

Multi-Criteria Analysis as a Decision Support Tool for Remediation Alternatives at Contaminated Sites

Pär-Erik Back^{1,3}, Patrik Brodd¹, Lars Grahn², Lars Rosén^{2,3}, Åsa Soutukorva⁴, Tore Söderqvist⁴

¹SWECO, Stockholm, Sweden

²SWECO, Göteborg, Sweden

³FRIST, Chalmers University of Technology, Göteborg, Sweden































⁴Enveco Environmental Economics Consultancy, Skärholmen, Sweden

Contents

- **What is Multi-Criteria Analysis (MCA)?**
- **The suggested methodology**
- **Example application**
- **Conclusions**

A simple MCA for remediation alternatives

Performance matrix

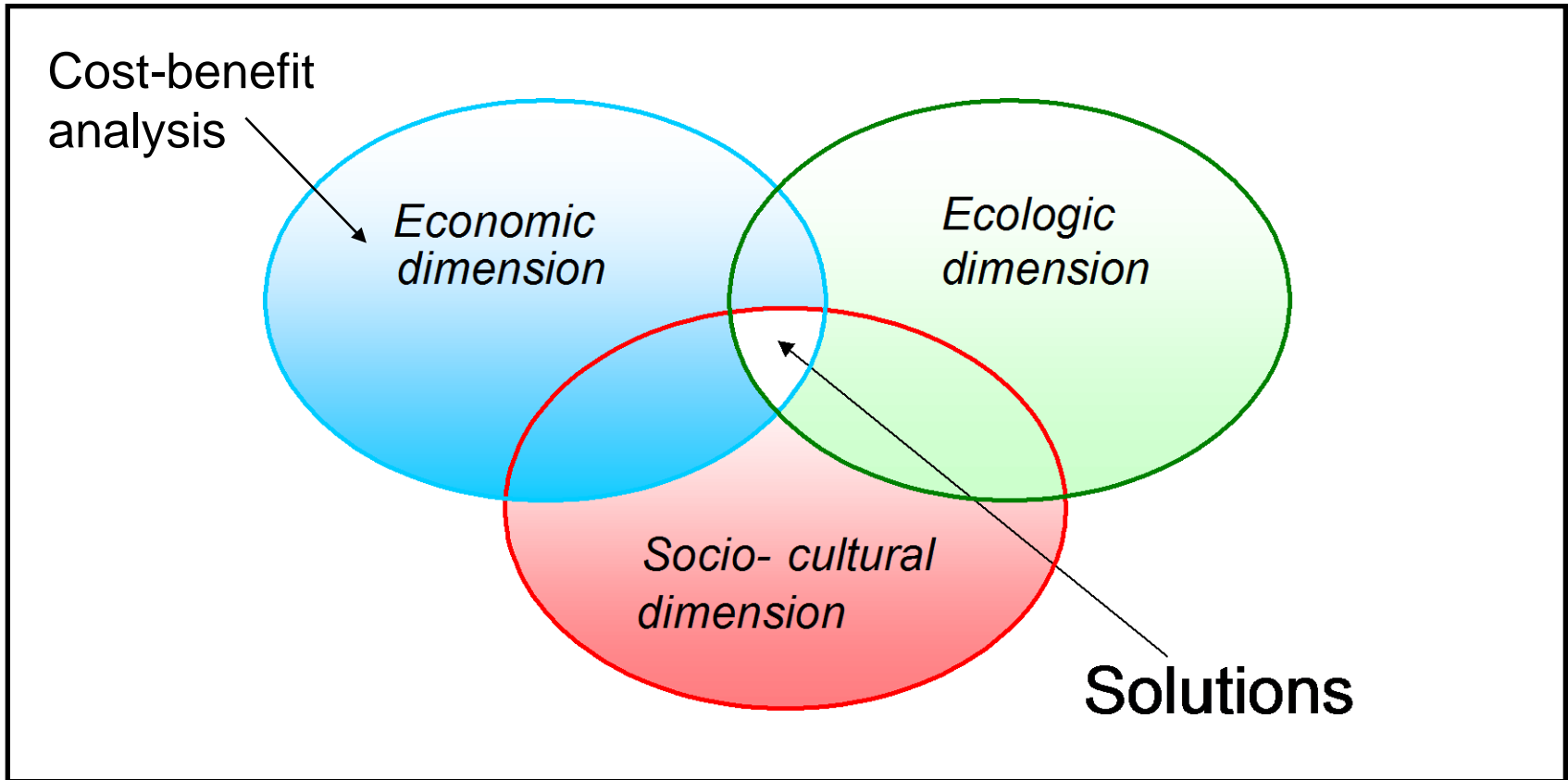
Remediation alternative	Fulfilment of remediation goals	Cost	Environmental impact during remediation	Temporary impact on on-going activities	Benefit to society after remediation	Restrictions on landuse after remediation
1						
2						
3						
4						
5						

Example of MCA methods

- **Multi-attribute utility methods**
- **Linear additive methods**
- **Analytical hierarchy process, AHP**
- **Outranking**
- **Non-compensatory methods**

The three dimensions of Sustainable Development

Multi-criteria analysis



The suggested methodology

Step 1: Define remediation alternatives

Modify alternatives

Step 2: Evaluate the ecological and socio-cultural dimensions:

- Assign scores to performance criteria
- Set up performance matrix

Step 3: Perform Cost-Benefit Analysis (CBA)

Step 4: Identify sustainable remediation alternatives

Step 5: Calculate sustainability index

Step 6: Rank alternatives

Best
2nd best
3rd best
...

Key performance criteria

Table 1. Suggested key performance criteria for the ecological and the socio-cultural dimensions of sustainability.

Ecological dimension	Socio-cultural dimension
Land environment	Equity and acceptance
Groundwater	Health, concerning contamination at the site
Surface water	Health, concerning remedial actions
Air	Cultural environment
Sediment	Recreation
Consumption of natural resources	Landuse in the surroundings
	Landuse at the site



Assigning scores to performance criteria

Probable negative effect = -2

Possible negative effect = -1

Negligible or nonexistent effect = 0

Possible positive effect = 1

Probable positive effect = 2

Supporting information are provided for each performance criterion regarding what to consider when scores are assigned.

Strong and weak sustainability

Strong sustainability

- No form of capital (natural capital, human capital, man-made capital) is reduced over time.



A reduction in one form of capital cannot be compensated by an increase in a different form of capital.

Weak sustainability

- The sum of all forms of capital does not decrease over time.



Compensation between different forms of capital can take place.

Sustainability in the Ecological dimension

Strong sustainability:

All scores ≥ 0

Performance criteria for the Ecological dimension
Land environment
Groundwater
Surface water
Air
Sediment
Consumption of natural resources

Weak sustainability:

Negative scores compensated by positive scores

Sustainability index

Ecological dimension:

$$H_{E,i} = \sum_{e=1}^E (K_{e,i})$$

Socio-cultural dimension:

$$H_{S,i} = \sum_{s=1}^S (K_{s,i})$$

Economic dimension:

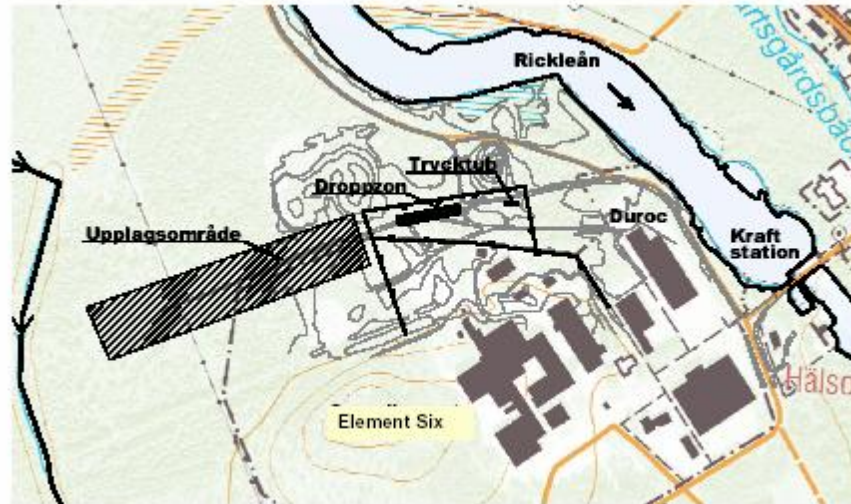
$$H_{\Phi,i} = \Phi_i \quad (\text{net benefit})$$

Sustainability index for alternative i :

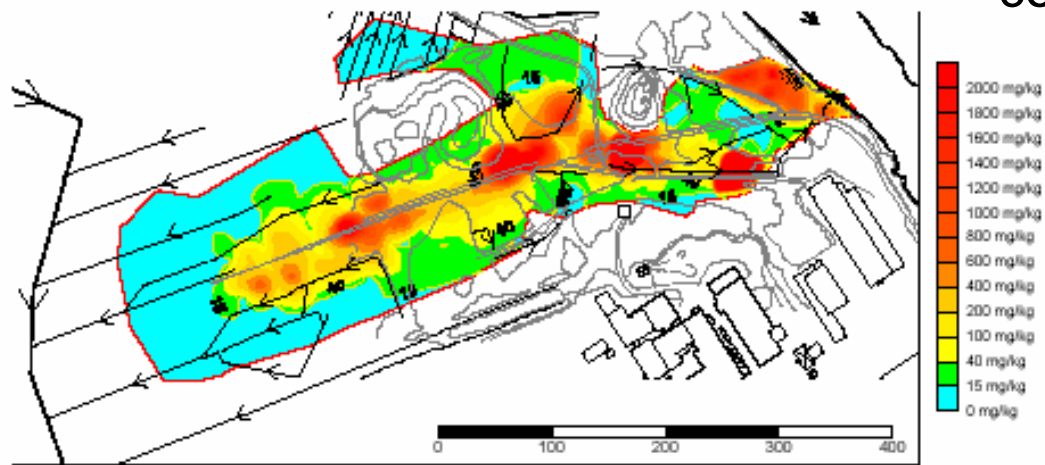
$$H_i = \frac{H_{E,i} - \text{Min}(H_{E,1..N})}{\text{Max}(H_{E,1..N}) - \text{Min}(H_{E,1..N})} + \frac{H_{S,i} - \text{Min}(H_{S,1..N})}{\text{Max}(H_{S,1..N}) - \text{Min}(H_{S,1..N})} + \frac{\Phi_i - \text{Min}(\Phi_{1..N})}{\text{Max}(\Phi_{1..N}) - \text{Min}(\Phi_{1..N})}$$

$$0 \leq H_i \leq 3$$

Example application: Old wood treatment plant



Arsenik
contaminated soil



Scores for the ecological dimension



<i>Performance criteria</i>	<i>Alt. 0</i>	<i>Alt. 1</i>	<i>Alt. 2</i>	<i>Alt. 3</i>
Land environment	-1	+1	+1	+1
Groundwater	-1	+1	+1	0
Surface water	-1	+1	+1	0
Air	0	-1	0	0
Sediment	-1	+1	+1	+1
Consumption of natural resources	-1	-1	+1	+1


Alt. 0: Baseline condition – As today (fence)

Alt. 1: Excavation and disposal to landfill

Alt. 2: Cover system with vertical barrier

Alt. 3: Cover system and removal of sediments

Scores for the socio-cultural dimension



<i>Performance criteria</i>	<i>Alt. 0</i>	<i>Alt. 1</i>	<i>Alt. 2</i>	<i>Alt. 3</i>
Equity and acceptance	-1	+2	+1	-1
Health, concerning contamination at the site	-1	+2	+2	+1
Health, concerning remedial actions	0	-1	0	0
Cultural environment	0	0	0	0
Recreation	-1	+2	+1	+1
Landuse in the surroundings	-2	+2	+1	0
Landuse at the site	-2	+2	+1	+1

Alt. 0: Baseline condition – As today (fence)

Alt. 1: Excavation and disposal to landfill

Alt. 2: Cover system with vertical barrier

Alt. 3: Cover system and removal of sediments

Results

	Alt. 0	Alt. 1	Alt 2.	Alt. 3
Ecological dimension, H_E	-5	2	5*	3*
Socio-cultural dim, H_S	-7	9	6*	2
Economic dimension, H_ϕ	0*	-54	-1	-1
Sustainability index	1.00	1.70	2.79	2.34
Strong sustainability	No	No	No	No

* = Fulfills strong sustainability

Conclusions

- **The suggested MCA methodology can be used to identify sustainable remediation alternatives and to rank the alternatives.**
- **The methodology is transparent and can be used as a tool for communication between the involved parties.**
- **The scores assigned to the performance criteria can deviate substantially between different decision-makers. Therefore, the analysis should be performed by a team.**
- **The suggested methodology is relatively simple, which is an advantage for practical application.**

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