

DECISIONS, DECISIONS, DECISIONS
DECISION ANALYSIS PROCESS FOR MINE CLOSURE

Carman Stevens, Michelle Murphy,
Andy Small

November 2021

Outline

- Goals of Decision Making
- Decision Analysis Approach
- Overview of Steps
- Refer to Legacy Gold Mine Closure Decision Analysis

Goals of Decision Making

- Positive interaction among stakeholders
- Build consensus (or agreement)
- Satisfaction and pride that the decision is a good one
- Level of trust and credibility
- Reduce misunderstandings
- Consideration to stakeholders
- Create an atmosphere where opinions and efforts are valued. This leads to more good ideas.
- Make you feel proud of the decision.



Decision Analysis Approach

- Websites:
 - <http://www.kepner-tregoe.com/>
 - <http://www.decision-making-confidence.com/kepner-tregoe-decision-making.html>
 - [ICMM • Integrated Mine Closure: Good practice guide \(2nd edition\)](#)
- Structured common sense
- Balanced decision
- Strength is in getting and keeping everyone on the same wavelength

Decision Analysis Approach

- Decision Analysis
 1. Identify stakeholders
 2. State decision
 3. Objectives
 4. Cost metrics
 5. Alternatives
 6. Score the alternatives
 7. Risk assessment
 8. Make decision and set course of action



Strengths/Advantages of Process

- Focuses a group on one item at a time
- Provides clarity to ideas
- Sorts out fact from fiction
- Gains consensus
- Semi-quantitative
- Streamlines activities
- Identifies risks and plans to deal with them

Multiple Accounts Analysis

- Guidance developed by Environment Canada
 - [Guidelines for the assessment of alternatives for mine waste disposal - Canada.ca](#)
- International Council on Mining & Metals (ICMM) Integrated Mine Closure Good Practice Guide
 - <https://www.icmm.com/en-gb/guidance/environmental-stewardship/integrated-mine-closure-2019>
- Fundamentals are the same as Decision Analysis
- Difference in terminology (ledger, accounts) and how costs are handled

Terminology

- **Objectives** - are based on the understanding of the issues and overall project objective. They have been subdivided into “musts” and “wants”.
- **Musts** - are criteria that must be met in order for an alternative to be successful (e.g., design criteria (earthquake/flood) and regulatory criteria).
- **Wants** - are objectives that provide the means of differentiating between alternatives (e.g., maximize opportunity to reach passive care); they do not need to be met for an alternative to succeed. (3 categories - technical/operational, environmental, socio-economic/sustainability).

Terminology (cont'd)

- **Element** – individual items required to meet an objective. i.e., water treatment.
- **Alternative/Option** – a group of elements that make up an alternative.
- **Domain** – a smaller area within the project site that has individual requirements separate from other areas within the project. i.e., tailings.

Step 1 – Identify Stakeholders

Approach

Identify people that:

- Could be affected by the decision
- Could have input to the decision
- Have to approve the decision
- Could block the decision

Outcome

- Develop stakeholder list
- Identify core group that will do “the heavy lifting” to make the recommendation
- Develop communication protocols
- Develop RASCI matrix

Step 2 - Establish Decision Statement

Approach

Determine the fundamental purpose. What are you trying to do? What problem is being solved? Include action and object words. This statement should be restrictive and defines the battery limits.

Outcome

A Decision Statement that will guide the process. The statement is not set-in-stone and will be revisited through the process.

Decision Statement - Examples

Potential Decision Statements:

- Determine the best way to manage the site based on the government protocols.
- Determine the best way to close the site.
- Best – optimizing costs, technical merit, risks

Consensus point

Step 3A - Establish Objectives – “Musts”

Musts

Absolute Requirements: criteria that must be met in order for an alternative to be successful (e.g., regulatory criteria).

Approach

Identify requirements from policies, regulations, corporate requirements, etc.

Outcome

A list of objectives that outline the absolute requirements; e.g., *Mines Act*, *Environmental Management Act*, Corporate policies (such as a Health, Safety and Environment policy).

Consensus point

Step 3A - Establish Objectives – “Musts” Example

Element	Objective (Musts)	Notes
Regulatory requirements	CCME Tier II and the provincial government managed site requirements.	Meet CCME Tier II criteria
Human health	Reduce exposure to humans through surface contact, ingestion and dust.	CCME Tier II criteria: As = 750 mg/kg, Hg 29 mg/kg.
Ecological health	Ecological criteria	CCME Tier II criteria
Safety during construction.	Health and safety during construction and development	Local, provincial and federal OHS criteria.

Step 3B - Establish Objectives - "Wants"

Wants

Objectives that provide the means of differentiating between options.
Cost is dealt with separately.

Approach

Examples include Passive Care, Simplicity of Operation and Implementation, Water Management and Treatment, etc.

Outcome

The list of objectives are used to compare the alternatives.

Consensus point

Step 3B - Weight Objectives - Example

Technical/Operational Elements	Objective (Wants)
Simplicity of closure alternative	Maximize simplicity of the closure alternative construction methodology.
Timeline for Significant Improvement	Minimize timeline to achieve significant improvement to the site conditions.
Timeline for Complete Implementation	Minimize timeline to complete implementation of overall site closure activities.
Long term maintenance requirements	Minimize maintenance (e.g., erosion structures, dams, fencing, vandalism).
Progressive reclamation	Maximize opportunity for progressive rehabilitation (proceed in stages) to meet cash flow requirements and allow for observational monitoring.
Environmental Elements	Objective (Wants)
Fish passage	Maximize fish passage opportunity (e.g., from upstream lake along local brook through site to downstream lake).
Wetland creation	Maximize the opportunity for wetland creation.
Socio-economic/Reputational Elements	Objective (Wants)
Reputation and Stakeholder Expectations	Minimize adverse public perception of the site closure.
Terrestrial green space	Maximize the development of terrestrial green space including recreational use.

Step 3B - Weight Objectives

Weighting

Objectives are provided a weighting based on their relative importance to the Client (1 to 10).

Approach

Each person assigns a weighting for each objective. Where there are differences, the weightings will be discussed to reach consensus.

Outcome

Alignment on objectives and their relative importance.
Clarity on what each objective means.

Consensus point

Step 3B - Weight Objectives - Example

Technical/Operational Elements	Objective (W ants)	Weighting
Simplicity of closure alternative	Maximize simplicity of the closure alternative construction methodology.	9
Timeline for Significant Improvement	Minimize timeline to achieve significant improvement to the site conditions.	7
Timeline for Complete Implementation	Minimize timeline to complete implementation of overall site closure activities.	5
Long term maintenance requirements	Minimize maintenance (e.g., erosion structures, dams, fencing, vandalism).	8
Progressive reclamation	Maximize opportunity for progressive rehabilitation (proceed in stages) to meet cash flow requirements and allow for observational monitoring.	7
Environmental Elements	Objective (W ants)	Weighting
Fish passage	Maximize fish passage opportunity (e.g., from upstream lake along local brook through site to downstream lake).	9
Wetland creation	Maximize the opportunity for wetland creation.	5
Socio-economic/Reputational Elements	Objective (W ants)	Weighting
Reputation and Stakeholder Expectations	Minimize adverse public perception of the site closure.	7
Terrestrial green space	Maximize the development of terrestrial green space including recreational use.	6

Step 3C - Rate Objectives

Rating

Objectives are divided into rating categories to identify how well an alternative meets the objective (0 to 10).

Approach

Define the "bookends" (i.e., the best and worst criteria) of the objective to be used for alternative scoring.

Outcome

Clarity on what each objective means will provide guidance.

Consensus point

Step 3C - Rate Objectives - Example

Element	Objective (Wants)	10	8	6	5	4	2	0
Technical/Operational								
Simplicity of closure alternative	Maximize simplicity of the closure alternative construction methodology	Very simple technology			Current conditions			Complex solution
Timeline for Significant Improvement	Minimize timeline to achieve significant improvement to the site conditions	Implement alternative by 2024	Implement alternative by 2025	Implement alternative by 2026	Implement alternative by 2027	Implement alternative by 2028	Implement alternative by 2029	Implement alternative followed 2030
Timeline for Complete Implementation	Minimize timeline to complete implementation of overall site closure activities	Inspections and maintenance required every 5 - 10 years			Annual inspections, minimal maintenance			Monthly inspections, frequent maintenance requirements
Long term maintenance requirements	Minimize maintenance (e.g., erosion structures, dams, fencing, vandalism)	Tax gain or facility use fees						No revenue generation
Progressive reclamation	Maximize opportunity for progressive rehabilitation (proceed in stages)	Adaptable to changes with staged or progressive reclamation		Moderate changes required to accommodate progressive reclamation		Significant changes required to accommodate progressive reclamation		Unable to accommodate progressive reclamation

Step 3C - Rate Objectives - Example

Element	Objective (Wants)	10	8	6	5	4	2	0
Environmental								
Fish passage	Maximize fish passage opportunity (e.g., Trout Brook)	Significantly improve fish passage from Lake A through to the Lake B						Close fish passage from Lake A to Lake B
Wetland creation	Maximize the opportunity for wetland creation	No additional permitting required for wetland development	Some permitting required but will take less than 1 -year to get a permit		More challenging permits		Extensive studies to support permitting may take several years to get a permit	Proving new approaches to tailings storage in relation to water quality
Socio-economic/Reputational								
Reputation and Stakeholder Expectations	Minimize adverse public perception of the site closure	Implementation of solution will enhance public perception and reputation			No change in public perception or reputation			High degree of adverse public reaction and harm to company reputation
Terrestrial green space	Maximize the development of terrestrial green space	Convert the waste areas into useable green space			Convert some of the waste areas into useable green space			Areas remain unusable and unsightly

Step 4 – Cost Metrics

Costs

Costs are treated separately.

Approach

Identify metrics: capital cost, operating cost, cash flow, Net Present Value.

Outcome

Identification of cost metrics that will have a bearing on the decision.

Consensus point

Step 5 - Develop Alternatives

Elements

Identify elements that could form part of the solution. Be open and imaginative.

Approach

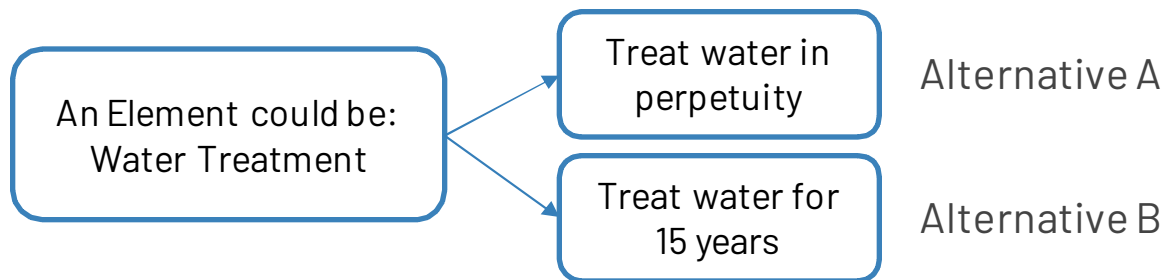
Combine elements to develop Alternatives.

Outcome

A set of Alternatives that cover various options for meeting the Decision statement that can then be assessed against the Objectives.

Consensus point

Developing Alternatives (Options) – cont'd



More Elements for Alternative A, and Alternative B can be developed based on this initial Elements

Step 6 - Alternatives Scoring

Approach

Assess each Alternative against each Objective to rank each Alternative. Each Objective is assigned a Rating based on how well the Alternative meets that objective. This approach leads to a quantitative score for each Alternative.

Outcome

Alternatives are ranked technical score and ranks the Alternatives.

Step 6 - Alternatives Scoring - Example

Option Number		Weighting Factor	0		1		2		3	
Option Description			Status Quo		Consolidate Exposed Tailings into a Cell and Cover with Low Permeable Cover		Consolidate Exposed and Buried Tailings into a Cell and Cover with Low Permeable Cover. Infill wetlands with granular fill and soil to create dry environment		Consolidate Exposed Tailings into a Cell and Apply a Soil Solidification Process	
Synopsis			Leave site as is		Do not disturb tailings within the wetland		Excavate tailings and soils with an arsenic concentration greater than CCME Tier I human and ecological health criteria limits		Excavate tailings and soils with an arsenic concentration greater than CCME Tier I human and ecological health criteria limits	
Scoring			Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Technical/Operational Elements	Objective (Wants)									
Simplicity of closure option	Maximize simplicity of the closure option construction methodology	9	10	90	9	81	8	72	7	63
Timeline for Significant Improvement	Minimize timeline to achieve significant improvement to the site conditions	7	0	0	2	14	5	35	8	56
Timeline for Complete Implementation	Minimize timeline to complete implementation of overall site closure activities	5	10	53	8	42	6	32	6	32

Step 6 - Alternatives Scoring - Example

Option Number		Weighting Factor	0		1		2		3	
Option Description			Status Quo		Consolidate Exposed Tailings into a Cell and Cover with Low Permeable Cover		Consolidate Exposed and Buried Tailings into a Cell and Cover with Low Permeable Cover. Infill wetlands with granular fill and soil to create dry environment		Consolidate Exposed Tailings into a Cell and Apply a Soil Solidification Process	
Synopsis			Leave site as is		Do not disturb tailings within the wetland		Excavate tailings and soils with an arsenic concentration greater than CCME Tier I human and ecological health criteria limits		Excavate tailings and soils with an arsenic concentration greater than CCME Tier I human and ecological health criteria limits	
Scoring			Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Technical/Operational Elements	Objective (Wants)									
Long term maintenance requirements	Minimize maintenance (e.g., erosion structures, dams, fencing, vandalism)	8	2	15	7	53	8	60	9	68
Progressive reclamation	Maximize opportunity for progressive rehabilitation (proceed in stages)	7	0	0	4	26	9	59	4	26
Technical/Operational Score		42	22	158	30	222	36	257	34	244
Environmental Elements	Objective (Wants)									
Fish passage	Maximize fish passage opportunity (e.g., Trout Brook)	9	5	46	9	83	2	19	4	37
Wetland creation	Maximize the opportunity for wetland creation	5	0	0	5	25	0	0	5	25
Environmental Score		14	5	46	14	108	2	19	9	62

Step 6 - Alternatives Scoring - Example



Option Number		Weighting Factor	0		1		2		3	
Option Description			Status Quo		Consolidate Exposed Tailings into a Cell and Cover with Low Permeable Cover		Consolidate Exposed and Buried Tailings into a Cell and Cover with Low Permeable Cover. Infill wetlands with granular fill and soil to create dry environment		Consolidate Exposed Tailings into a Cell and Apply a Soil Solidification Process	
Synopsis			Leave site as is		Do not disturb tailings within the wetland		Excavate tailings and soils with an arsenic concentration greater than CCME Tier I human and ecological health criteria limits		Excavate tailings and soils with an arsenic concentration greater than CCME Tier I human and ecological health criteria limits	
Scoring		Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	
Socio-economic/Reputational Elements	Objective (Wants)									
Reputation and Stakeholder Expectations	Minimize adverse public perception of the site closure	7	0	0	5	35	8	56	6	42
Terrestrial green space	Maximize the development of terrestrial green space	6	0	0	2	12	9	54	5	30
Socio-economic/Reputational Score		13	0	0	7	47	17	110	11	72
Maximum Technical Score			278		278		278		278	
Maximum Environment Score			143		143		143		143	
Maximum Socio-Economic Score			130		130		130		130	
Maximum Total Score			550		550		550		550	
Option Technical Score			143		169		197		177	
Technical Score % of Maximum			51%		61%		71%		64%	
Option Environment Score			46		108		19		62	
Environmental Score % of Maximum			32%		76%		13%		44%	
Option Socio-Economic Score			0		47		110		72	
Socio-economic Score % of Maximum			0%		36%		85%		55%	
Option Score			189		324		326		311	
Percent of Maximum Score			34%		59%		59%		56%	
Option Rank			4		2		1		3	

Step 6 – Alternative Cost Estimate

Costing

Develop a cost for each element to determine the Alternative cost.

Approach

High level costs based on experience, general cost ranges; using metrics developed earlier.

Outcome

Cost for each Alternative.

Step 7 – Risk Assessment

Approach

Select top alternatives and conduct risk assessment for each of them. If risks are above “Low”, then modify the design of the alternative to reduce to “Low”. May change costs. May not get all risks to “Low”.

Outcome

Alternatives are ranked in terms of risks.

Step 8 – Make Decision

Alternative	Technical Score	Risk Index	Cost
1			
2			
3			

Make decision on alternative(s) that should be advanced further based on balance of technical merit, risk, and costs.

Step 8 – Make Decision - Example

Alternative No.	Alternative Description	Weighted Score	Percent of Top Technical Rank Alternative	Technical Rank	Costs (Millions \$)	Risk Level	Risk factors	Final Rank
0	Status Quo with No Improvements	189	58%	4	0	High	On-going risks to human and ecological health.	4
1	Consolidate Exposed Tailings into a Cell and Cover with Low Permeable Cover	324	100%	2	\$12.0	Low- Med	Low risk of mobilizing arsenic in higher concentrations into the surface water and groundwater, and into the downstream environment "make the immediate situation worse than it already is".	1
2	Consolidate Exposed and Buried Tailings into a Cell and Cover with Low Permeable Cover. Infill wetlands with granular fill and soil to create dry environment	326	100%	1	\$25.0	Med-High	Risk of mobilizing arsenic in higher concentrations into the surface water and groundwater, and into the downstream environment "make the immediate situation worse than it already is".	2
3	Consolidate Exposed and Buried Tailings into a Cell and Utilize a Soil Solidification Process	311	95%	3	\$30.0	Med-High	Risk of mobilizing arsenic in higher concentrations into the surface water and groundwater, and into the downstream environment "make the immediate situation worse than it already is".	3

ADDITIONAL BENEFITS OF THE KCB DECISION ANALYSIS PROCESS

- Another benefit is that once the decision analysis has been completed for a specific project, the framework is easily updated throughout the life of the mine.
- Finally, decision makers (i.e., company management) are kept informed and are invited to provide input and direction, improving the likelihood of gaining their support – a vital step for a successful decision.

CONCLUSIONS

- The process can be utilized to make any decision, large or small, conceptual through detailed, and applied to new, existing, or legacy mine closure projects.
- The process provides a consistent framework, good practice guidance for integration, and a disciplined approach for mine closure, while allowing for project specific freedom.

CONCLUSIONS

- With a skilled facilitator and the correct stakeholders, a preferred alternative for a closure plan can be developed that balances competing objectives, costs, and risks to make a well-informed decision.