Multi-Criteria Decision Analysis in Energy Master Planning

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US Army Corps of Engineers
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Why Do We do Analysis?

TO SUPPORT A DECISION!

- Compare alternatives
- Decision metrics – criteria
- Some criteria may be more important – who decides?
- Quantitative vs. qualitative
- Record of decision process – e.g. NEPA requirements in U.S.

Alternative	Investment	Total Equivalent Annual Cost
		(Dollars/Year)
Baseline	0	12,249,182
Basecase	0	17,096,926
Better Case	29,111,488	15,736,697
Best Case	47,955,068	14,066,687
Best Case w 50% Renewables	71,635,072	11,779,615
Best Case Net Zero	185,848,672	13,318,683

- This presentation will describe a process to evaluate multiple criteria to support decision making
- Tool is available in the System Master Planning Tool (SMPL)
  - Working example in table – range of efficiency and generation measures up to and including islanded operation

Multi-Criteria Decision Analysis (MCDA)

- Method(s) for supporting decision-making when there are multiple criteria, often conflicting. Sometimes called MCDM*
- Define the context and the decision to be made
- Identify stakeholders
- Develop the decision model
  - ► Describe criteria for decision making
  - ► Stakeholders assign criteria weights
  - ► Many models – pros and cons discussed in the literature
- Delineate alternatives
- Rate alternatives and compare – may need to iterate

$$\text{Ai} = \sum_{J=1}^{n} Cj\ x\ Wj, for\ j = 1, 2, , \ldots n; i = 1, 2, \ldots k$$

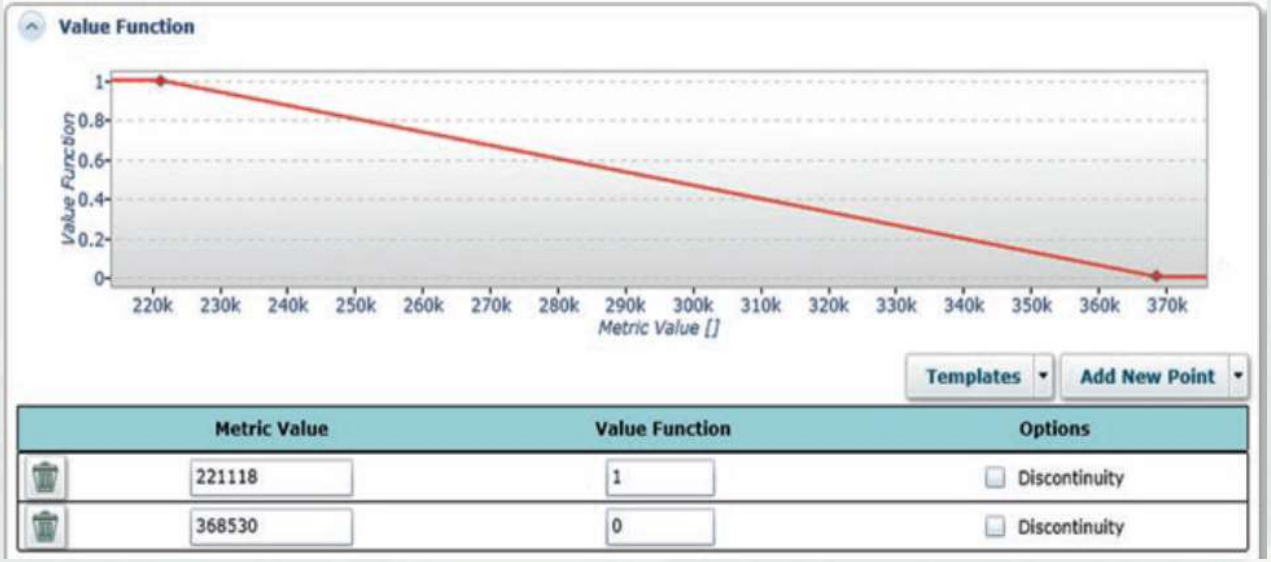
*Zionts, S. (1979). MCDM—if not a roman numeral, then what?. Interfaces, 9(4), 94-101.

Stakeholder Decision Criteria

- Multiple stakeholders may have different criteria and priorities
  - ► Can develop multiple stakeholder models and compare
- Typical Decision Criteria
  - ► Investment and life cycle costs ($)
  - ► Energy - Site and Source (MWhr)
  - ► Energy Security (electrical, thermal)
    - Maximum Single Event Downtime (time)
    - Robustness (% required energy available)
    - Energy availability (% time required energy available)
  - ► Community opinion - survey
  - ► Expert opinion – e.g., Delphi Method

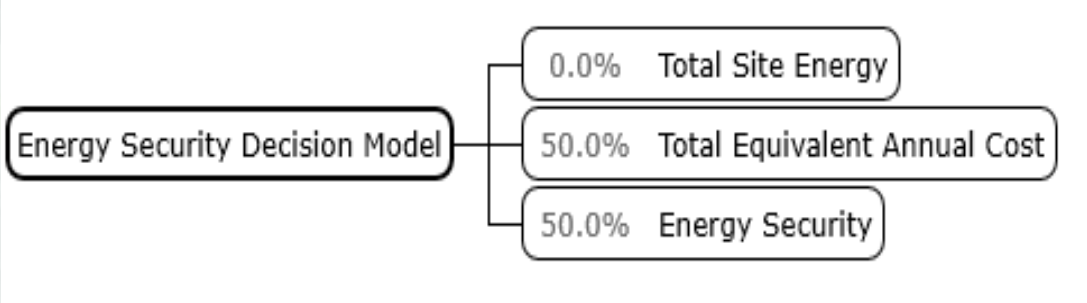
Assigning A Value Function to Criteria

- Assign each criterion a value between 0 and 1
- Below, any cost below $220K is assigned the highest value of 1.0, while any cost above $370K is assigned a value of zero.
- Assignment of value requires stakeholder participation
- Metric value may be pulled directly from simulation or input manually based on expert opinion.

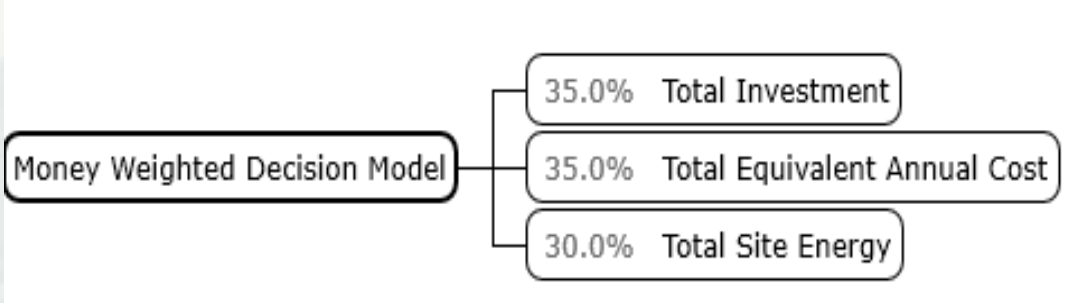


Decision Model Examples

- Energy Security Weighted



- Cost Weighted



Weighted Alternative Comparison

- Energy Security Weighted

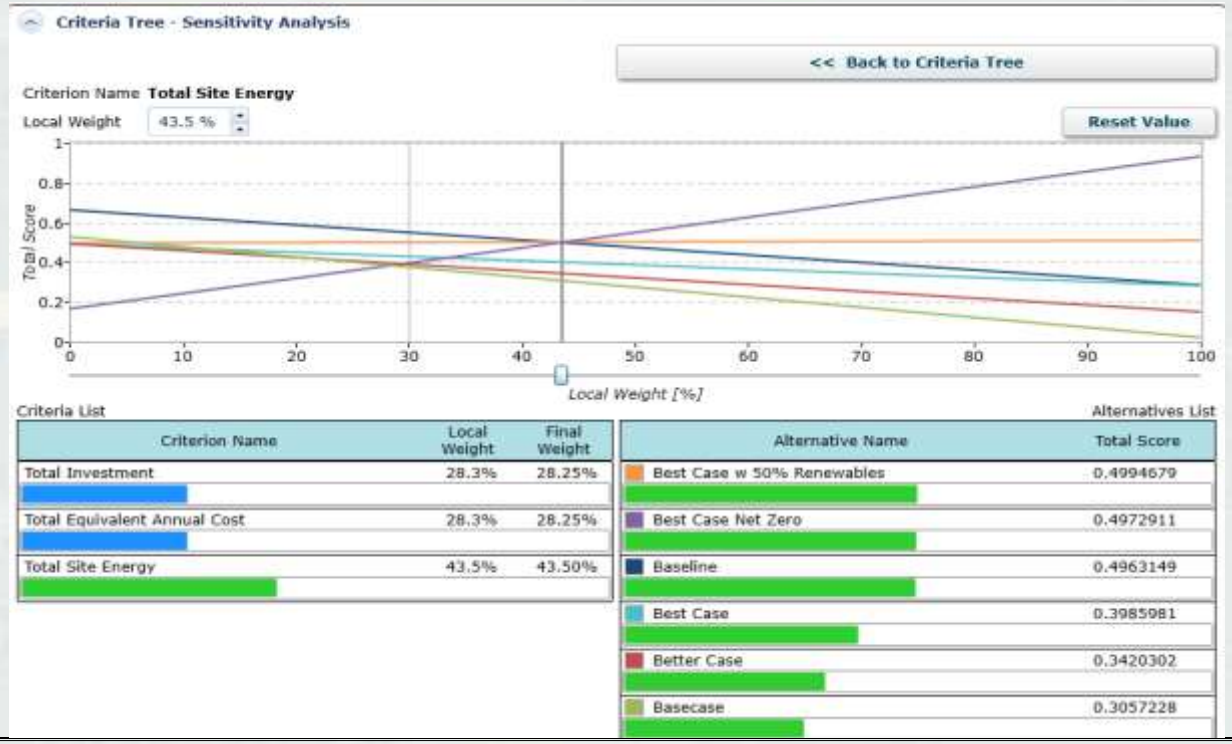
Rank	Alternative Name	MCDA Score
1	Best Case Net Zero	0.5222414
2	Best Case w 50% Renewables	0.3574308
3	Baseline	0.2403489
4	Best Case	0.1763139
5	Better Case	0.1173747
6	Basecase	0.0593616

- Cost Weighted

Rank	Alternative Name	MCDA Score
1	Baseline	0.5470346
2	Best Case w 50% Renewables	0.4976781
3	Best Case	0.426769
4	Best Case Net Zero	0.394295
5	Better Case	0.38798
6	Basecase	0.3738008

Sensitivity Analysis

- How sensitive is the ranking to rating weights?
- As a criterion weight is adjusted, alternative rankings may change
- Crossover points can be identified
- Helps stakeholders to assess relative importance of weightings



Comparison of Decision Models

- Different stakeholder groups may have different priorities
- 50% renewable energy option was 2nd choice of both models and may represent best compromise choice between resilience and cost

Decision Analysis - Results

Ranking Summary:

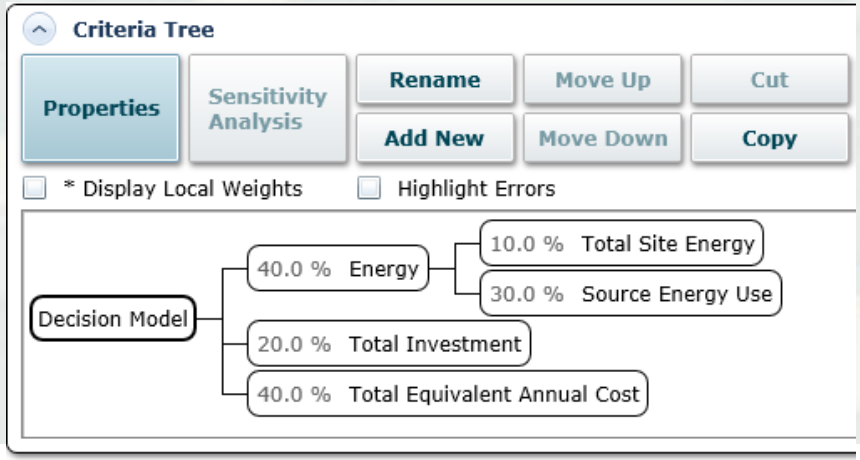
Alternative Name	Highest Rank	Average Rank	Lowest Rank
Baseline	1	2	3
Best Case w 50% Renewables	2	2	2
Best Case Net Zero	1	2.5	4
Best Case	3	3.5	4
Better Case	5	5	5
Basecase	6	6	6

Ranking Details:

MCDA Models / Alternatives	Energy Security Decision Model	Money Weighted Decision Model
Baseline	3	1
Best Case w 50% Renewables	2	2
Best Case Net Zero	1	4
Best Case	4	3
Better Case	5	5
Basecase	6	6

Another Example

Centralized system allows for higher energy security and flexibility (in this case)

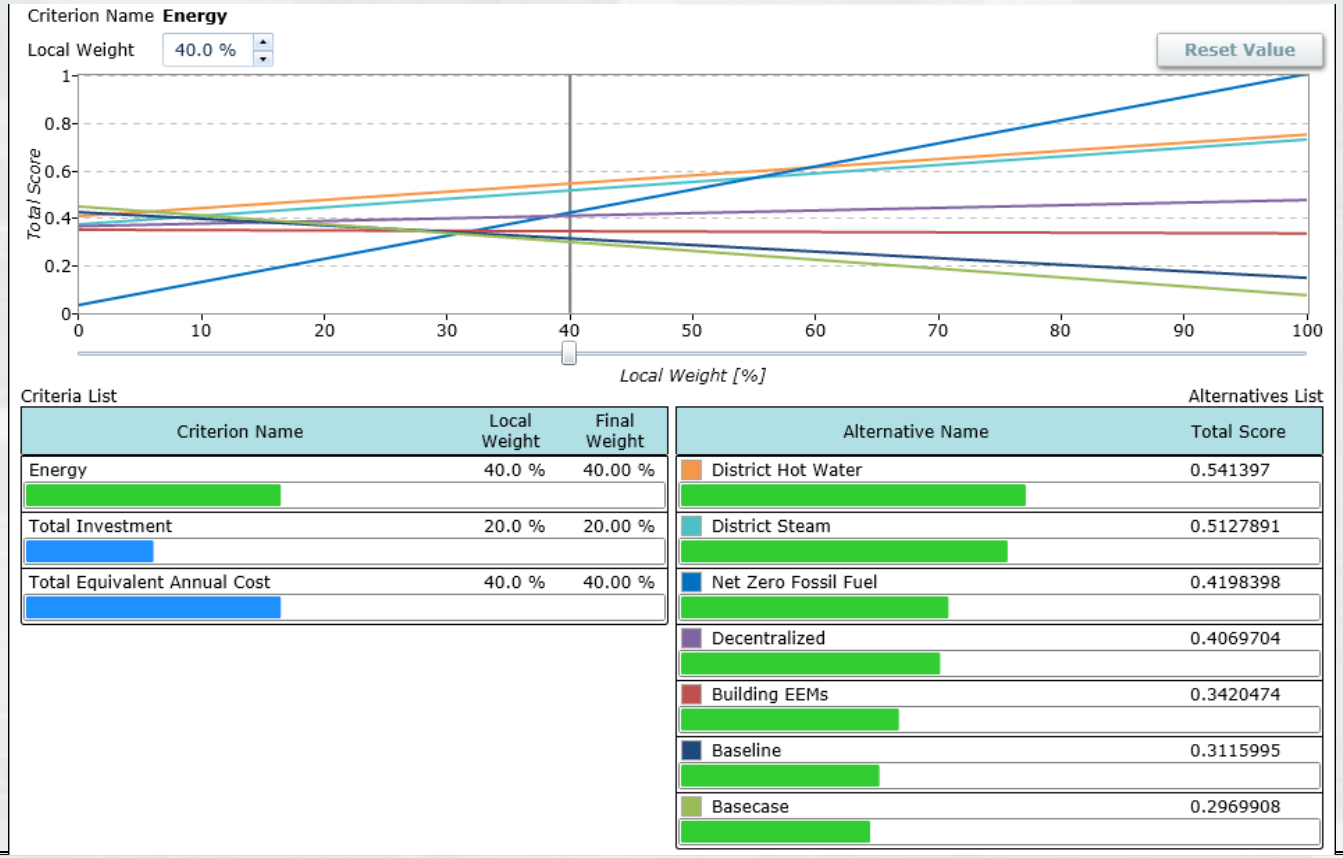


Rank	Alternative Name	MCDA Score
1	Dist HW Reduced DD Loads	0.6854429
2	District Hot Water	0.5586616
3	District Steam	0.5157574
4	Net Zero Fossil Fuel	0.4435413
5	Decentralized	0.3951311
6	EEM Case for Buildings	0.1326775
7	Baselin	
8	Basecas	

Decentralized attractive when done building by building and allows for site energy use reduction

Relative Sensitivity

- Some alternatives more sensitive to weighting
- Most rankings barely change with energy weight
- Net zero alternative is highly sensitive to energy weight



Summary

- Multi-Criteria Decision Analysis (MCDA) can support stakeholders in using quantitative and qualitative information to make decisions
- Development of alternatives, criteria, and weights provides an opportunity for stakeholder participation and buy-in
- MCDA can provide a record of the decision making process
- Sensitivity analysis can help to determine relative importance of weighting and decision crossover points
- Models from different stakeholder groups can be compared and help to identify compromise solutions