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## **USE OF THE MULTIPLE ACCOUNTS ANALYSIS PROCESS FOR SUSTAINABILITY OPTIMIZATION**

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## ABSTRACT

There is an increasing requirement for mines to meet a certain minimum criteria for sustainability within the context of the physical environment, ecosystem and socio-economic system in which they are located. The mining industry has wrestled to develop methods for assessing the 'sustainability' value of a mining project and indicators of 'sustainability success'.

A methodology for the evaluation of sustainability of a mining project using the Multiple Accounts Analysis (MAA) system was developed. The MAA is a platform for engagement of stakeholders and for the assessment of site-specific alternatives based on both qualitative and quantitative indicators of success.

## INTRODUCTION

Mining projects aim to be developed, operated and reclaimed according to standards that ensure that the mine site meets certain minimum criteria for sustainability of the site and project long-term. The mining industry has struggled with definitions of 'sustainability', and to develop methods for assessing the 'sustainability' value of a mining project and indicators of 'sustainability success', under initiatives such as the MMSD (Mining and Metals Sustainable Development) initiative and the Global Reporting Initiative (GRI).

Project specific evaluation criteria include indicators of process – the adequate involvement of stakeholders, including effected persons and the succeeding custodians – as well as indicators of sustainability of the project (economic feasibility) and the mine site (physical, chemical, and ecological), and the sustainability of the socio-economic benefits of the economic and social stimuli from the mining activity into the post mining period.

Once indicators are defined however, how does one evaluate the combined effect of all the indicators? Is the net effect a positive or negative contribution to society?

The methodology for the evaluation of sustainability of a mining project uses the Multiple Accounts Analysis (MAA) system both as a platform for engagement of stakeholders and for the combined assessment of indicators. The MAA process allows indicators and values for intangible issues (e.g. aesthetics, risk etc.) as well as very tangible issues (e.g. costs, stability and safety etc.) to be included in an alternatives evaluation. Indicators of sustainability are defined and a methodology described for the assessment of

project sustainability by comparing alternative options.

The MAA process allows for the evaluation of an alternative from a list of alternatives for mine development or mine reclamation by weighing the advantages and disadvantages of each alternative. The technique was developed to be transparent, defensible and easily communicated to stakeholders and other interested parties. The MAA makes it possible to differentiate among alternatives in ways that are not possible if data, or issues, are viewed and assessed singly and independently. This method allows the user to consider numerous and variable issues, even issues historically considered too imprecise for evaluation.

The MAA evaluation tool was developed in a similar manner to the "Multiple Objective Decision Support Systems", or MODSS (El-Swaify and Yakowitz, 1998) that is used in the agriculture industry for land management practices aimed at attaining sustainability while providing for increased food demands by the world's growing population. The mining industry, like the agriculture industry, shares this conflict between "production-driven" and "environment-driven" objectives of natural resource use and management.

Industries such as mining and agriculture often face decisions that must take into account all substantive impacts or issues of concern to any of the multiple stakeholders directly or indirectly, positively or negatively and unequally affected by the outcome of a decision. In order to do so, the relative advantages and disadvantages of the alternatives must be evaluated, either formally or informally.

This requires a collective understanding of positive and negative impacts of various alternatives. The MAA was developed to provide a formalized framework under which a comparison of alternatives can be made. With the MAA, participants can express their concerns and communicate their assessments of the relative values of positive and negative impacts. The MAA provides a clear, transparent and defensible evaluation tool for alternatives assessments and attempts to reach consensus in ranking of alternatives.

The diversity of impacts that must be considered in mine reclamation evaluations makes integrated (combined and cumulative impacts) assessment difficult. To a large extent any comparison is subjective and depends on the value basis, or opinion of the analyst(s). It is not possible, and probably not desirable, to remove this subjectivity as each analyst seeks to have his/her value basis

applied in the analysis. It is therefore an advantage if the evaluation methodology (analysis) is systemized and transparent, allowing the various analysts to clearly indicate their value basis and results. If the results of analyses from two analysts are similar, despite differences in value basis, then there is likely to be consensus on the option selected. If results are materially different, then the root cause of the difference can be identified and discussions focused on the material issues to determine if a consensus resolution can be reached.

## METHODOLOGY

The MAA involves three steps:

Step 1. Identify the impacts (adverse and beneficial) to be included in the evaluation.

Step 2. Quantify the impacts (adverse and beneficial) for each of the Alternatives.

Step 3. Assess the combined or cumulative impacts for each Alternative and compare these with other Alternatives to develop a preference list (ranking, scaling and weighting) of options.

Steps 1 and 2 are completed in what is termed the MAA Ledger. This ledger consists of an explicit list of issues (potential impacts) that must be considered and are organized into what has been termed accounts, sub-accounts and indicators of the impacts from various Alternatives (Step 1). An **account** is an issue of concern, and is typically one of technical, economics, environmental and socio-economics (Figure 1). There are a number of issues within each account that are termed **sub-accounts**. For example air quality, water quality and effects on wildlife are typical sub-accounts of the environmental account. Sub-accounts are further divided into **indicators**. Indicators are a measure (either qualitative or quantitative) of an impact in terms that stakeholders understand, e.g. an indicator of air quality may be fugitive dust emissions. A sub-account may have only one indicator, or may have numerous indicators.

Once the accounts, sub-accounts and indicators are defined in the ledger, the list of issues to be considered is completed. The ledger is then 'filled-out' (Step 2) whereby each indicator is assessed for each alternative systematically. In this manner, the relative impacts for each alternative are quantified. Some indicators such as capital costs or area revegetated etc. can be expressed in quantitative terms and are readily measured and relatively straightforward with respect to the assignment of values. Others, such as aesthetics or hazards to wildlife, are more difficult to measure and assign values to and by necessity require qualitative values or descriptions. It is important in these

circumstances to have experienced participants in the MAA evaluation who can confidently suggest qualitative values and defend those values to the group. If the group does not have the experience required to assess a particular indicator, help can be sought from professionals in the appropriate fields.

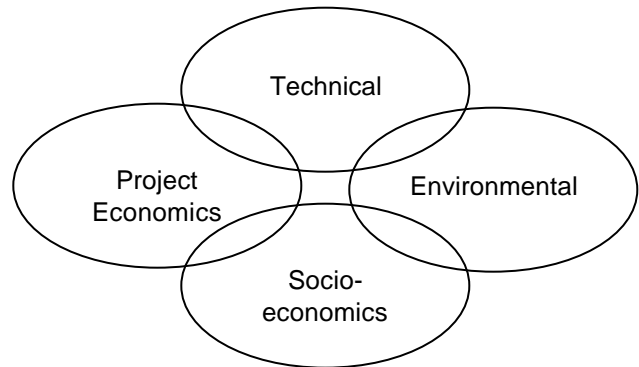


Figure 1. Four Accounts that are Typically Included in an MAA for a Mining Project.

Qualitative values typically take the form of a ranked value such as "worst to best" or "highest to lowest". For example, Alternative 1 may have the "best" aesthetic value and Alternative 2 may have an "intermediate", or "medium", value. While not quantitative, these descriptors provide a context, or forum, for communicating impacts (positive or negative) that may be equally as important as other indicators, but not as easily measured.

One can appreciate that it is important that the evaluators consist of credible, experienced specialists who can assist in the establishment of appropriate indicators and the assessment of values for the given alternatives. Since the accuracy of quantification as well as the ability to rank, scale and weigh alternatives all have some uncertainty, it is appropriate to use fairly coarse classification methods. Typically, a 5-point measure of values is appropriate, for example Low, Somewhat Low, Moderate, Somewhat High, and High.

Step 3, involves a value-based assessment, or numerical evaluation. There are many models that use variations on the same theme to provide a value-based evaluation, the procedure used in the MAA involves ranking, scaling and weighting in a systematic manner such that the combined, or cumulative impacts for each alternative can be assessed (Gregory and Slovic, 1997; Gregory and Keeney, 1994; Hope, 1998; Robertson and Shaw, 1998; Robertson and Shaw, 1999).

Ranking involves a straightforward listing of alternatives in order from best to worst with respect to each indicator independently. Because ranking is

a simple ordered list and does not distinguish how great the difference in impact between the best and worst alternatives within an indicator is, the rankings are then normalized to a common scale. Once normalized, the indicators on the list are all based on the same 'scale' and can be assessed in combination. The scale of preference in the MAA is a 9-point scale whereby the 'best' alternative is always given a '9' regardless of whether it was valued 'moderate', 'good' etc. The other alternatives are then scaled by 'mapping' them to the '9', if the "worst" alternative is considered to be half as good as the "best", it is assigned a scalar value of 5 and the rankings for the remaining alternatives are distributed between these values. The methodology accommodates separation of the best from the worst ranking that is either very slight or very significant.

Weighting of the accounts, sub-accounts and indicators instills a level of importance to the issues being considered. Typically, the MAA employs a scale of 1 - 5 for weighting factors. If an analyst considers the relative "importance" of one indicator to be twice that of another then the relative weightings would be 2 to 1 (or 4 to 2 etc). The higher the indicator weight is, the greater the importance of that indicator relative to the other indicators in that

sub-account. All the indicators within a single sub-account are normalized to the 'weight' applied to that sub-account. Similarly, all the sub-accounts within each account are normalized to the weight applied to that account.

To accomplish this, the scalar values for each alternative in every indicator are multiplied by the weighting factor for that indicator. The weighted scalar values are then summed within a given sub-account and normalized to the original 9-point scale by dividing by the sum of the indicator weighting factors (see Figure 2). The result is a normalized "sub-account score" for each alternative that provides a comparative measure, i.e. the alternative with the highest score is the "best" option with respect to the sub-account considered, and the alternative with the lowest "score" is the "worst".

A similar process of weighting, summation and normalizing is applied to the sub-account scores to obtain "account scores" for each account considered in the analysis. Finally, the process is repeated again with the account scores to obtain final MAA scores for each of the alternatives.

Account	Account Weight	Sub-Account	Sub-Account Weight	Indicator	Indicator Weight	Alt A	Alt B	Alt C
Technical	3	Groundwater Capture System	5	Efficiency	5	5	3	9
				Maintenance Requirements	1	9	7	7
				Operating Requirements	2	9	3	1
Sub-Account Score						6.50	3.50	6.75

$$\text{Sub-Account Score} = \text{SUM} (W_i \times S_{i,A}) / \text{SUM}(W_i)$$

$$\text{Scalar Value } S_{i,A}$$

Figure 2. Hypothetic Example to Illustrate Score Calculations.

The reader should understand that the assignment of values to the alternatives for any one line item is done so *relative to the other alternatives* being evaluated. As such, a qualitative value of 'somewhat high' for one indicator is not necessarily equal to a value of 'somewhat high' in another line.

This relative assessment must be kept in mind during the evaluation. Similarly, it should be noted that while an alternative may be given a value of 'high' for something such as maintenance requirements, it does not necessarily imply that the maintenance requirements would be onerous or

extreme, but that *relative to other alternatives*, the requirements are considered high.

Weights are assigned to each account, sub-account and indicator in order to provide a level of importance to the various issues evaluated in the MAA at each level of the evaluation. A scale of 1 to 5 is used whereby '5' marks issues of high importance and '1' marks issues of low relative importance. It is best to attain consensus in applying weights to the components in the ledger, however this is not always possible. In such a case where opinions differ and consensus cannot be reached, sensitivity analyses can be completed whereby the evaluation is completed with a series or set of varying weights for those controversial issues. In this manner, if the resulting preference order of alternatives is the same, a general consensus on the results can be attained regardless of the differences of opinion on specific issues. If the resulting preference order is different, then the route cause of the difference can be identified and further evaluated.

An added component can be incorporated into the MAA ledger if deemed appropriate for a specific project. That is an assessment of the evaluators' level of confidence in assigning values to each of the indicators. What this does is allow the evaluators' the ability to evaluate certain issues that are poorly understood in conjunction with those that are well understood and provide a 'flagging' system for those with a low level of confidence, either due to disagreement or to uncertainties in predictive capabilities, long-term performance etc. If a certain indicator becomes a highly discriminating issue

amongst the alternatives and is one that the evaluators' had a low level of confidence in their assessment of, then a closer look at issue may be warranted.

Similarly an assessment of the level of confidence in the ability to evaluate each alternative can be incorporated. This is related to the collective confidence in the estimates and predictions (the parameters, methodologies and sensitivities) intrinsic in the evaluation of a particular alternative.

## RESULTS

The results of the MAA can be viewed as an overall score, or as account scores, or as combinations of certain account scores, or all of the above. An example is provided in Figure 3. One should be cautioned that looking at any one score in isolation of others can be misleading and decisions based only on certain scores are often inappropriate. For instance, if interested in water quality impacts, looking only at the environmental scores may not provide the entire picture if there are particular technical or engineering features that manage the flow of water to and from the site.

One combination of scores that can be particularly insightful is to calculate the MAA score without the project economics account and plot the results against the estimated costs. This, in effect, is similar to a more traditional cost-benefit analysis. Figure 4 provides an example of this type of graphical representation.

Accounts	Account Weights	ALT A	ALT B	ALT C	ALT D	ALT E
Scoring with all Accounts weighted by relative importance.						
Technical	3	5.68	7.28	7.69	8.17	7.58
Project Economics	2	7.88	7.32	6.54	5.13	3.29
Environmental	5	5.96	7.31	7.21	7.64	7.69
Socio-economics	3	4.45	5.81	5.69	6.83	7.30
<b>MAA Score</b>		<b>5.84</b>	<b>6.96</b>	<b>6.87</b>	<b>7.19</b>	<b>6.90</b>
Re-scoring with Project Economics weighted a '0'						
Technical	3	5.68	7.28	7.69	8.17	7.58
Project Economics	0					
Environmental	5	5.96	7.31	7.21	7.64	7.69
Socio-economics	3	4.45	5.81	5.69	6.83	7.30
<b>MAA Score (Excluding Costs)</b>		<b>5.47</b>	<b>6.89</b>	<b>6.93</b>	<b>7.56</b>	<b>7.55</b>

Figure 4. Example Summary of Account Scores and MAA Score with and without Project Economics.

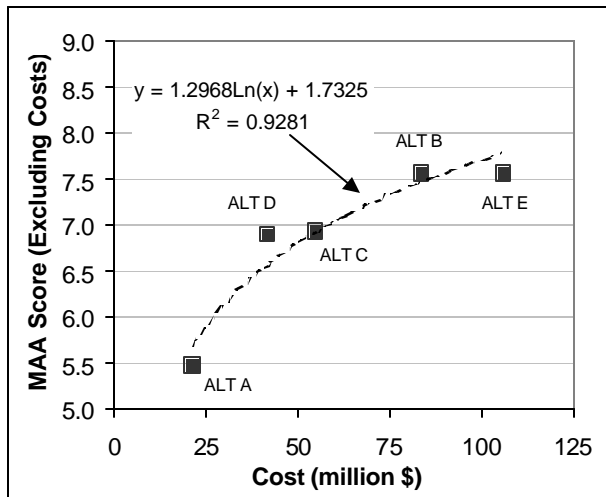


Figure 4. Example Plot of MAA Score (excluding costs) Versus Cost.

In this type of graph, groupings of alternatives with similar features or key components are often evident. In the example provided, alternatives D and C are similar and alternatives B and E are similar, while alternative A clearly does not compare. In addition, when assessing the added benefit of any given alternative for the cost of that alternative, decision-makers can assess whether the overall improvement is worth the cost. In this example, it would be difficult to justify the selection of alternative E given that it scores similarly to alternative B and is roughly \$25 million more expensive. If, however, a stakeholder were only interested in the socio-economic impacts (beneficial and adverse), then comparing the scores for alternative B and E for the socio-economic account would potentially lead to the endorsement of alternative E.

If the difference in the overall scores is very little and it is desirable to show a greater spread in the scoring, then a discrimination value filter can be applied to each indicator. A discrimination value filter can be set at a value that is comfortable for the evaluators. We have used a value of 20% in the past, whereby if the difference between the 'best' and the 'worst' alternative's scalar value  $x$  the weight for any particular indicator is less than 20% of the maximum difference, then the issue is deemed 'non-discriminating' and can be 'zero-ed' from the scoring. In this manner, only those indicators that show greater than 20% difference between alternatives are included in the calculation. Typically, this filter acts to increase the differences between scores.

#### UTILIZATION OF THE MAA

The MAA process described in this paper has been utilized for a number of purposes in practical applications, including:

- Identification of information gaps and data needs from which studies can be developed;
- Providing an objective and simplified basis on which sensitive issues can be discussed;
- Providing a defensible and transparent tool with which decision makers can evaluate the positive and negative impacts of available alternatives;
- Providing a framework for describing alternatives considered, evaluation basis and conclusions for inclusion in other documents (e.g. EIS, EA, permit applications etc.); and,
- Providing a set of criteria or indicators against which to measure sustainability.

This last point is one that is receiving ever-increasing interest by the industry, regulators and public on a global scale. The Global Reporting Initiative (GRI) being an example whereby guidelines on sustainability reporting have been published and are being used by numerous companies worldwide on a volunteer basis for reporting on economic, environmental and social dimensions of their activities, products, and services. GRI was started by the Coalition for Environmentally Responsible Economies (CERES), but has been an independent organization since 2002 and an official collaborating center of the United Nations Environment Programme (UNEP). While the supplemental guidelines for the mining and metals sector have not yet been published, a work group of experts is working on this supplement that will focus on economic, environmental and social performance indicators specific to mining.

The structure of the MAA allows for the definition of these indicators, as well as the technical, or engineering indicators, for any specific site and for the evaluation of a set of alternatives based on these indicators. With the context of sustainability being essentially in-perpetuity, it is the mine closure and the post closure period that must be subjected to the measures of sustainability.

#### INDICATORS OF SUSTAINABILITY

In order for regulators, mining companies and society to evaluate the success and reliability of closure alternatives and the relative and cumulative impacts of a mine post closure, criteria are typically applied to 'test' the performance of those measures. The assessment criteria, as to what constitutes 'a

reasonable level of post closure social, environmental and aesthetic impact, land use, active and/or passive care, costs and environmental risk' will differ for various stakeholders with interests in the mining operations and the surrounding impacted region. Definition of appropriate indicators and assessments of the appropriate criteria, for each of these indicators, must be made during closure planning in order to form a basis for decision-making. The rapid changes that are being experienced worldwide in the increase in the number of indicators (for air quality and water quality, aesthetics, land use, re-vegetation, ecosystem restoration, landform engineering, social impacts etc.) and the application of ever more stringent environmental standards for mining projects results in considerable uncertainty as to the acceptability of many criteria, particularly those involving on-going active care and risk of environmental impacts.

For most decision-making processes, there are a number of decision 'drivers', i.e. issues that are so important that they tend to determine the conclusions of the decision process. These are often related to:

- Surface and groundwater quality and impacts on the receiving environment,
- Long term stability and erosion of structures that will remain on the site,
- Land use and post closure aesthetics,
- Social and economic impacts related to a potential reduction in economic potential of an area and the potential long term burden placed on future generations related to post mining maintenance, and
- Economic consequences of closure costs to both the mining company and the financial stakeholders.

Selection of inadequately 'low' criteria may result in the rejection of a closure plan or the imposition of additional and stringent closure requirements in the permits. Selection of 'high' criteria may result in closure costs that are not economically achievable or result in incremental costs that are out of proportion relative to the gain or improvement in performance (e.g. Alt E in Figure 4). Unjustifiable closure cost expenditures waste fiscal resources that may otherwise be available for other local or national needs. The selection of criteria is therefore a balance between costs and benefits of reducing requirements for future active care and of future risk to the environment. Minimum criteria are those that just meet regulatory 'standards' and are protective of the environment, health and safety.

During mine planning and operations, it is often difficult, if not impossible, to predict, with the degree

of confidence required, the precise impact on the environment and the resulting ability to meet closure objectives or standards. Regulatory criteria are likely to change over time ('moving goalposts'), and criteria selected for the purposes of closure planning early in operations, may not be applicable at the time of closure. Therefore, it is not necessarily appropriate during mine planning, development or early operations to select quantitative closure criteria that may or may not be realistic or valid at the time of mine closure. Early in the mine's life, it may be more appropriate to discuss closure objectives, and sustainability indicators for such issues as surface water quality, groundwater quality, stability and erosion, land use, revegetation etc. in more general terms. Thus the 'tests' by which the anticipated effects of various closure measures are judged typically range from quantitative values (believed to be most realistic for long term criteria values), to semi-quantitative or qualitative (descriptive) indicators of impacts or benefits.

Typical indicators for water quality are published water quality guidelines prior to setting site-specific standards.

Stability and erosion indicators are applied to ensure the integrity of long-term stability of structures. Typically civil engineering safety standards (such as a factor of safety of 1.5 for slope stability) applies during the operating life of the mine. Durability of structures, post closure, is dependent on the durability of the materials the structure relies upon for stability. Wooden support in the underground openings, bridges, dams and buildings will fail over time resulting in failure of supported structures. Not so obvious is the long-term deterioration of other materials such as geomembrane liners or covers, reinforced concrete and corrosion protected steel structures. Yet less obvious is the long term weathering of rock, including tunnels, pit walls and waste rock, resulting in strength deterioration and failures. Rip-rap protection on a dam face or lining a ditch will last only for the period over which the rock from which it was quarried is durable.

Structures are under the continual attack of both perpetual 'forces' such as weathering and corrosion, erosion by wind and water, sedimentation, biotic action by roots and burrowing animals and frost action.

Structures are also subject to extreme events, which, because of the long period of post closure interest (and the need to be sustainable) have a much greater probability of occurrence than during the operating period of the mine. Further, the consequences (economic, environmental and socio-

economic) of structural failures of, for instance mine rock piles, tailings dams etc., are also oftentimes large. Therefore, it is typical for long-term closure planning, that measures will consider larger events where the consequences of failure would be catastrophic, i.e. 1:10,000 year or maximum credible earthquake (MCE).

The selection and computation of design floods is another important part of many mine closure plans for features associated with water management (e.g. spillways, ditches, tailings dams, diversions, ARD capture and transport facilities, water treatment plant storage ponds etc.). Non-critical structures are typically designed to accommodate the 1 in 100 year flood event while structures that would cause large, but not catastrophic impacts, or are critical to the operations of specific facilities would require design to accommodate the 1 in 1000 year event. Those structures for which failure could result in casualties or cause catastrophic environmental impacts should be designed for the probable maximum flood (PMF). The provision for long term post closure operation of water management structures is often one of the most challenging aspects of closure measures design but imperative for maintaining a sustainable post closure system.

The post mining land use and socio-economic impacts are extremely important issues for consideration in closure planning. Mine site development is often responsible for significant changes in the local social and economic conditions in an area. In industrialized and highly developed countries, the priority for rehabilitation of mine sites located remote from population centers is usually to return the site to the conditions that existed prior to mining, or an agreed equivalent. In industrialized countries, large mines have often been the catalyst around which a larger industrial and urbanized community has developed (i.e. the Witwatersrand of South Africa; Bingham Canyon/Salt Lake City, Utah; Berkley Pit/ Butte, Montana). A return to pre-mining socio-economic conditions is sometimes not contemplable, in particular in regions with very little previous industry development (e.g. areas of Peru, Indonesia, Papua New Guinea etc.). To the extent reasonably achievable, mine closure must address the facilities and conditions that should be maintained post mining, to sustain the social and economic benefits generated during mining. While it is not possible to select closure criteria for all these issues, comparative assessments using indicators such as maintenance of access and power, on-going protection of health and safety, on-going job opportunities, sustainability of tax revenue etc. should be completed.

## SUMMARY

The cumulative assessment of the various benefits and impacts of all the closure measures can be completed on this basis using the MAA methodology. The resulting evaluation of all stakeholder issues, including water quality, stability and erosion, land use, socio-economics and economics, provides a comparative 'test' of success of a closure plan without necessarily applying or committing to closure criteria too early in the closure planning process.

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