closure is still at an early stage of development in Myanmar and experience relating to the mine closure process is still lacking. There are also some limitations with respect to interview participants' time constraints. According to the assessment results, there are some aspects of closure that still need to be improved in the current Sabetaung closure. These aspects are:

1. Post-mine land use.
2. Closure objectives and completion criteria.
3. Post-closure planning.
4. Financial provisioning for mine closure.

The S&K mine project needs to improve these aspects by consulting more with local stakeholders and other related stakeholders in a transparent manner. Overall, it can be concluded that the S&K mine follows several good mine closure practices in the Sabetaung closure process and has managed to establish an effective closure process.

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