The Role of Multi-Criteria Decision Analysis (MCDA) in Project Development: Case Studies

Igor Linkov, John T. Vogel, Kelsie Baker, and Burton C. Suedel

US Army Corps of Engineers

Engineer Research and Development Center

EwN Decision Problems

- EwN problems are complex because:
  - Nature of the navigation systems we manage
  - Multiple objectives of EwN projects
  - Number and diversity of interested and affected parties

- MCDA is an approach for:
  - Resolving complex decision problems
  - Analyzing relevant uncertainties

Main Points

- There are clear benefits to be gained by using formal risk and decision analysis methods for conflict resolution:
  - Opportunities to explore trade-offs among diverse objectives
  - The ability to distinguish science and engineering inputs to a decision from values associated with objectives
  - Means for exploring the implications of uncertainty and the value of reducing it
  - Provides a quantitative framework to implement adaptive management

MCDA Process

Elements of Decision Process	Multi-Criteria Decision Analysis
Define problems	Stakholder input incorporated at beginning of problem formulation stage. Often provides higher stakeholder agreement on problem definition. Thus, proposed solutions have a better chance at satisfying all stakeholders.
Generate alternatives	Alternatives are generated through involvement of all stakeholders including experts. Involvement of all stakeholders increases likelihood of novel alternative generation.
Formulate criteria by which to judge alternatives	Criteria and subcriteria hierarchies are developed based on expert and stakeholder judgment.
Gather value judgments on relative importance of criteria	Quantitative criteria weights are obtained from decision makers and stakeholders.
Rank/select final alternatives	Alternative chosen by systematic, well-defined algorithms using criteria scores and weights.

Problems

Alternatives

Criteria

Weights

Evaluation

Decision

Stakeholder Elicitation Process: Overview

- What is value elicitation?
  - The practice of quantifying judgments as numeric values
- Various techniques exist for eliciting judgments
  - There is no “one size fits all” approach
- Role of the expert – to share current state of knowledge
  - There are no “right” answers, just good answers
  - The quality of a judgment is a function of the information in that judgment and the correct expression of reasoning
- Making judgments quantitative allows them to be combined with other information and modeled

Case Study 1
Long Island Sound Dredged Materials Management Plan

LIS Project Background

- 2005 LIS disposal site designations did not resolve differences between states of NY and CT
- This resulted in initiation of an LIS-wide DMMP to evaluate a broad range of sediment management alternatives
- ERDC-EL was engaged to provide a transparent and meaningful way to integrate stakeholder opinions and values into DMMP
- Value elicitation will be used to inform development of dredging plan

Initial Stakeholder Meeting

- Justify the approach
- Clarify stakeholder roles
- Explain the process for addressing stakeholder concerns
- Explain/demonstrate the model and related assumptions and process (i.e., dredging needs, lack of actionable contamination)

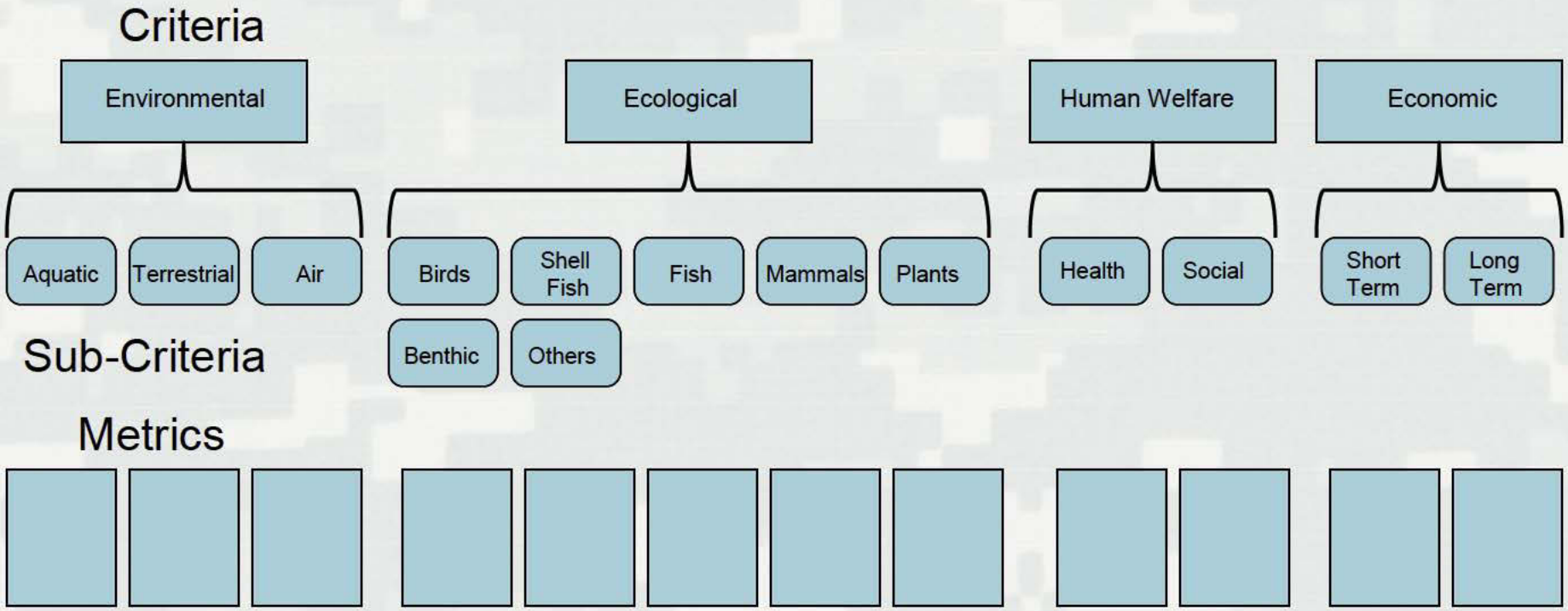
Solicit Stakeholder Criteria

- Start with a list, and a hierarchy, of criteria and metrics to assess different disposal sites/options
- Incorporate all concerns as general criteria
  - ► Why is a particular disposal site/option of concern?
- Brainstorm about metrics (measures) that can be used to quantify those concerns

Solicit Stakeholder Weights

- Develop a survey instrument to obtain weights (most likely pairwise) for the criteria
- Convert answers to percent weights for each category and each criteria within the category
- Multiple analyses follow – individual members, group analysis, sensitivity analysis, etc.

Hierarchy of Criteria and Sub-Criteria

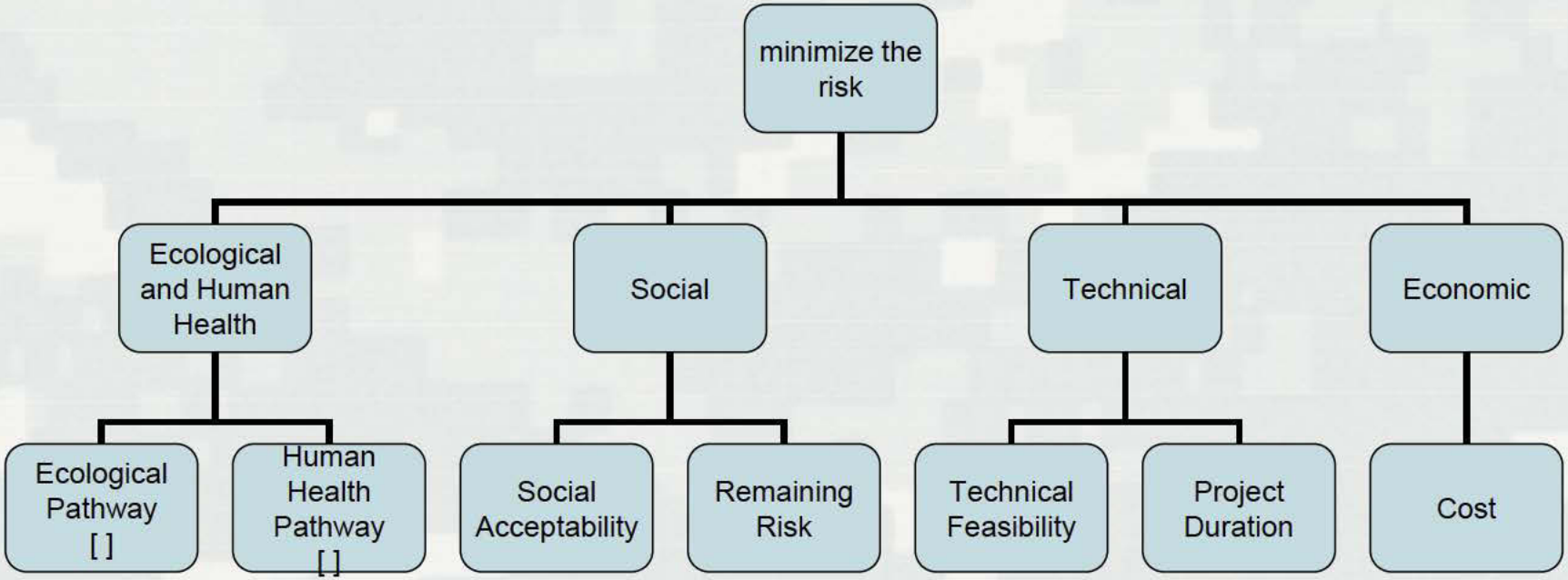


Case Study 2
Southern Busan Harbor
S. Korea: Assessing Options for Managing Contaminated Sediments

Southern Busan Harbor, S. Korea

- Busan is extremely densely populated
  - ► 4,785 individuals / km2
- The largest harbor in Korea
- Major fishing port whose fish sales account for 30% of sales nationwide
- Contaminated with organics and metals
- No open water dumping since 2008
- Expected dredged material
  - ► 220,000 m3

Decision Criteria



- Social acceptability: As the number of stakeholders increases, there is an increasing likelihood of encountering conflicting values among stakeholders.
- Remaining risk: the residual portion of dredged material left out during project implementation for each alternative method and the relative chemical concentrations in dredged material before and after implementation of each alternative
- Technical feasibility: (1) whether the technology has been applied (2) the availability of equipment in S. Korea; and (3) whether some or all of the processes involved in the alternative are patented, which may be considered an indicator of process reliability.

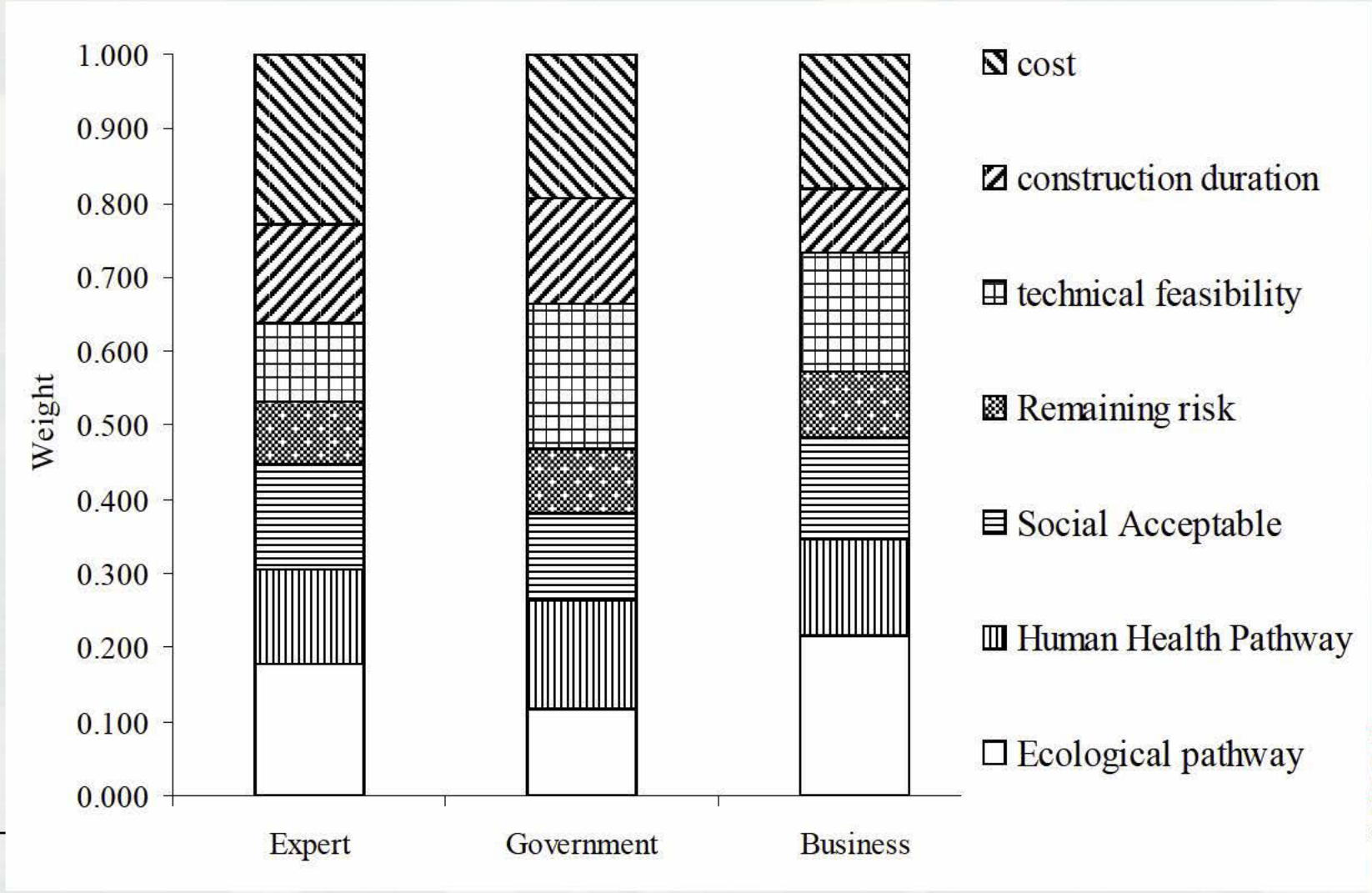
Performance Matrix

Criteria, *i* / Alter. *J*	Environmental		Social		Technical		Econ.
	Ecological Pathways	Human Health Pathways	Social Accept.	Remaining Risk	Technical Feasibility	Project Duration	Cost ($M)
Cement Lock	14	25	67	0.01	63	220	12
Sediment Washing	5	22	67	0.92	75	358	22
CAD (Hopper)	22	18	17	1.20	75	220	8
CAD (Geotextile)	7	18	17	0.10	50	275	12
CAD (Solid.)	7	18	0	0.10	25	220	15
Reclamation (Solid.)	13	21	50	0	63	220	7

Eliciting Weights

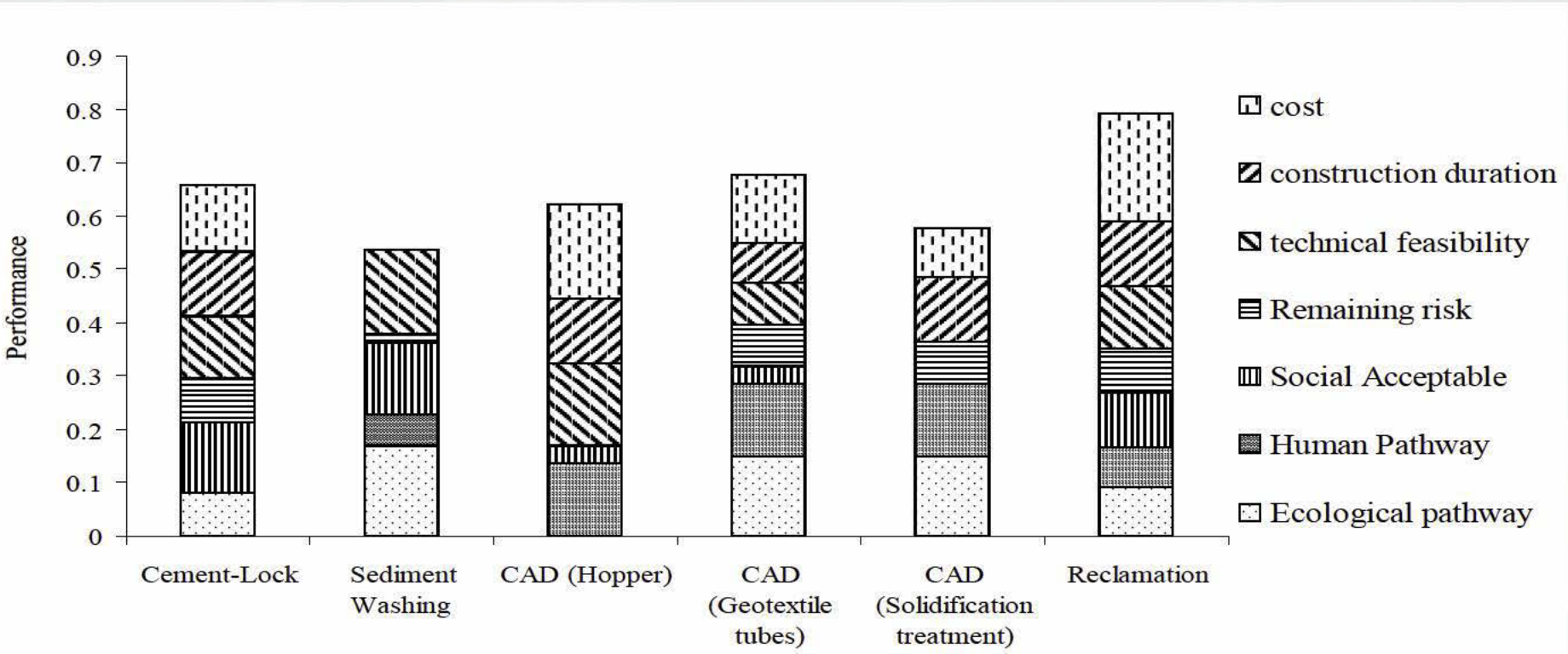
- Three stakeholder groups
  - ▶ scientists and engineers
  - ▶ federal and local government stakeholders
  - ▶ local businesses and interest groups representing, for example, ship-building and fisheries industries
- A total of 53 participants
- The swing weight method was used

Weight Results



Preferred Alternative and Performance

Group	Cement - lock	Sediment Washing	CAD (Hopper)	CAD (Geotextile tubes)	CAD (Solid. treatment)	Land (Reclamation)	Total
Expert	0	0	0	3	0	17	20
Gov	0	0	2	3	0	18	23
Business	0	2	0	1	0	7	10



Case Study 3
Louisiana Coastal Protection and Restoration (LACPR)

Purpose of Stakeholder Engagement

- Capture stakeholder value information that will guide the ranking of plans and recommendations
- Document differences among stakeholders
- Identify areas for consensus and potential compromises
- Capture additional feedback and guidance for Corps planners
- Iterate, as needed

LACPR Objectives and Metrics

Planning Objectives

- Reduce risk to public safety from catastrophic storm inundation
- Reduce damages from catastrophic storm inundation
- Promote a sustainable ecosystem
- Restore and sustain diverse fish and wildlife habitats, and
- Sustain the unique heritage of coastal Louisiana by protecting historic sites and supporting traditional cultures

Risk Metrics

- National Economic Development
  - Residual damages
  - Life-cycle costs (Implementation, O&M)
  - Construction time
- Regional Economic Development
  - Regional Economic Development (jobs, income, regional output)
- Environmental Quality
  - Spatial integrity
  - Wetlands restored and/or protected
  - Direct impacts
  - Indirect impacts
  - Historical properties protected
  - Archeological properties protected
- Other Social Effects
  - Residual population impacted
  - Historical districts protected

LaCPR Stakeholder Weightings Workshops

- Baton Rouge (22)
- New Orleans (23)
- Houma (22)
- Lake Charles (20)
- Abbeville (22)

Federal and State

LDNR, FEMA, FHWA, USGS, USFWS, NMFS, NOAA, USEPA, LADOTD, etc.

Local and Parish

New Orleans, St. Bernard, St. Tammany, Jefferson, Terrebonne, Vermillion Parishes, Ports, Levee districts, Congressional offices, mayors, etc.

NGOs and Academia

BTNEP, CRCL, LPBF, Audubon, NWF, UNO, LSU, Ducks Unlimited, etc.

Business/Developers

ConocoPhillips, Shell, Tower Land Co., etc.

Analysis of Stakeholder Weight Data

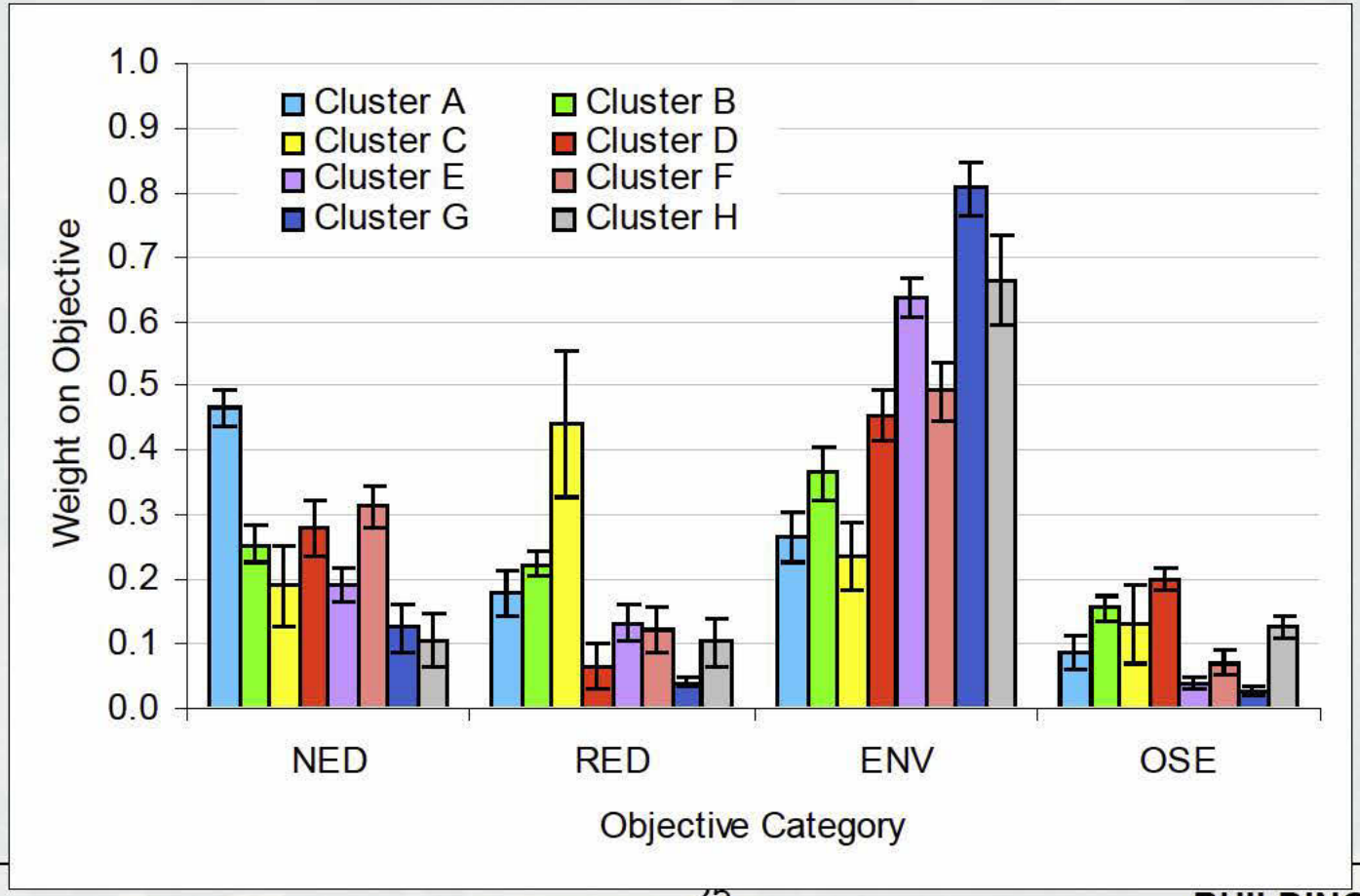
- Objective: to summarize weight elicitation results and identify distinct patterns of preferences that exist among stakeholders with respect to decision objectives
- Cluster analysis used to classify stakeholders with similar types of preferences
  - Provided an objective approach to classifying stakeholders based on shared characteristics
  - Grouped stakeholders who expressed essentially similar sets of interests into a single group
  - Document characteristic preferences among stakeholders and more efficiently explore the sensitivity of project decisions

Analysis of Stakeholder Weight Data

- Evaluate whether the resulting solutions can be explained and are meaningful in the context of their purpose
- Characteristic preference patterns were used to analyze the sensitivity of the decision to stakeholder preferences
- Enables sensitivity analysis to focus only on those preference patterns that have been observed
- Natural vs. contrived groupings

LACPR Weightings Results

Mean weights by aggregate planning objective for eight clusters, A through H. Uncertainty bounds represent 95% confidence limits on the estimated mean weight.



Summary

- Stakeholders appreciate having their voices included
- Open lines of communication between the Corps and stakeholders has proved beneficial
- MCDA incorporates aspects of transparency, comparative analysis, and stakeholder input
- How should weights be elicited? In-person interaction, online surveys, etc. Consistency is key.
- A minimum number of stakeholders is needed to capture the range of values that exist in a population
- Experienced professional facilitation helpful when eliciting stakeholder weights
- Widely applicable