Multi-Criteria Decisional Analysis: Methodology & Case Studies

Engineer Research and Development Center

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Interagency Performance & Risk Assessment Community of Practice, 2/23/2016

US Army Corps of Engineers®

Outline

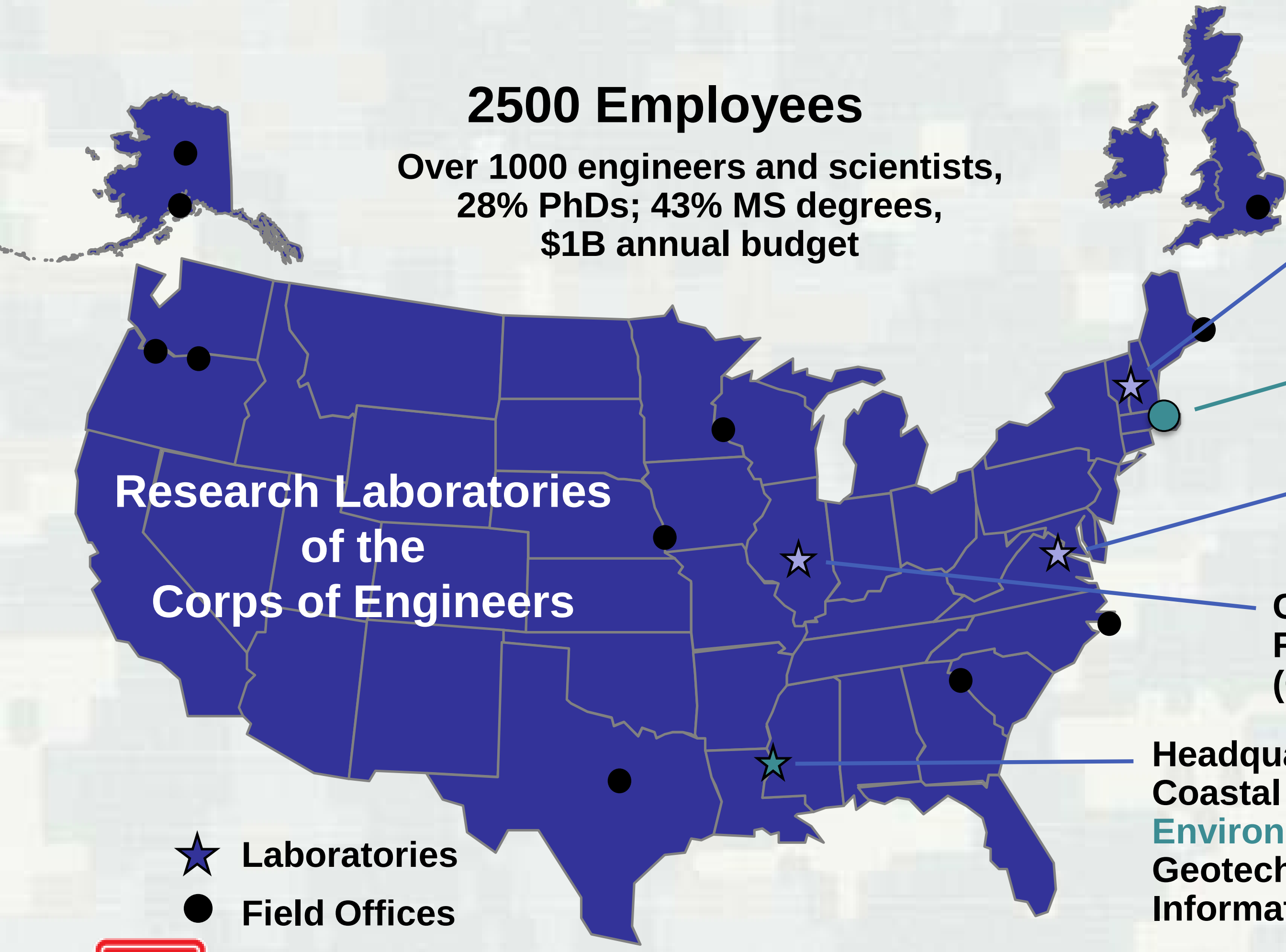
- Introduction
- Overview of MCDA Methods
- MCDA for Stakeholder Engagement
- Multi-Objective Optimization
- Geospatial MCDA

Engineer Research & Development Center

US Army / US Army Corps of Engineers

2500 Employees

Over 1000 engineers and scientists,
28% PhDs; 43% MS degrees,
$1B annual budget



Cold Regions Research Engineering Laboratory (Hanover, NH)

Risk & Decision Science Team (Boston, MA)

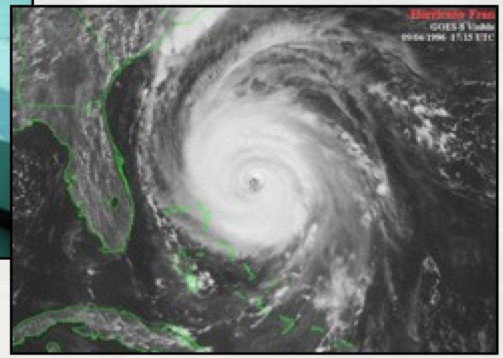
Geospatial Research Laboratory (Alexandria, VA)

Construction Engineering Research Laboratory (Champaign, IL)

Headquarters (Vicksburg, MS)
Coastal & Hydraulics Laboratory
Environmental Laboratory
Geotechnical & Structures Laboratory
Information Technology Laboratory

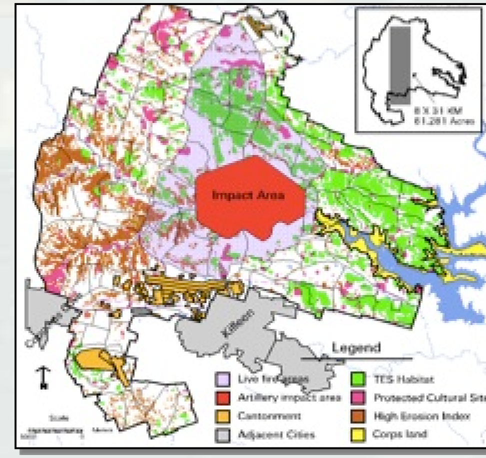
ERDC

ERDC Research Business Areas



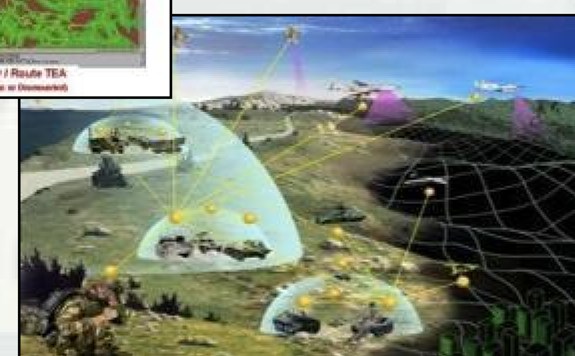
Civil Works/Water Resources

Environmental Quality/Installations



Military Engineering

Geospatial Research & Engineering



Risk and Decision Science Team

- **Mission:** to improve decision-making and stakeholder engagement through application and development of risk and decision science techniques.
- **Execution:** through risk assessment, technology-supported stakeholder engagement, decision modeling, portfolio optimization, life cycle assessment, and software development.
- **Results:** help clients to describe relevant risks, identify and compare risk management alternatives, develop consensus among disparate stakeholder groups, and provide repeatable and transparent processes for future decisions.

Risk and Decision Science Team

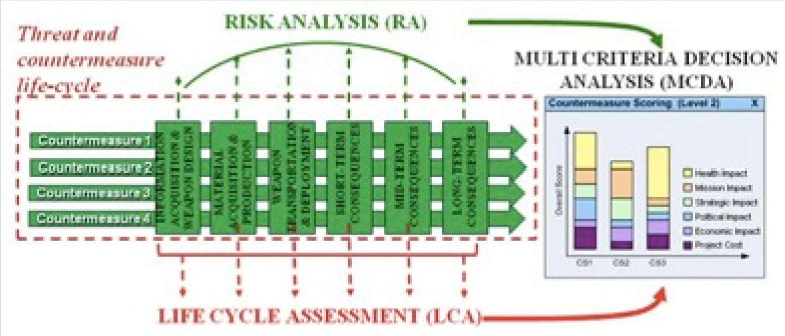
Capabilities

- Over 15 risk, decision and environmental scientists developing solutions that support decisions across a broad spectrum of military and civilian needs
- State-of-the-science models and tools for structuring and conducting risk assessment, stakeholder engagement, resource prioritization, planning, and other emerging issues relevant to USACE, DoD, and Nation

Current Programs

- Cutting edge R&D for DoD as well as for DHS, DHHS, EPA, CPSC and others
- Applying Decision-Analytic tools to evaluate alternatives, integrate stakeholder values in product development, and prioritize research for a variety of technologies & industries.

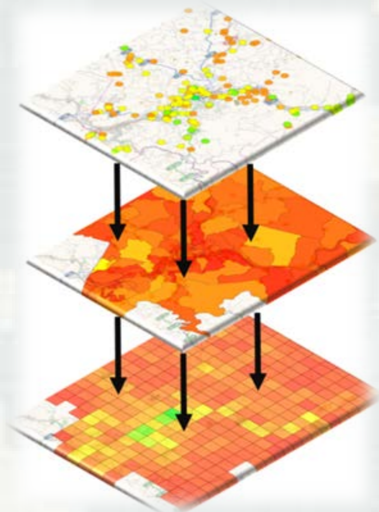
Connecting Information and Decision is our goal



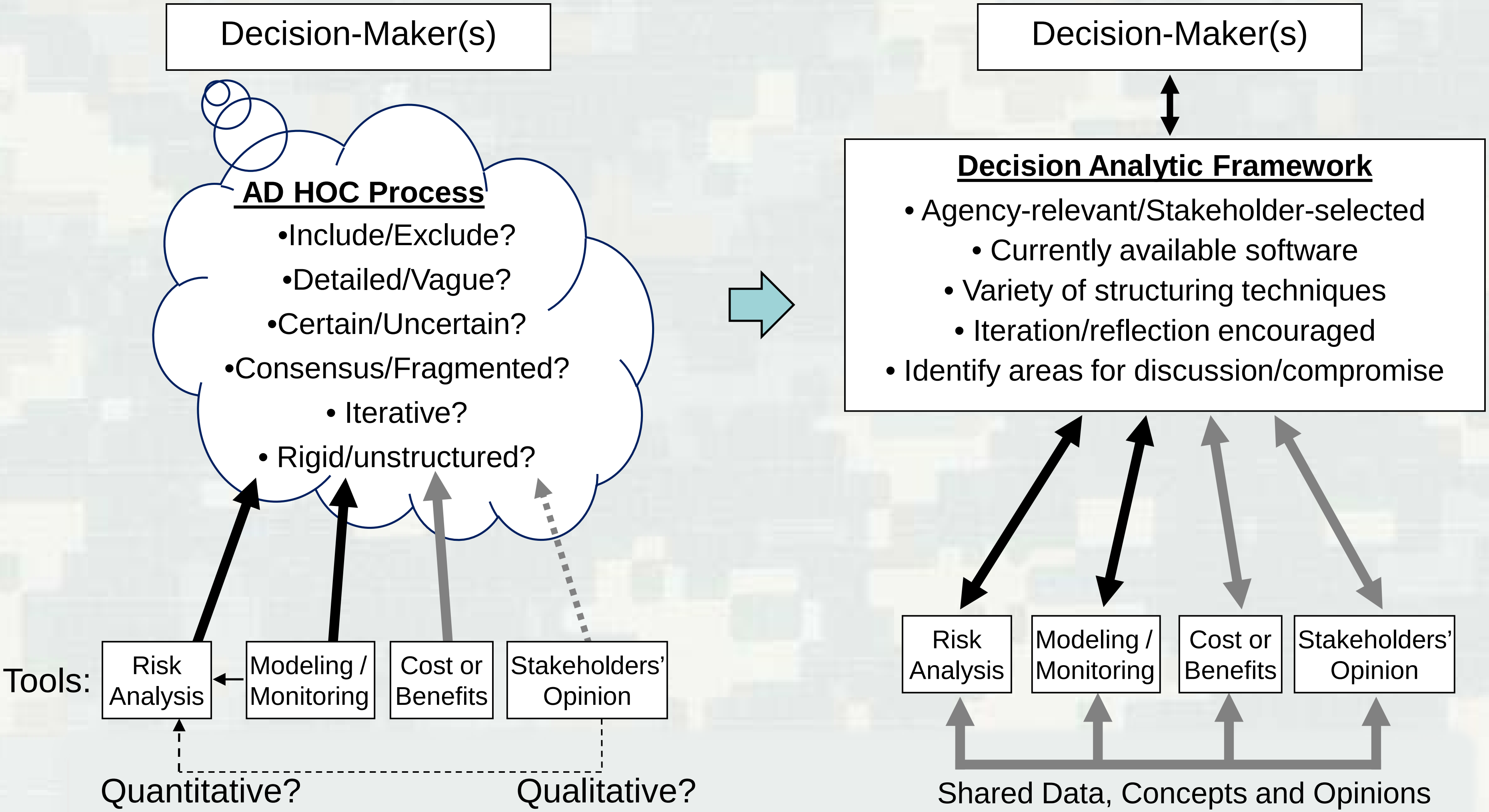
Integrating Risk Analysis, Life Cycle Assessment, and Multi-Criteria Decision Analysis models for the assessment of emerging materials & risks

ERDC Risk and Decision Science Team: Project Types

- Alternative Prioritization
- Project Portfolio Assessments
- Decision Support
- Resource Allocation
- Stakeholder Engagement with Technology Support
- Scenario Analysis
- Adaptive Management
- Value of Information



Evolving Decision-Making Processes



Challenge: Multiple & Uncertain Criteria

Transparent & Quantitative Integration

An Integration Approach

Top-Down
Decision Analysis

Goal Identification and Problem Framing
-
What are the goals, alternatives, and constraints?

Decision Model
-
What are the criteria and metrics, How do we measure decision-maker values

Metrics Generation and Alternative Scoring
-
How does each alternative score along our identified criteria and metrics?

We Integrate Across Traditional Top-Down and Bottom-Up Approaches

Management

Modeling

Data Collection

Bottom-Up
Risks Assessment

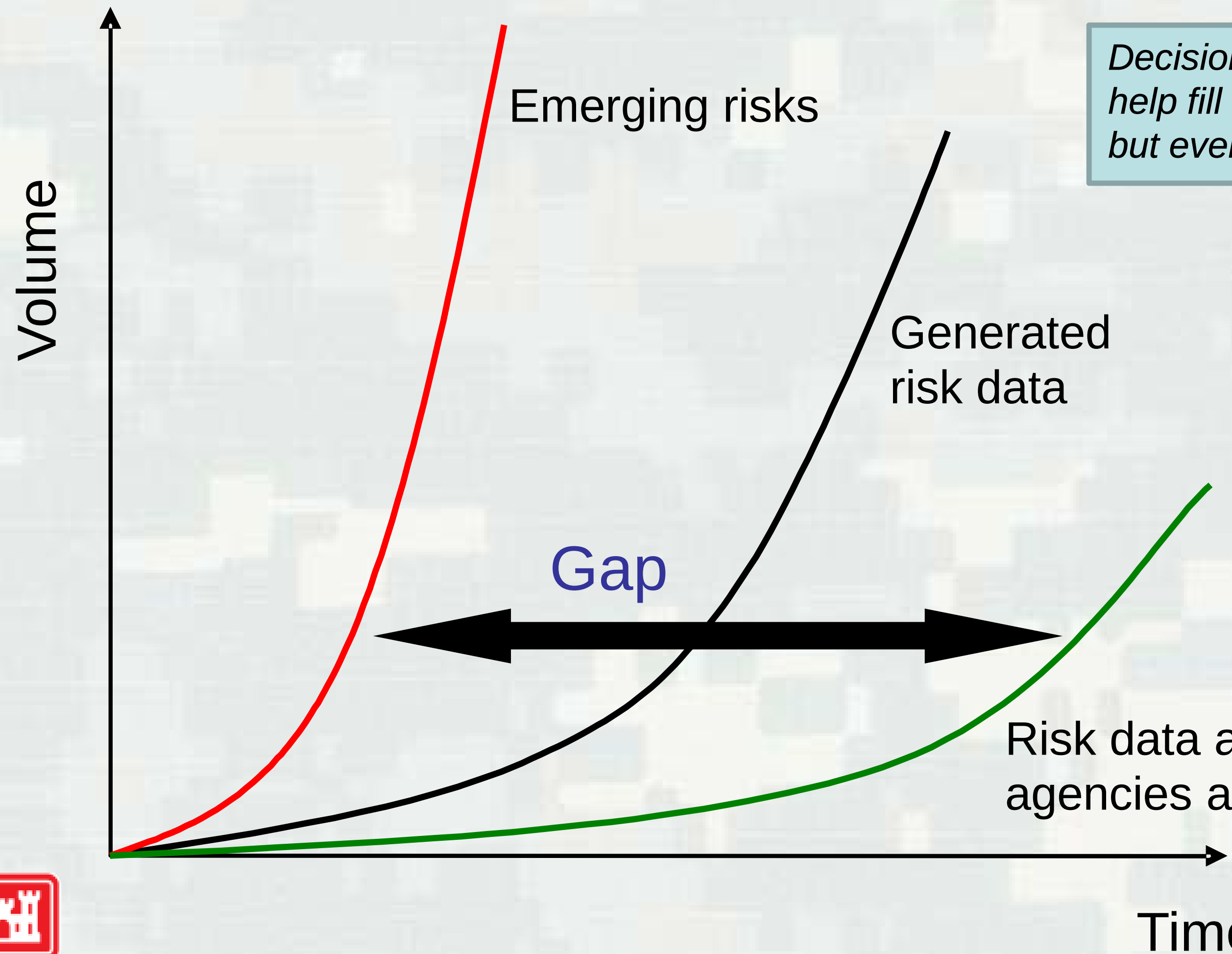
Risk Characterization
-
What are the risks relative to a threshold? How do they compare to other alternatives?

Physical/Statistical Model
-
What is the hazard? What is exposure?

Data Collection
-
What are fundamental properties/mechanisms associated with each alternative?

Linkov et al., 2014

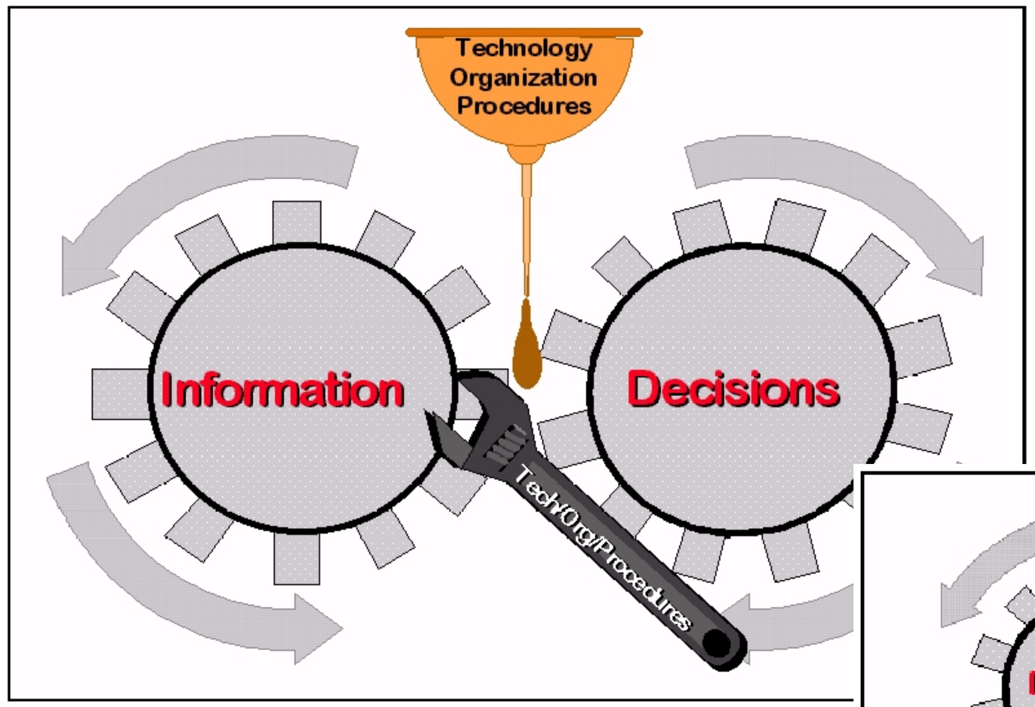
Challenge: Emergence Risks & Delays in Generated Risk Data



Decision analytic tools can help fill these ever changing but ever present gaps.

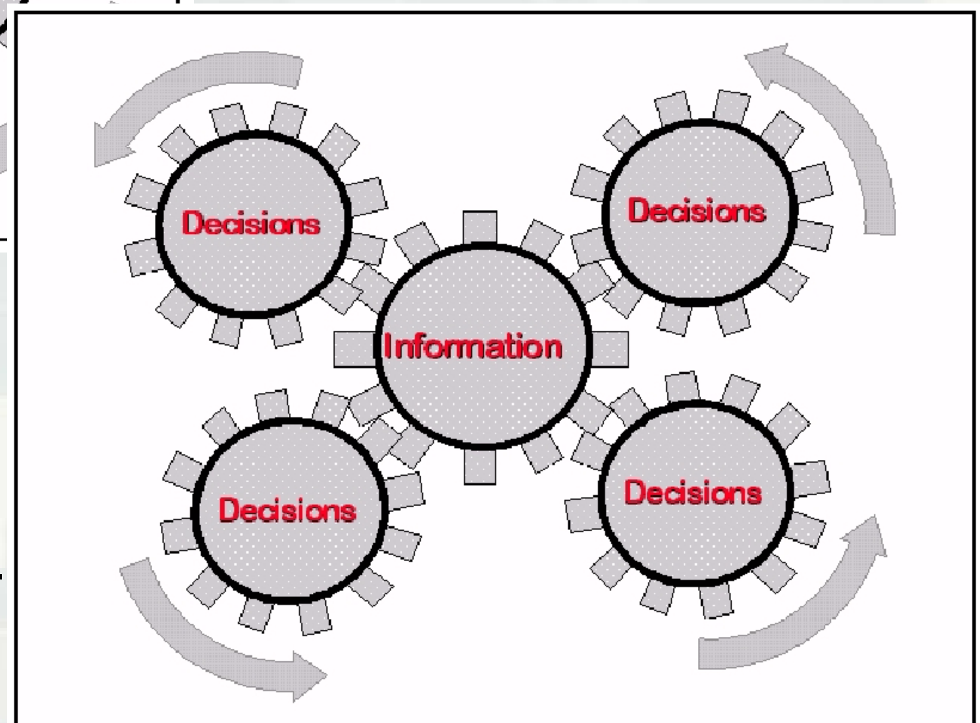
from Linkov and Satterstrom, 2008

Challenge: Need for Real Time Decisions



What Can Be Done to Help in Decision Making?

Increasing data availability should lead to quicker & better decisions.



Need for revolutionary changes: fusion of information and decisions reflecting stakeholder values.

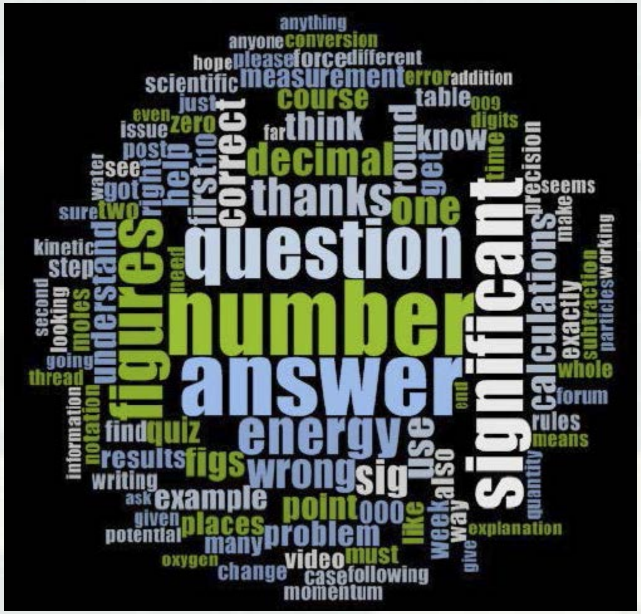
After Roman, 1996

Challenge: Avoiding Data Overload

- Does current data availability lead to data overload?

- Better to have ways to quantitatively integrate information.

- DA tools can synthesize available information to aid decisions while still preserving the underlying data attributes & uncertainty.



What is Decision Analysis? Why Do We Use It?

Decision Analysis

- Provides frameworks for comparing data for alternatives across dissimilar criteria.
- Facilitates making relative tradeoffs between criteria of different importance.
- Normalizes data w/r/t context of decision at hand.
- Aggregates across criteria to prioritize alternatives.

Summary of MCDA Benefits

- Some benefits of implementing formal decision analysis:
  - Transparent – always clear how and why each item is scored.
  - Replicable – anybody will receive the same answer.
  - Generalizable – methods are easily ported between contexts.
  - Robust – there is a science behind this that we can leverage.
  - Tractable – break large problems down to focus on like parts.
  - Scalable – decision framework can be applied to large data.
  - Quantitative – easier to justify outcomes to ‘higher-ups’.
  - Helps you identify the full set of objectives for the analysis.
  - Allows exploration of trade-offs between these objectives.
  - Separates subjective (weights) from objective (scores) data.
  - Can integrate values across a group with diverse views.
  - Enables scenario & sensitivity analyses.

Typical Decision Making Challenges

- "Humans are quite bad at making complex, unaided decisions" (Slovic et al., 1977).
- A variety of psychological biases tend to skew our rationality.
- We can only keep a few factors in 'working memory' at a time, so are liable to miss considerations without decision aids.
- Individuals respond to complex challenges by using intuition and/or personal experience to find the easiest solution.
- Groups can devolve into entrenched positions resistant to compromise
- "There is a temptation to think that honesty and common sense will suffice" (USACE IWR-Drought Study p.vi)

Decision Making Involves Tradeoffs

- There are often more considerations than just money
  - Health
  - Environment
- Explicit tradeoffs
  - Spending $100K on Construction vs Monitoring in a restoration
  - More of one means less of the other
- Implicit tradeoffs
  - "Keeping local stakeholders happy" vs "Keeping HQ happy"
  - Terms of trade are not following physical laws
- Value tradeoffs
  - 100 acres of woodland vs 100 acres of wetland
  - Choice may depend on what each person "values"

- ***Good trade-off analysis turns "implicit" things into "explicit" things***

Approaches to Evaluation

- **Subjective Prioritization ("Gut Feeling")**
  - **Pros:** easy to do
  - **Cons:** no rigor, potential mistakes, poor transparency/reliability, susceptible to gaming, suboptimal (potentially inefficient and/or ineffective)
- **Ad hoc weighting using Excel Spreadsheets**
  - **Pros:** everybody can use Excel, relative ease of implementing
  - **Cons:** requires arbitrary weighting for multiple criteria, ad hoc metrics, etc.
- **Multi-Criteria Decision Analysis**
  - **Pros:** transparent, state-of-the-art methods, can be tailored/modified in real time, records and visualizes differences among commands and individual opinions
  - **Cons:** time and resource intensive, potentially costly, expertise required

Multi-Criteria Decision Analysis

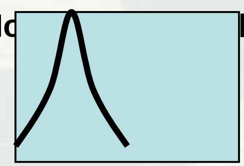
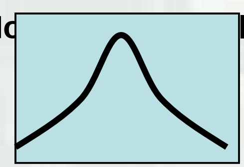
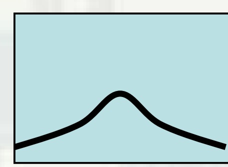
- MCDA:
  - Evolved as a response to the observed inability of people to effectively analyze multiple streams of dissimilar information
  - Has many different technical approaches based on similar theoretical foundations
- MCDA integrates various technical inputs & evaluations with stakeholder & decision maker preferences/values.
- MCDA allows you to ask the right people for right info.
- MCDA methods show why a particular alternative is most valued.
- MCDA allows you to explore impact of scenario/data uncertainty and value of reducing it.

Example Decision Matrix

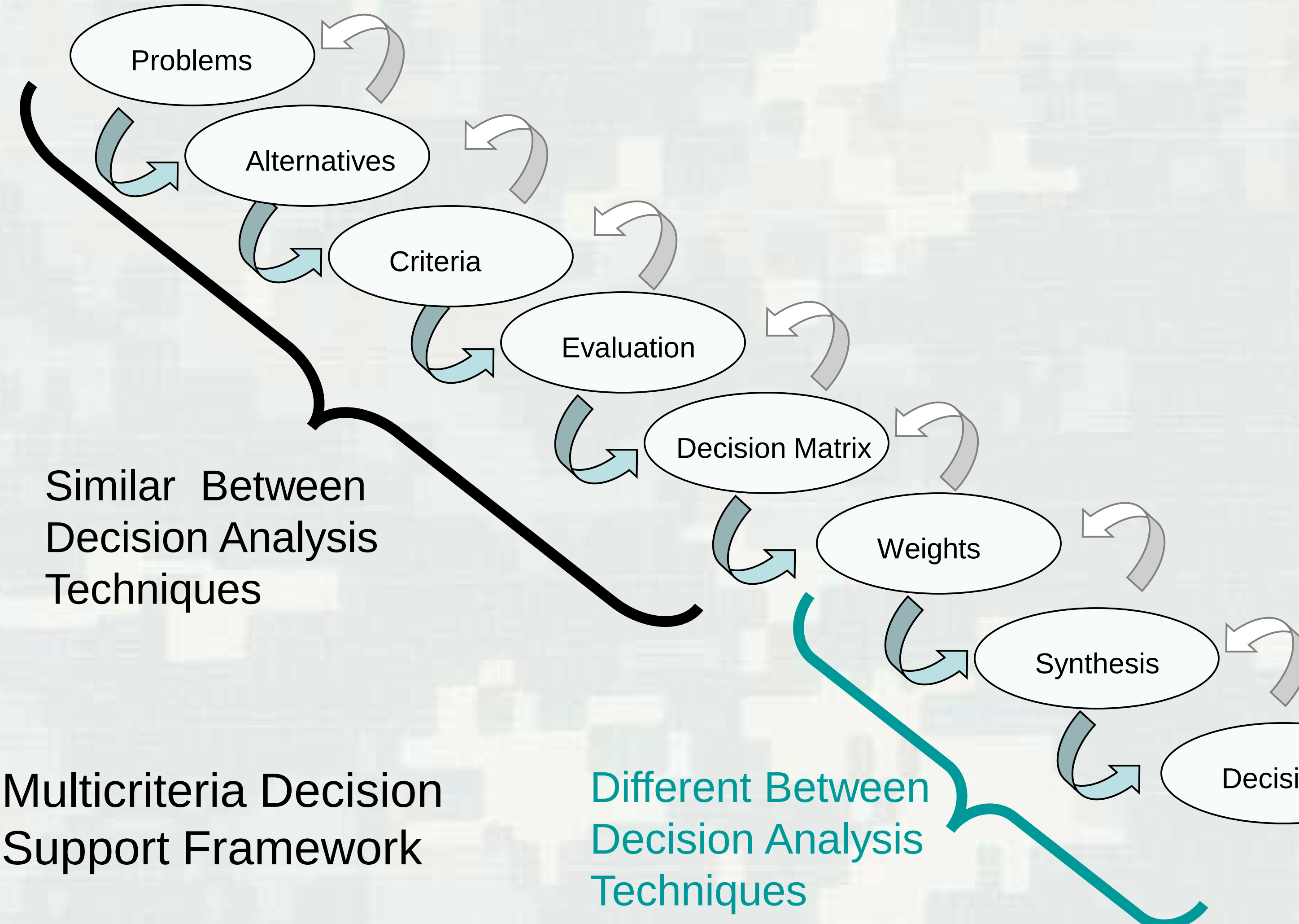
How to combine these criteria? (weights)

How to compare these alternatives?
(MCDA evaluations)

How to interpret these data/results? (normalized scores)

	Criteria 1	Criteria 2	Criteria 3	Criteria 4
Alt.				
Alt.	Monitoring Results	Stakeholder Preference	Economic Cost	Non-monetary benefit
Alt.	Mo  lts	Stakeholder Preference	Economic Cost	Non-monetary benefit
Alt.	Mo  lts	Stakeholder Preference	 st	Non-monetary benefit

Decision Analysis and Decision Tools



Multicriteria Decision Support Framework

After Yoe (2002)

Essential Decision Ingredients

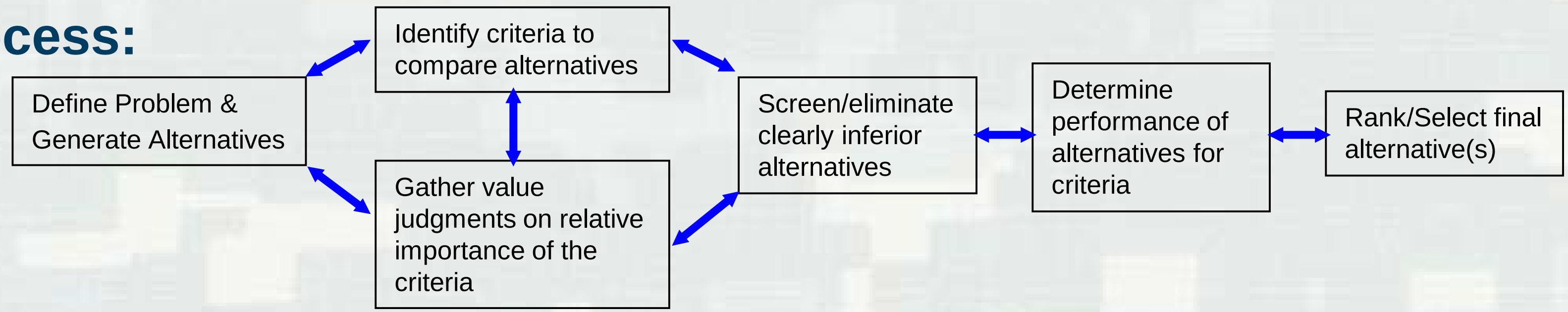
People:

Policy Decision Maker(s)

Scientists and Engineers

Stakeholders (Public, Business, Interest groups)

Process:



Tools:

Environmental Assessment/Modeling (Hydro/Risk/Ecological/Environmental Assessment & Simulation models, etc.)

Decision Analysis (Group Decision Making Techniques/Decision Methodologies & Software)

MCDA Process

(1) Identify objectives

Purchase a safe and reasonably priced vehicle.

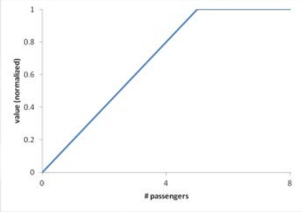
(2) Identify criteria

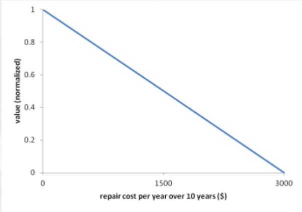
Cost
Resale Value
Repair Cost
Fuel Efficiency
Passenger Space
Style and Comfort
Safety

(3) Identify metrics

Cost :	$K
Resale Value:	$K in 3yrs
Repair Cost	$/yr per10yrs
Fuel Efficiency:	EPA mpg est
Passenger Space :	# seats
Style and Comfort:	1-5 rating
Safety:	NHTSA rating

(4) Develop value f(x)





(5) Elicit weights

Cost (25%)
Resale Value After Three Years (5%)
Repair/Maintenance Cost Per Year (5%)
Fuel Efficiency (15%)
Passenger Compartment Space (15%)
Style and Comfort (5%)
Safety Rating (30%)

$$\sum_{m=1}^{M} w_m = 1$$

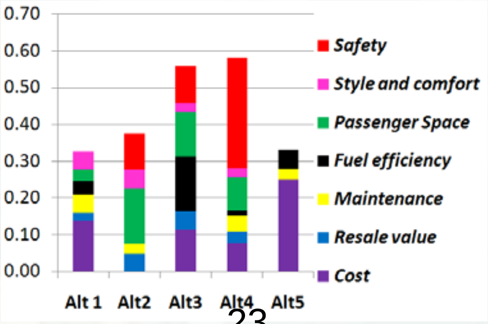
(6) Generate alternatives

Honda
BMW
Audi
Volvo
Toyota

(7) Score alternatives

	Alt 1	Alt2	Alt3	Alt4	Alt5
Cost	0.136	0	0.114	0.076	0.25
Resale value	0.023	0.048	0.05	0.033	0
Maintenance	0.05	0.028	0	0.042	0.028
Fuel efficiency	0.038	0	0.15	0.015	0.053
Passenger Space	0.03	0.15	0.12	0.09	0
Style and comfort	0.05	0.05	0.025	0.025	0
Safety	0	0.1	0.1	0.3	0

(8) Calculate MCDA



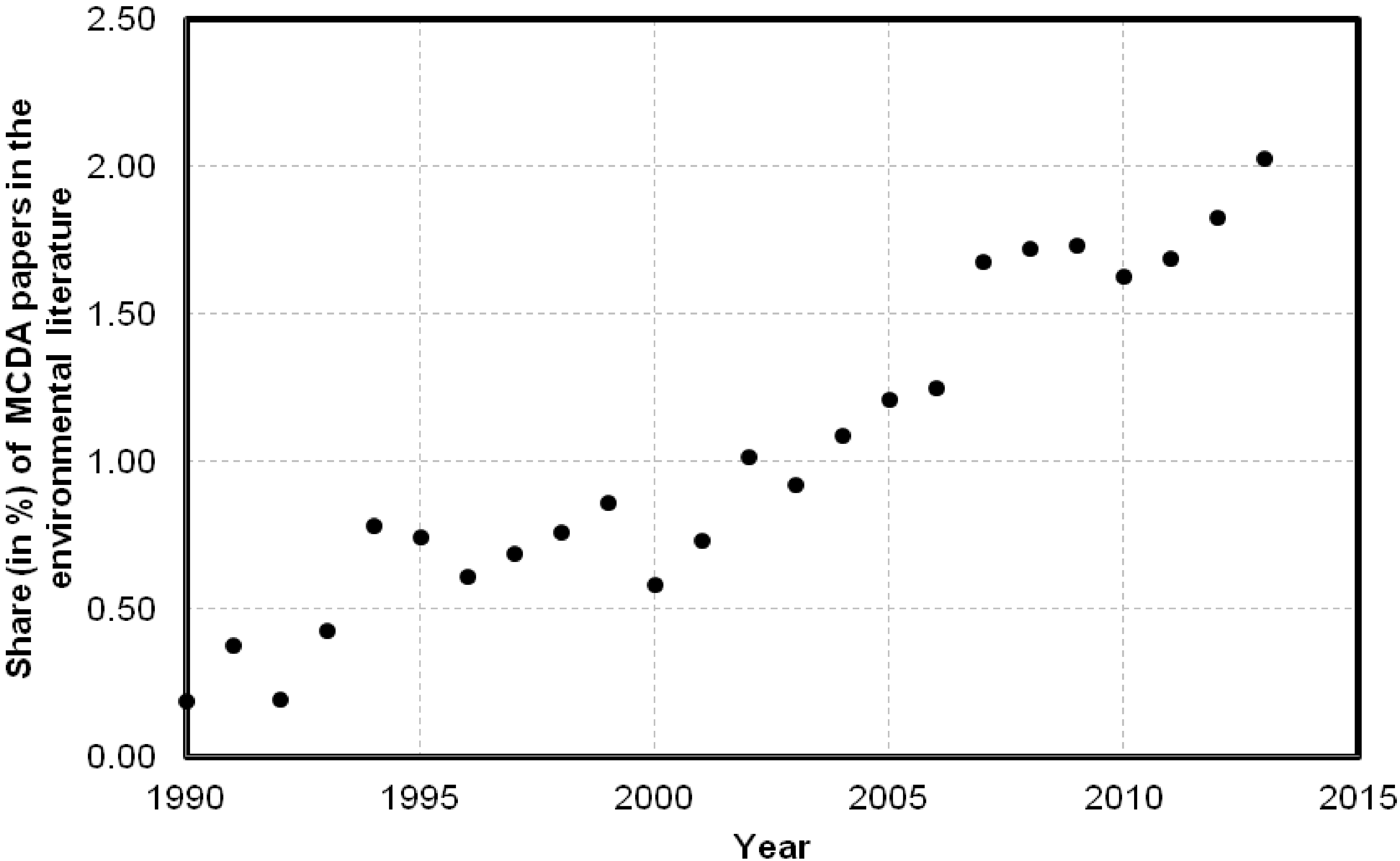
(9) Analyze sensitivity

- Evaluate score and weight parameters that most influence our preferences for alternative x over y.
- Vary scores/weights within a plausible range (e.g., +/- 10%).

Specifying Decision Criteria & Performance Measures

- A coherent set of criteria set is (Roy, 1985):
  - Exhaustive (nothing important left out)
  - Consistent (no secret preferences)
  - Non-redundant (no double counting)
- Effective criteria are (Yoe, 2002):
  - Directional (maximum, minimum or optimum)
  - Concise (smallest number of measures)
  - Complete (no significant impact left out)
  - Clear (understandable to others)
- Criteria are often somewhat correlated but may still be useful
- Criteria should be tested throughout the decision process

MCDA Use in Environmental Science



After Huang, Linkov 2011

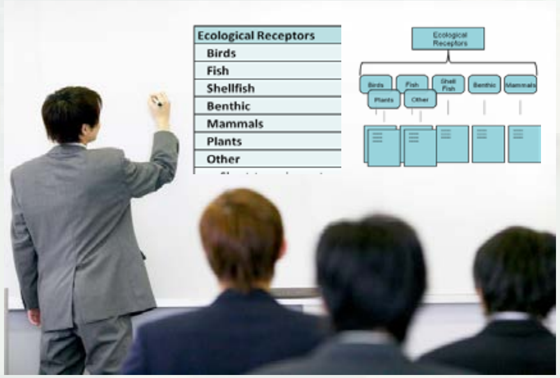
MCDA for Stakeholder Engagement

Context

- Formalized risk ~~communication~~ *discourse* can be accomplished through inclusion of stakeholders in a decision analytical process
- Work together to identify a course of action
- Important to consider how stakeholder groups can be included & considered in the process

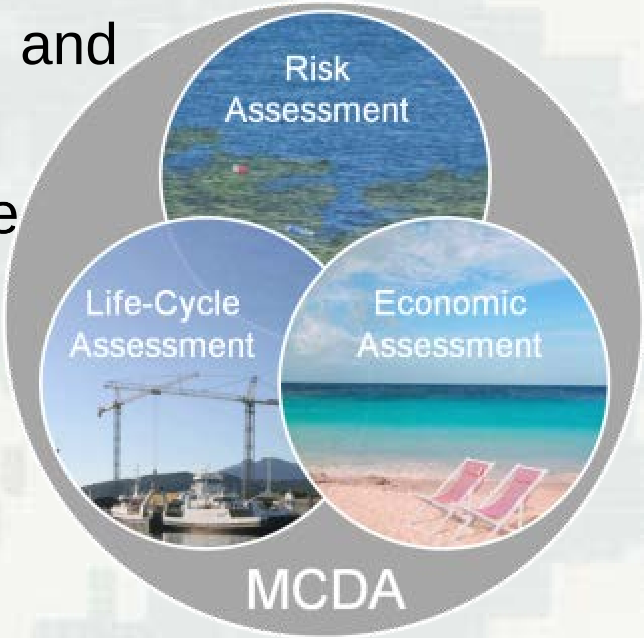
Using Decision Analysis to Structure Stakeholder Engagement

- Decision Analysis can help improve stakeholder engagement.
- Shifts the problem from fighting over outcomes to discussions of priorities.
- Helps make progress after roadblocks have been reached.
- We have applied this approach and always get good feedback from the organizations we work for and with.
  - Recent case studies: Multiple USACE districts, BOEM, NOAA



Lessons learned about stakeholder involvement using DA

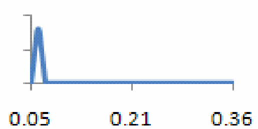
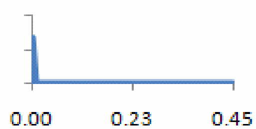
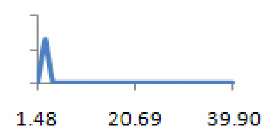
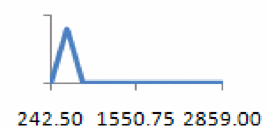
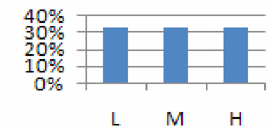
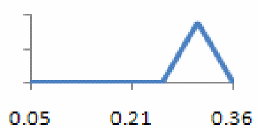
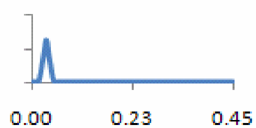
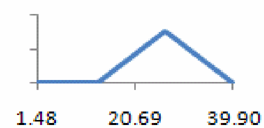
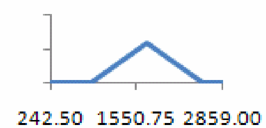
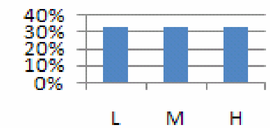
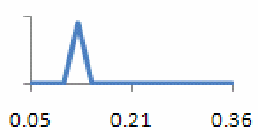
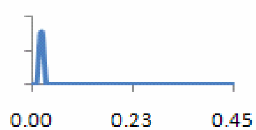
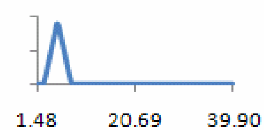
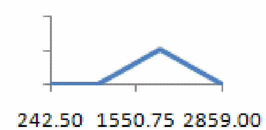
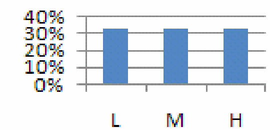
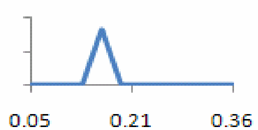
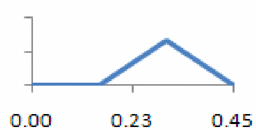
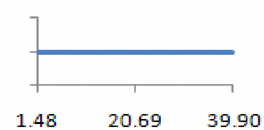
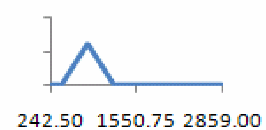
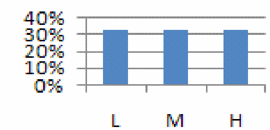
- Know your stakeholders.
- Design a process that is transparent and fair.
- Respect and appreciate different points of view.
- Ensure frequent and open communication and a variety of knowledge input.
- Be clear about how decisions will be made and the type of influence stakeholders can have on the decision.
- Minimalist inclusion exercises can may help to establish buy-in and prototype MORE inclusive exercises.



Degree of Stakeholder Inclusion

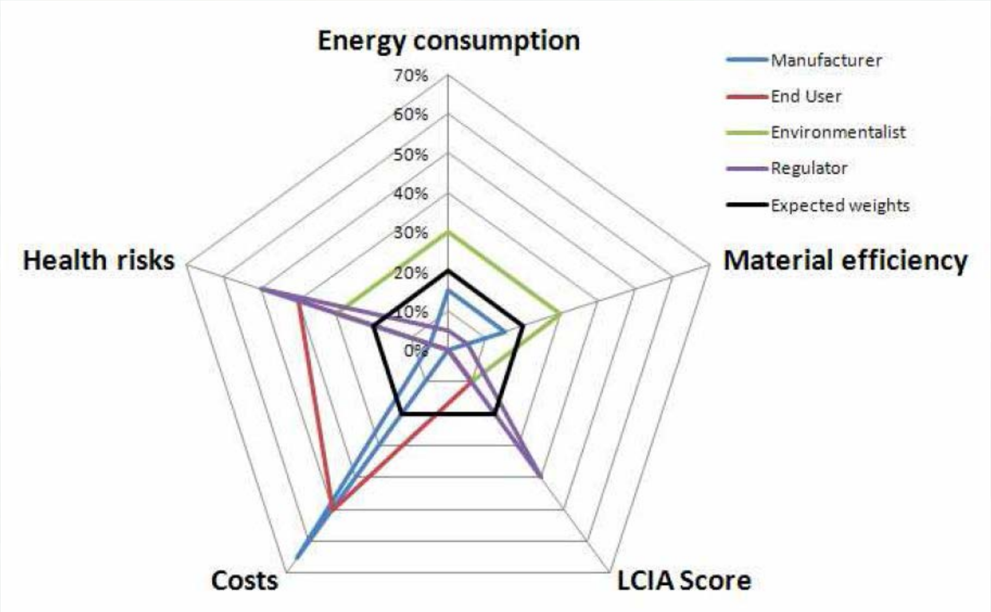
- Synthetic Stakeholders
  - Nanotechnology manufacturing example
- Limited Interviews
  - NY/NJ Harbor example
- Sustained & Active Participation
  - Long Island Sound

Synthetic Stakeholders: Nano Case Study

Alternative/ Criterion	Energy consumption (GWh/kg)	Material efficiency (% in mass)	LCIA Score (EcoPoints)	Cost ($/g)	Health risks
GOAL	Minimize	Maximize	Minimize	Minimize	Minimize
HiPco					
CVD					
Arc					
Laser					

Synthetic Stakeholders: Nano Case Study

- Use five stereotypical stakeholders to capture a range of viewpoints regarding criteria weights

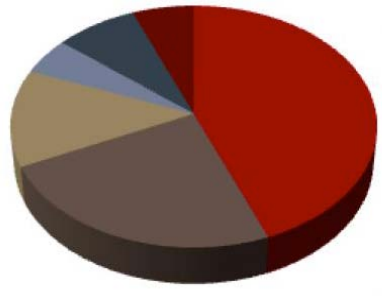


- Which manufacturing technology is best?

Synthetic Stakeholders: Nano Case Study

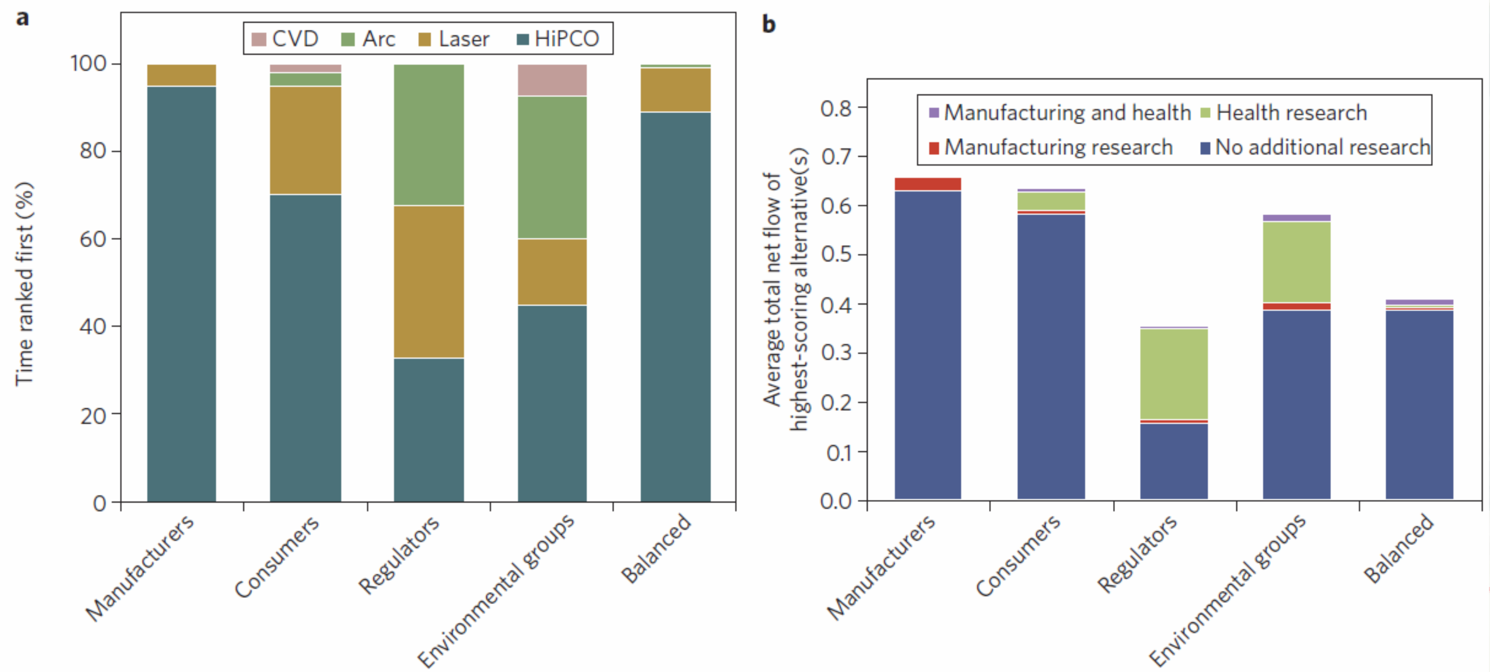
Value of Information (VOI):

- Uncertainty in decision making comes from imprecise information about how each alternative will perform on each criterion
- VOI evaluates how different reductions in uncertainty may affect decision confidence and alternative rankings
- Aids in prioritizing investment in further research



Synthetic Stakeholders: Nano Case Study

- One alternative dominant across most alternatives.
- Some stakeholder perspectives would appreciate more info.



Limited Interviews: NY/NJ Harbor Study

Site Issues

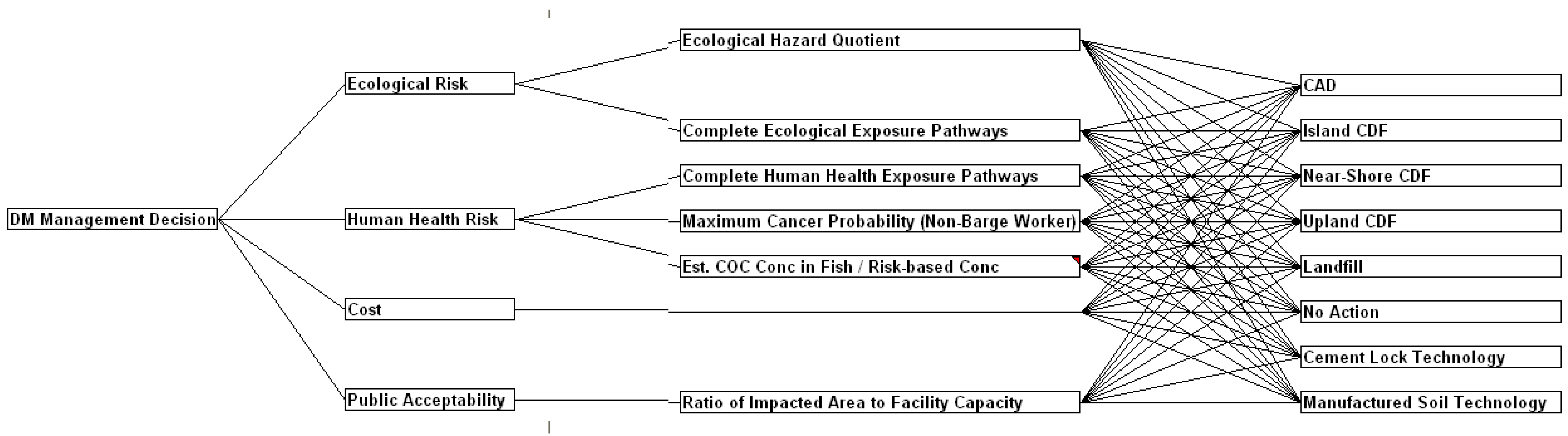
- Harbor among most polluted in U.S.
- >10^6 cy fail regional criteria for ocean disposal

Study Objectives

- Integrate comparative risk assessment results with cost and stakeholder decision criteria
- Use decision criteria/performance measures from published data and proposed costs

Limited Interviews: NY/NJ Harbor Study

Goal | Criteria | Sub-Criteria | Alternatives



Preference Weights - Stakeholders

Alternative Performance Scores - Experts

Limited Interviews: NY/NJ Harbor Study

	Cost	*Public Acceptability*	*Ecological Risk*		*Human Health Risk*		
DM Alternatives	($/CY)	Impacted Area/Capacity (acres / MCY)	Ecological Exposure Pathways	Magnitude of Ecological HQ	Human Exposure Pathways	Magnitude of Maximum Cancer Risk	Estimated Fish COC / Risk Level
CAD	5-29	4400	23	680	18	2.8 E -5	28
Island CDF	25-35	980	38	2100	24	9.2 E -5	92
Near-shore CDF	15-25	**6500**	38	900	24	3.8 E -5	38
Upland CDF	20-25	**6500**	38	900	24	3.8 E -5	38
Landfill	29-70	0	0	0	21	3.2 E –4	0
No Action	**0-5**	0	**41**	**5200**	12	2.2 E –4	**220**
Cement-Lock	**54-75**	0	14	0.00002	**25**	2.0 E -5	0
Manufactured Soil	54-60	750	18	8.7	22	**1.0 E –3**	0

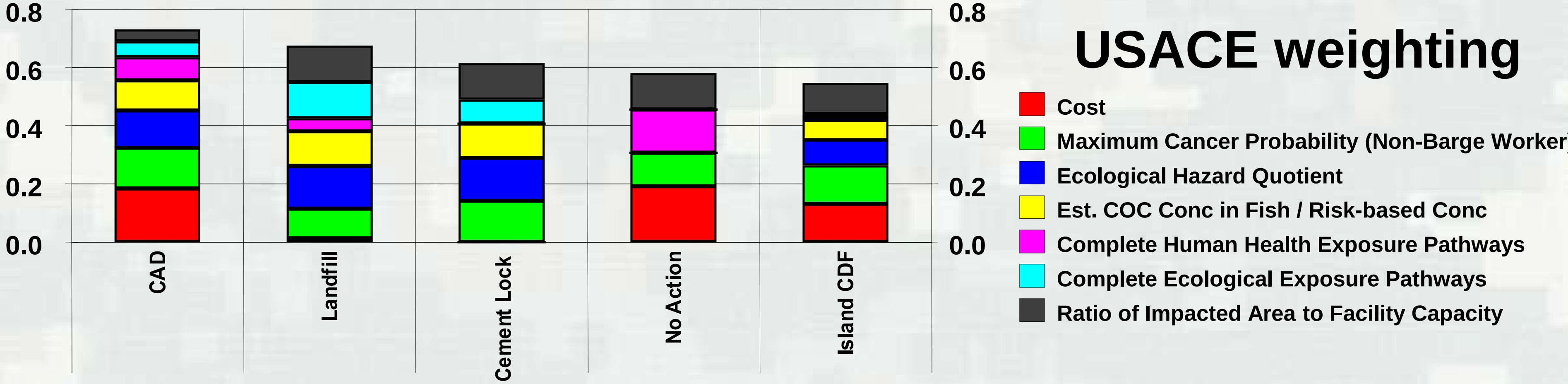
Blue Text: Most Acceptable Value

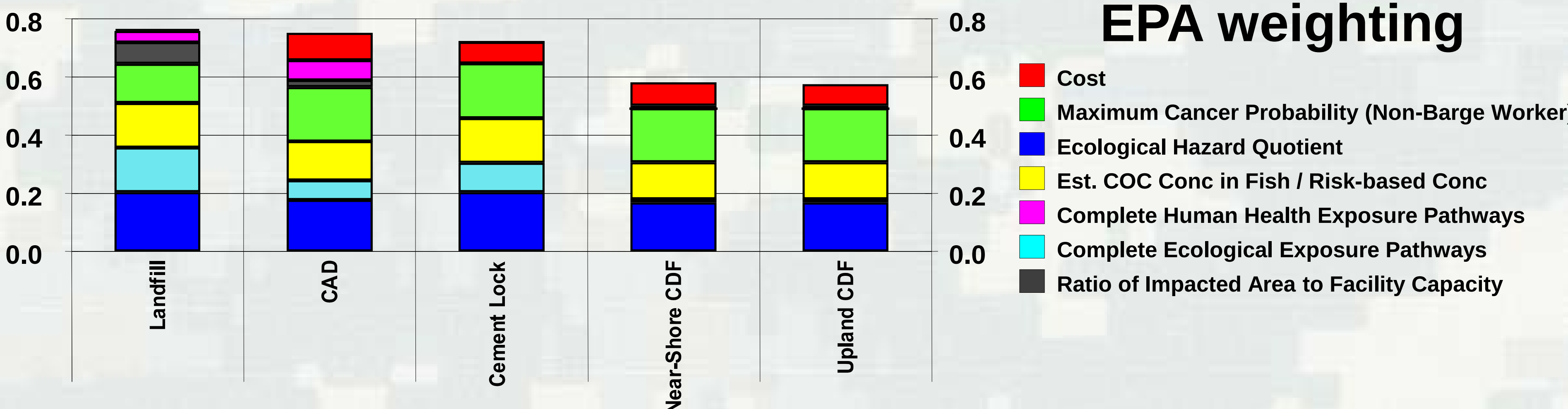
Red Text: Least Acceptable Value

Limited Interviews: NY/NJ Harbor Study

Weights	EPA	USACE
Public Acceptability	7.4	12.5
Ecological Health	35.6	27.1
Human Health	47.0	40.7
Cost	10.0	19.7

Limited Interviews: NY/NJ Harbor Study





Sustained & Active Participation:

Long Island Sound

38.5 million cubic yards of dredged material produced in 30 years

Majority of combined needs from CT:

New Haven

~8.7 million cy

Bridgeport

~4.6 million cy

New London

~2.5 million cy

Connecticut River

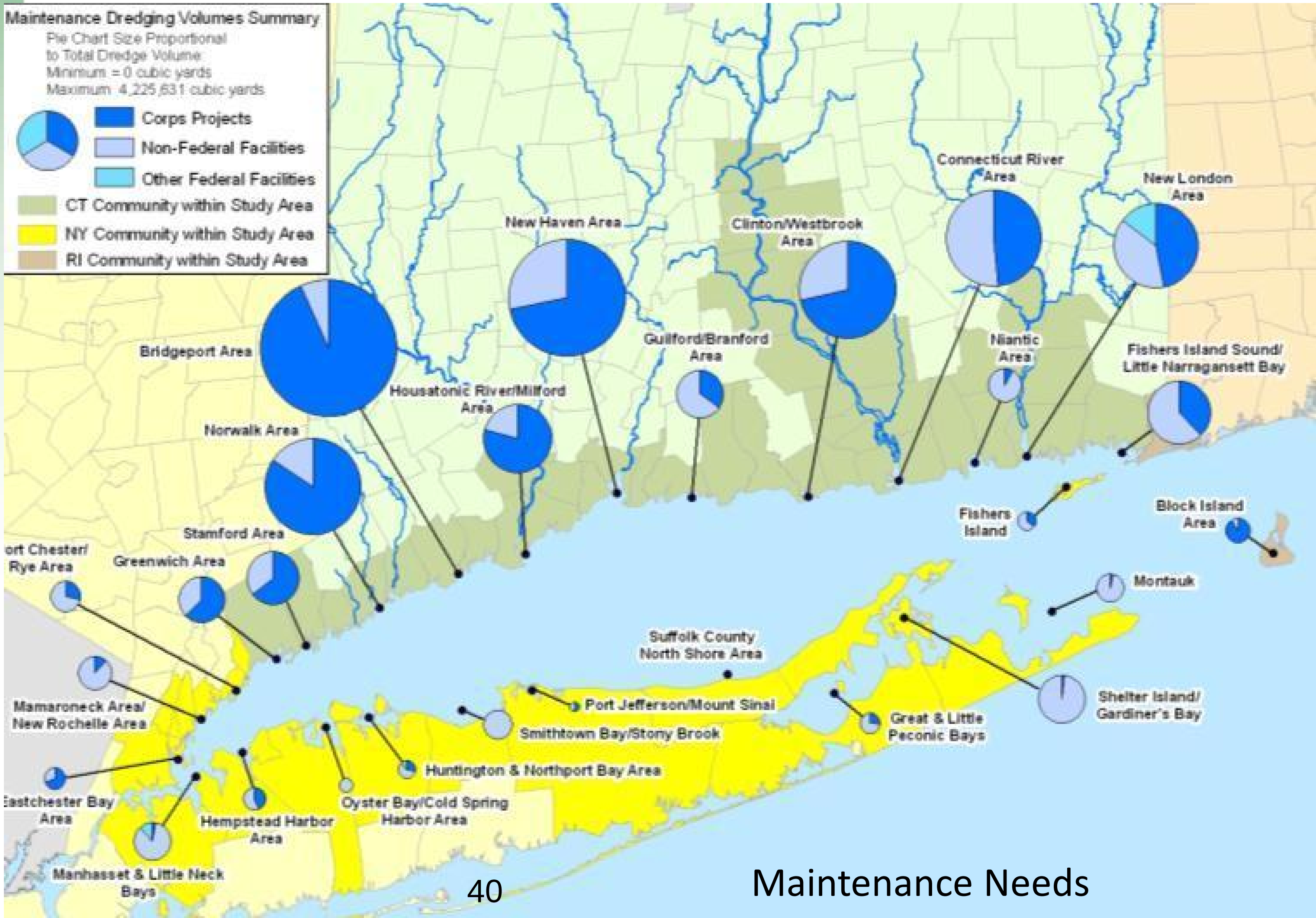
~2.4 million cy

Clinton/Westbrook

~2.4 million cy

Norwalk

~2.2 million cy



Maintenance Needs

Sustained & Active Participation: Long Island Sound

- DMMP requested by Governors of Connecticut and New York after the EPA designated changes to open water dredged-material disposal sites in LIS.

- Issue: Stakeholders disagree
  - States, Harbormasters, Marinas, Yacht Clubs, Boat Yards, Cargo Terminals, Power Plants, Military Facilities, State Piers, Ferry Terminals, Dredgers, etc.

- Result: $15M and 3 yrs later states & stakeholder fights reach US congress and process told to start over…

Sustained & Active Participation: Long Island Sound

- The process calls for Federal agencies to seek public input regarding development of the LIS DMMP.

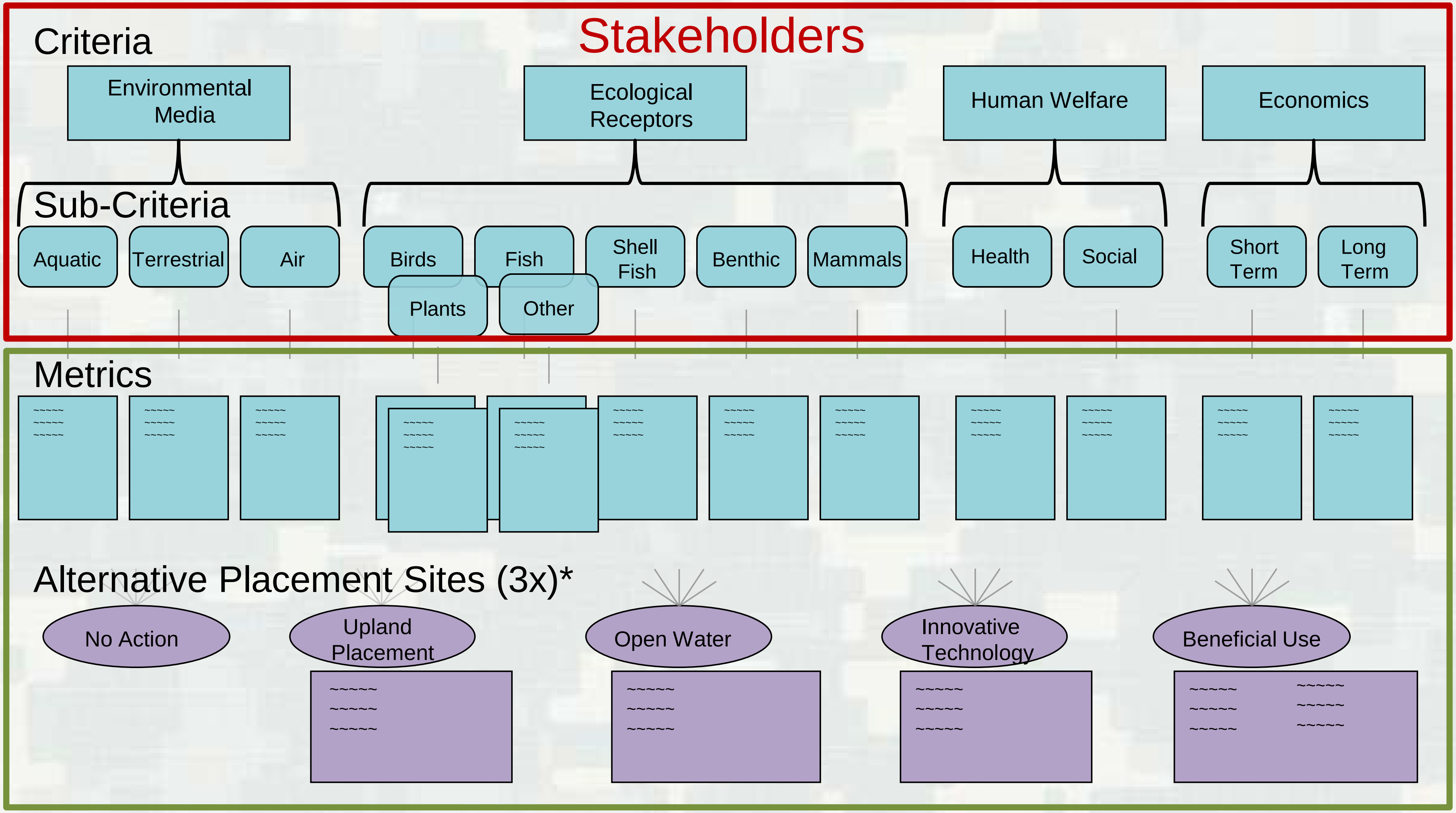
- Earlier attempts at generating criteria focused on site-specific screening constraints; did not comprehensively address stakeholder values.

- USACE hosted a series of Working Group meetings to identify evaluation criteria based on stakeholder concerns.

Sustained & Active Participation: Long Island Sound

- Individual stakeholder organizations to “weight” the criteria and sub-criteria (which are defined by the metrics) to determine relative priorities and tradeoffs.
- District staff and other experts to perform technical assessments to “score” the placement sites for each region of Long Island Sound against these metrics.
- The stakeholder weights and technical scores can be combined in an MCDA model to rank the placement sites in each LIS region. Results will be reported as one component of the final LIS DMMP.

Long Island Sound



Army Corps of Engineers

Sustained & Active Participation: Long Island Sound

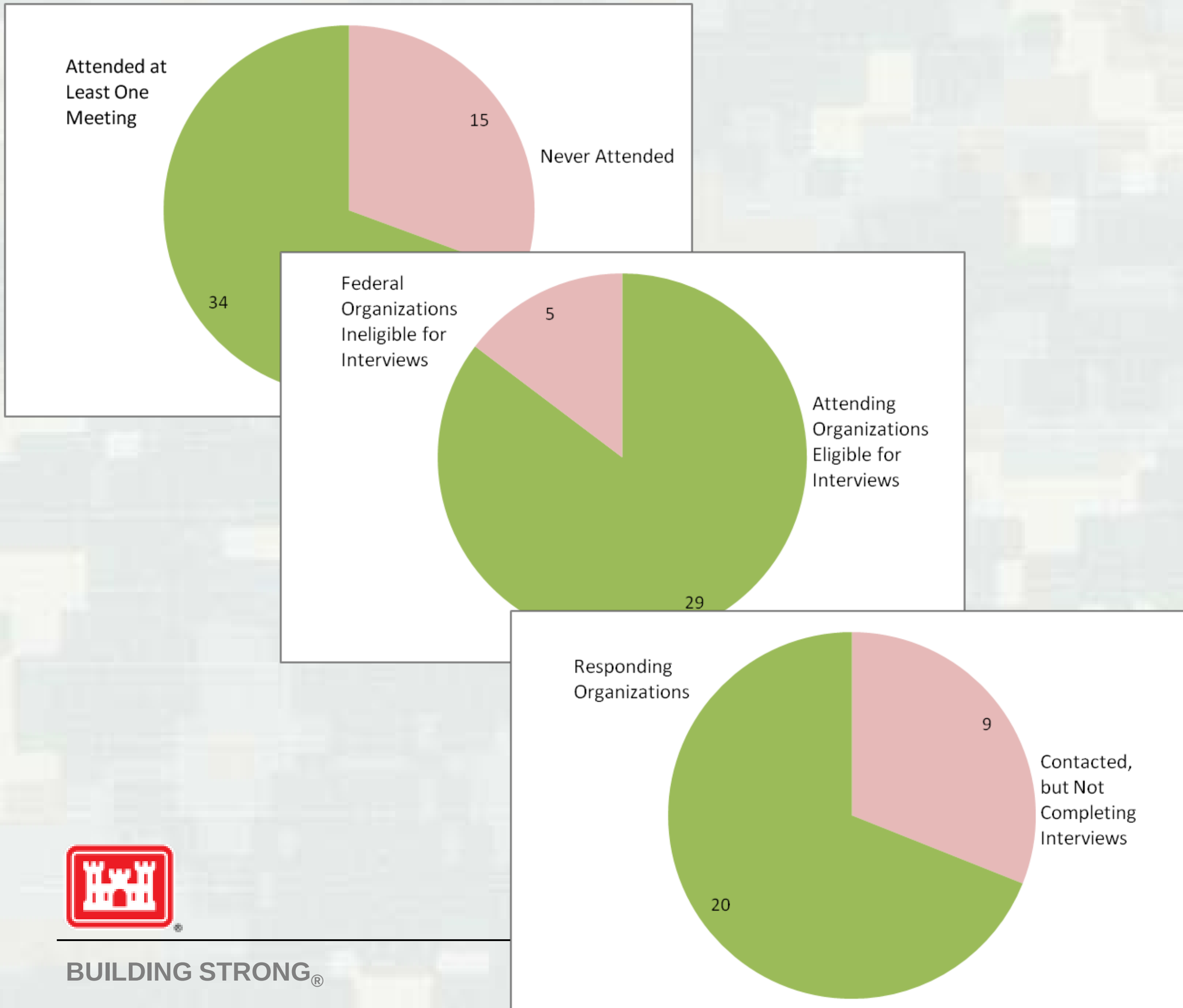
Environmental Media
Aquatic
-Source/destination water & sediment compatibility
-Water quality
-Sediment stability
Terrestrial
-Suitability for intended end use
-Material stability and potential for erosion
-Exposure and potential for transport
Air
-Short-term air quality (equipment & transportation)
-Exposure and potential for transport

Human Welfare
Health
-Operational safety
-Navigation safety
-Exposure to contaminants
Social
-Implementability
-Beneficial use
-Recreation, education, & research
-Cultural and historical
-Aesthetics
-Other conflicting uses
-Affected populations

Ecological Receptors
Birds
-Short-term impacts or benefits to individual animals & habitats
-Long-term impacts or benefits to populations & habitats
-Other considerations
Fish
-Short-term impacts or benefits to individual animals & habitats
-Long-term impacts or benefits to populations & habitats
-Other considerations
Shellfish
-Short-term impacts or benefits to individual animals & habitats
-Long-term impacts or benefits to populations & habitats
-Other considerations
Benthic
-Short-term impacts or benefits to individual animals & habitats
-Long-term impacts or benefits to populations & habitats
-Other considerations
Mammals
-Short-term impacts or benefits to individual animals & habitats
-Long-term impacts or benefits to populations & habitats
-Other considerations
Plants
-Short-term impacts or benefits to individual animals & habitats
-Long-term impacts or benefits to populations & habitats
-Other considerations
Other
-Short-term impacts or benefits to individual animals & habitats
-Long-term impacts or benefits to populations & habitats
-Other considerations

Economics
Short Term
-Direct construction
-Cost sharing requirement
-Monitoring costs
-Market and infrastructure limitations
-Indirect & opportunity costs
Long Term
-Maintenance & management costs
-Monitoring costs
-Change to commercial & recreational fisheries
-Ecosystem services
-Hurricane-barrier & flood-protection benefits
-Development & improvement
-Capacity issues
-Indirect, cumulative, & opportunity costs

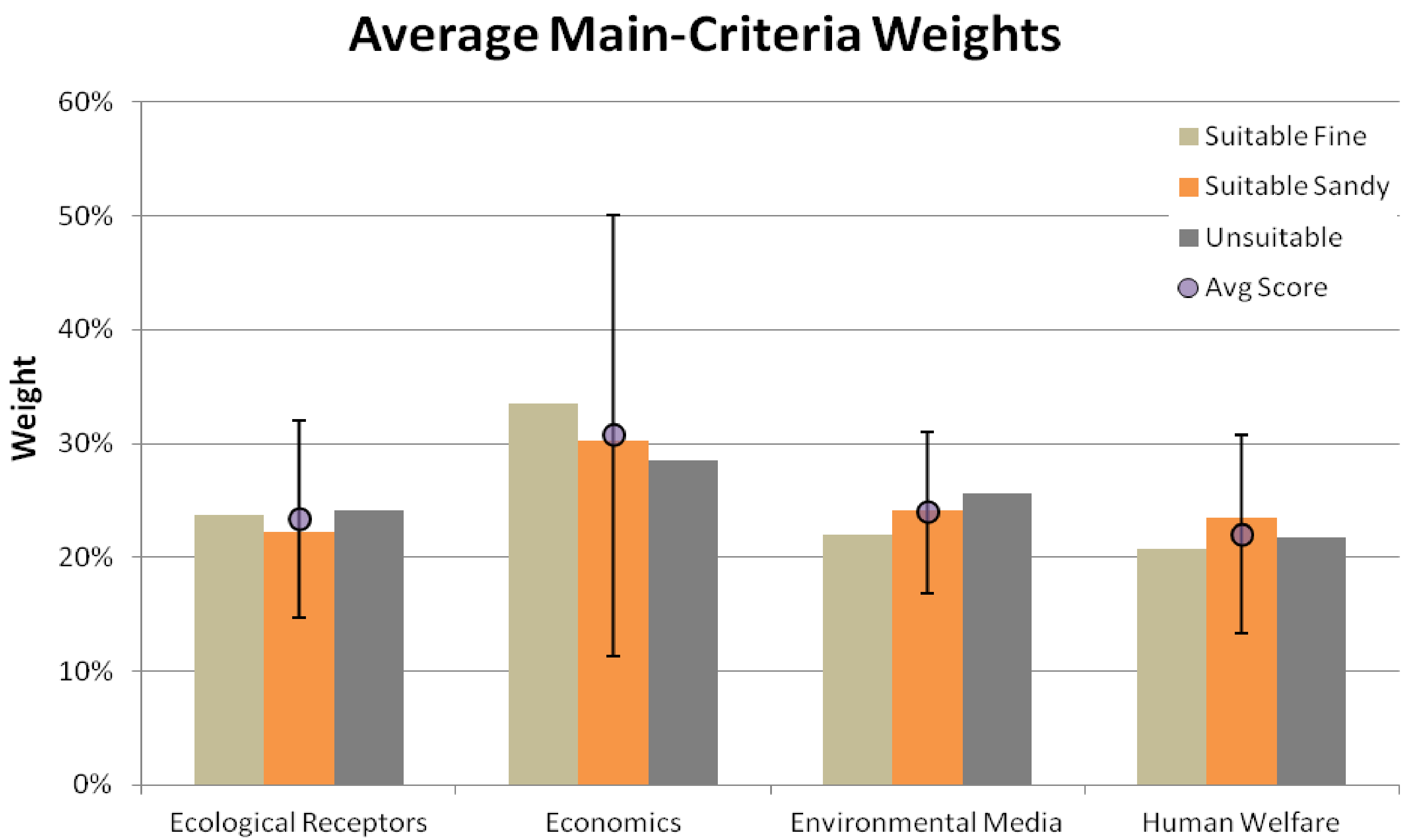
Sustained & Active Participation: Long Island Sound



Orgs Completing Interview Process

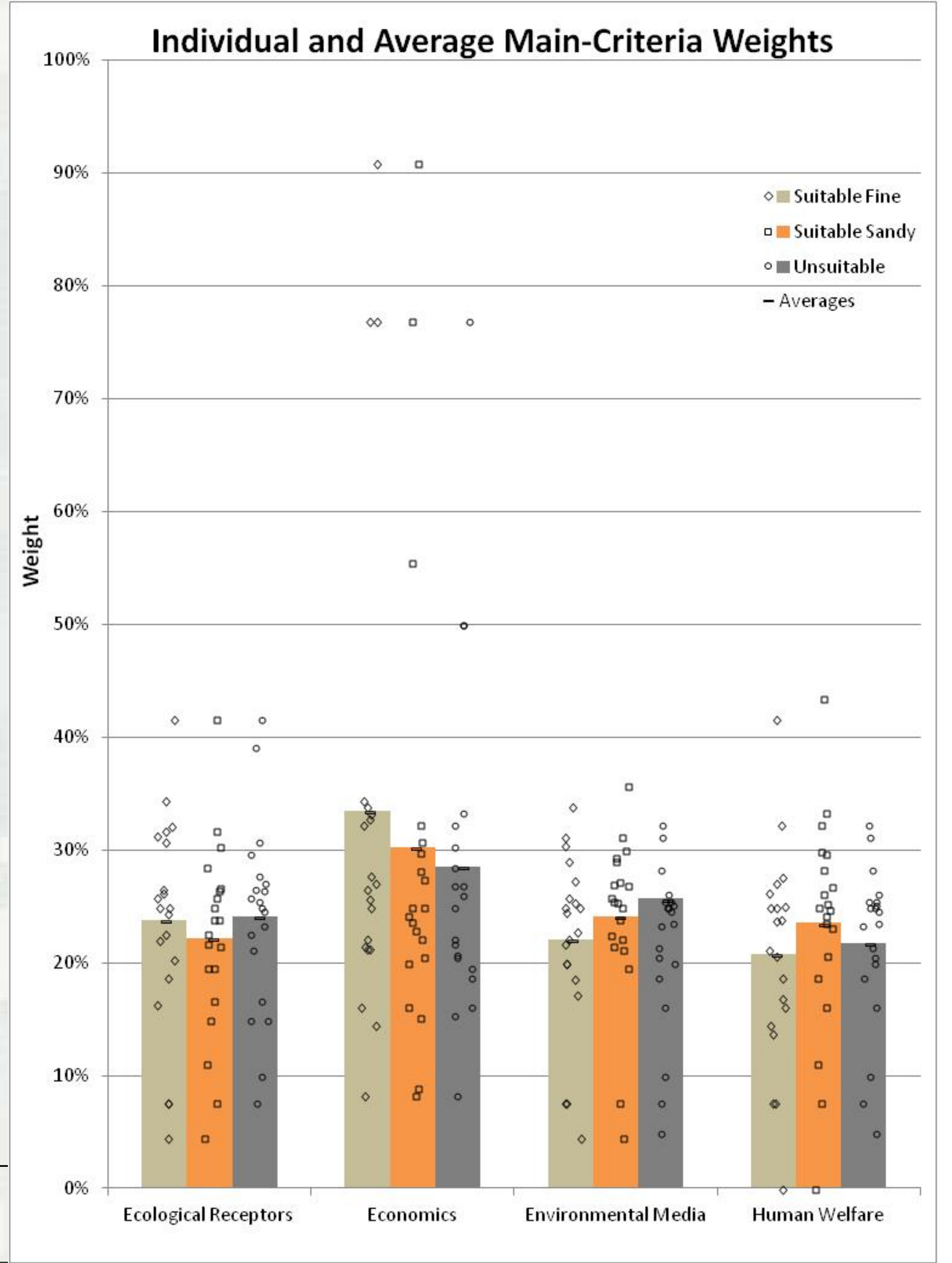
NY Dept. of State
CT Harbor Management Association
Norwalk Harbor Management Commission
Town of Guilford Harbor Mgmt. Association
US Navy - Submarine Base New London
New London Port Authority
Housatonic Valley Association
Long Island Sound Eastern Regional Council
LIS Assembly
CT Dept. of Transportation
Connecticut Marine Trade Association
Connecticut Maritime Coalition
New Haven Port Authority
NY Department of Environmental Conservation
Bridgeport Port Authority & Harbor Master
CT Dept. of Energy and Environmental Protection
CT Surfriders
Fairfield County Environmental Justice Network
US Coast Guard
Connecticut Fund for the Environment

Sustained & Active Participation: Long Island Sound



Note: error bars show one standard deviation about mean scores.

Sustained & Active Participation: Long Island Sound

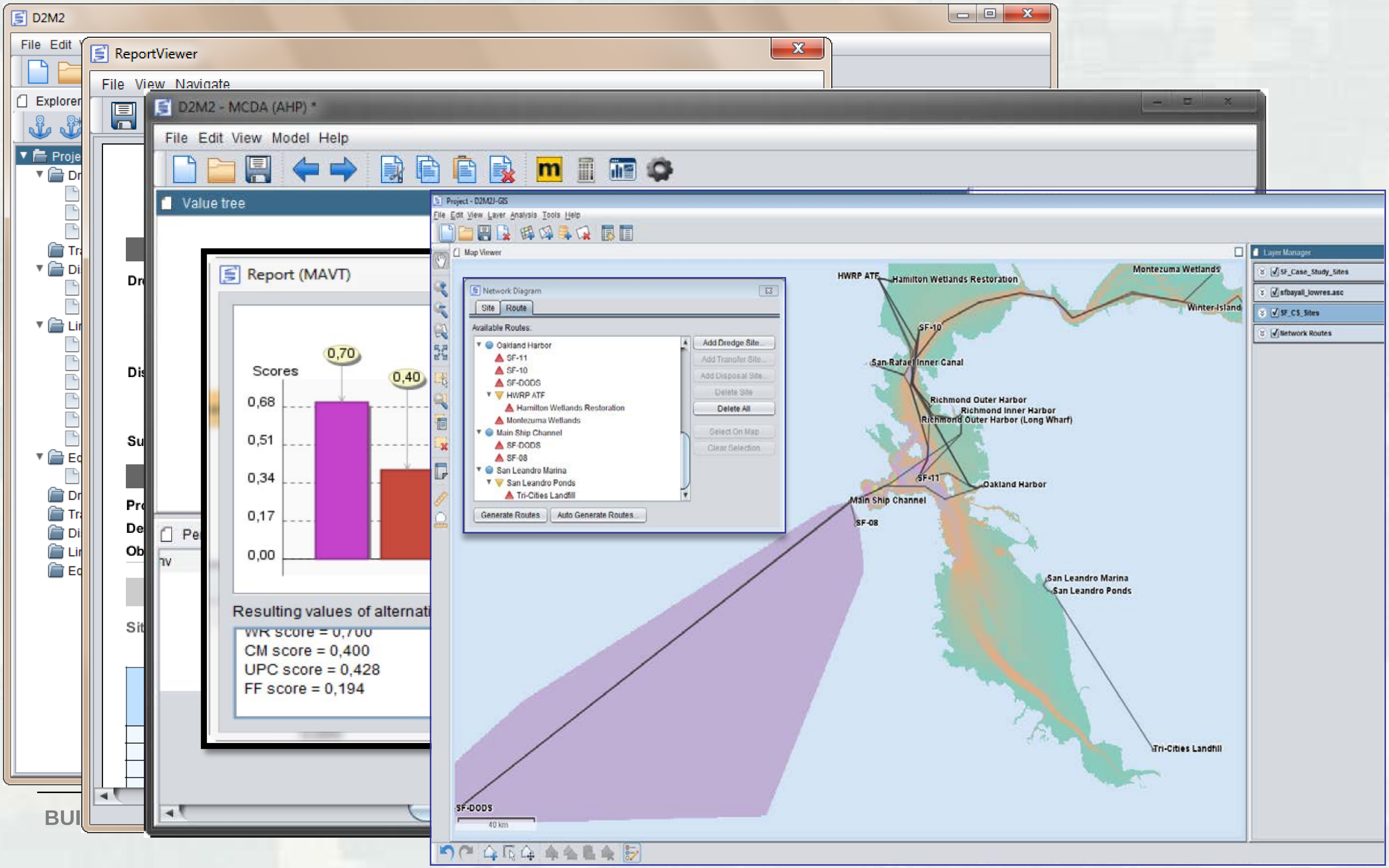


Multi-Objective Optimization

Multi-Objective Optimization with D2M2

- Dynamic tool for building transportation opt. models
- Mixed Integer Linear Programming approach
- Flexible, unique model formulation in each case:
  - Min/Max weighted sum of some multi-objective value function
  - Subject to set of volume & user defined system constraints
  - Given fixed and variable costs/impacts/effects for links and source & sink nodes (piecewise linear by volume & distance)
- Exclude prior solutions to explore near-optimal space
- Implemented with UI in Java & model in LPSOLVE

D2M2 Screenshots

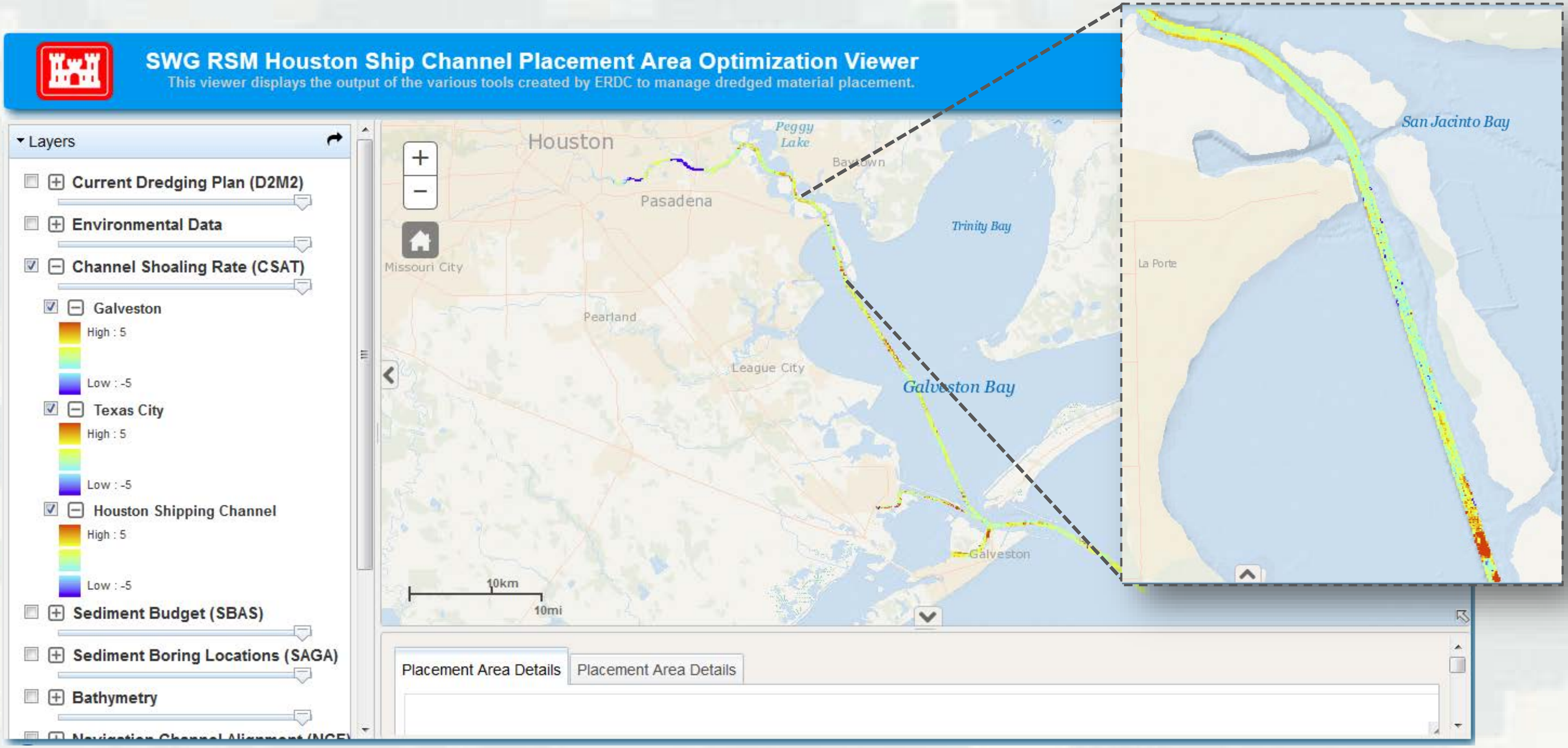


D2M2 Houston Ship Channel Model

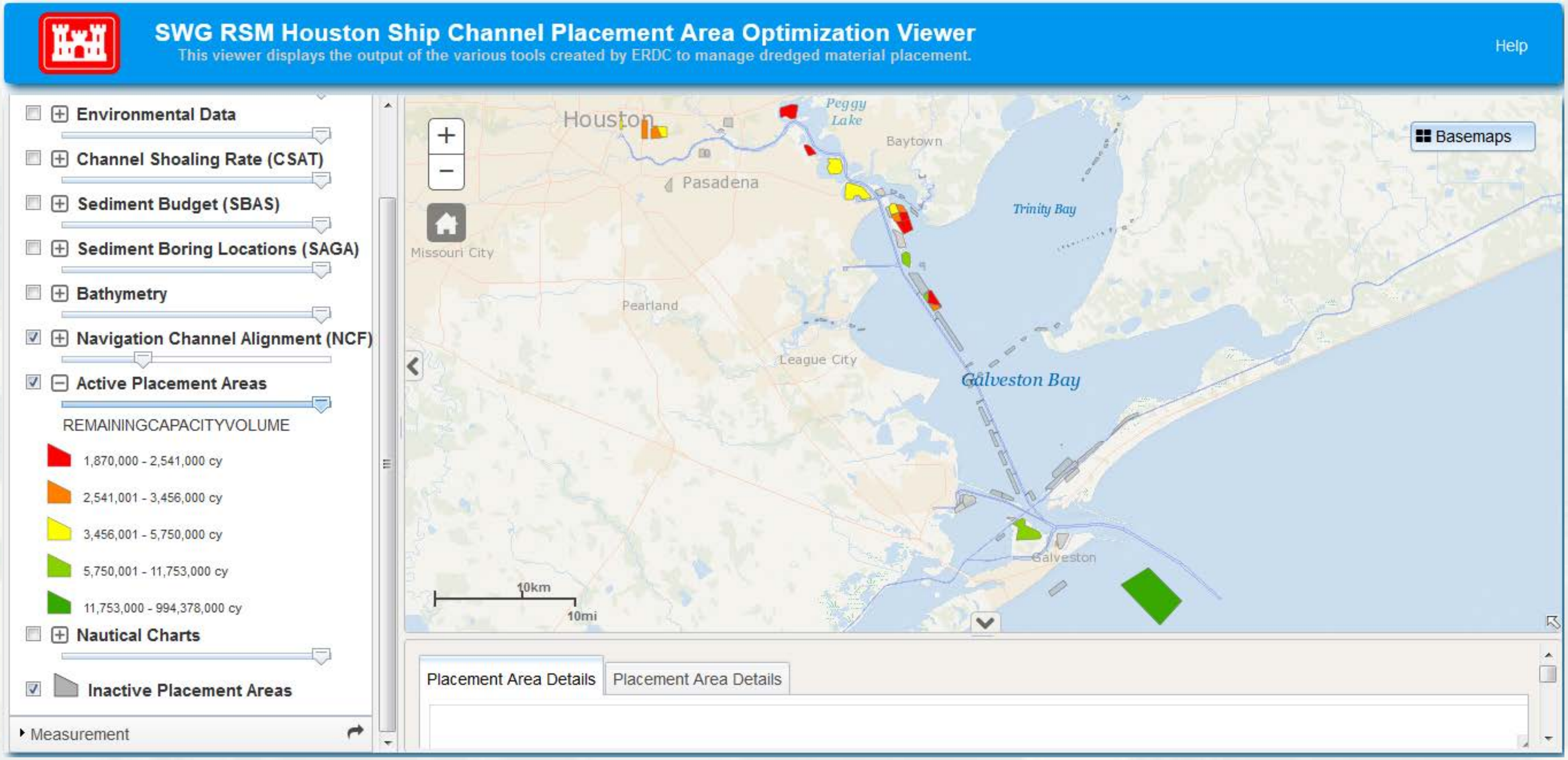
- Optimize navigation channel network, historical sedimentation and dredging, and system of placement areas for the Houston Ship Channel.

- Criteria include: Cost, oil & gas leases, endangered species, and oyster beds.

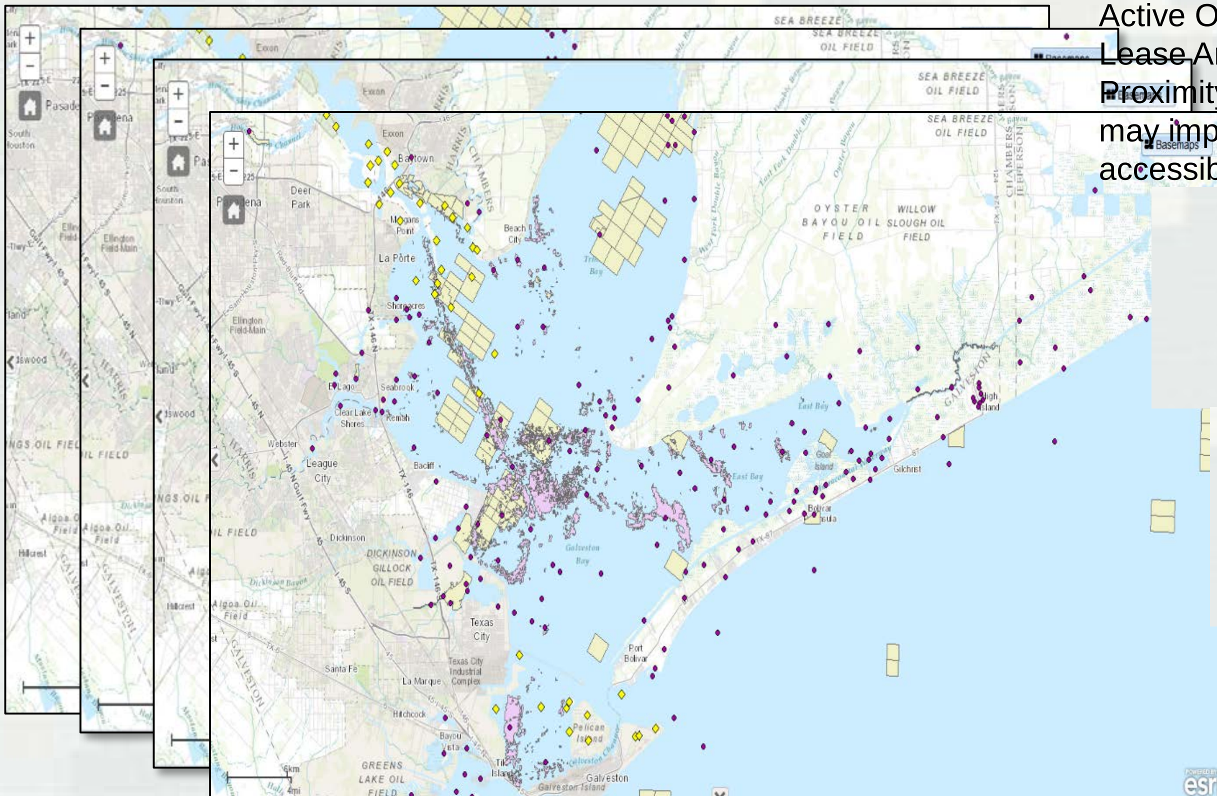
HSC Shoaling Rates (Dredging Needs)



HSC Placemen Areas & Capacities

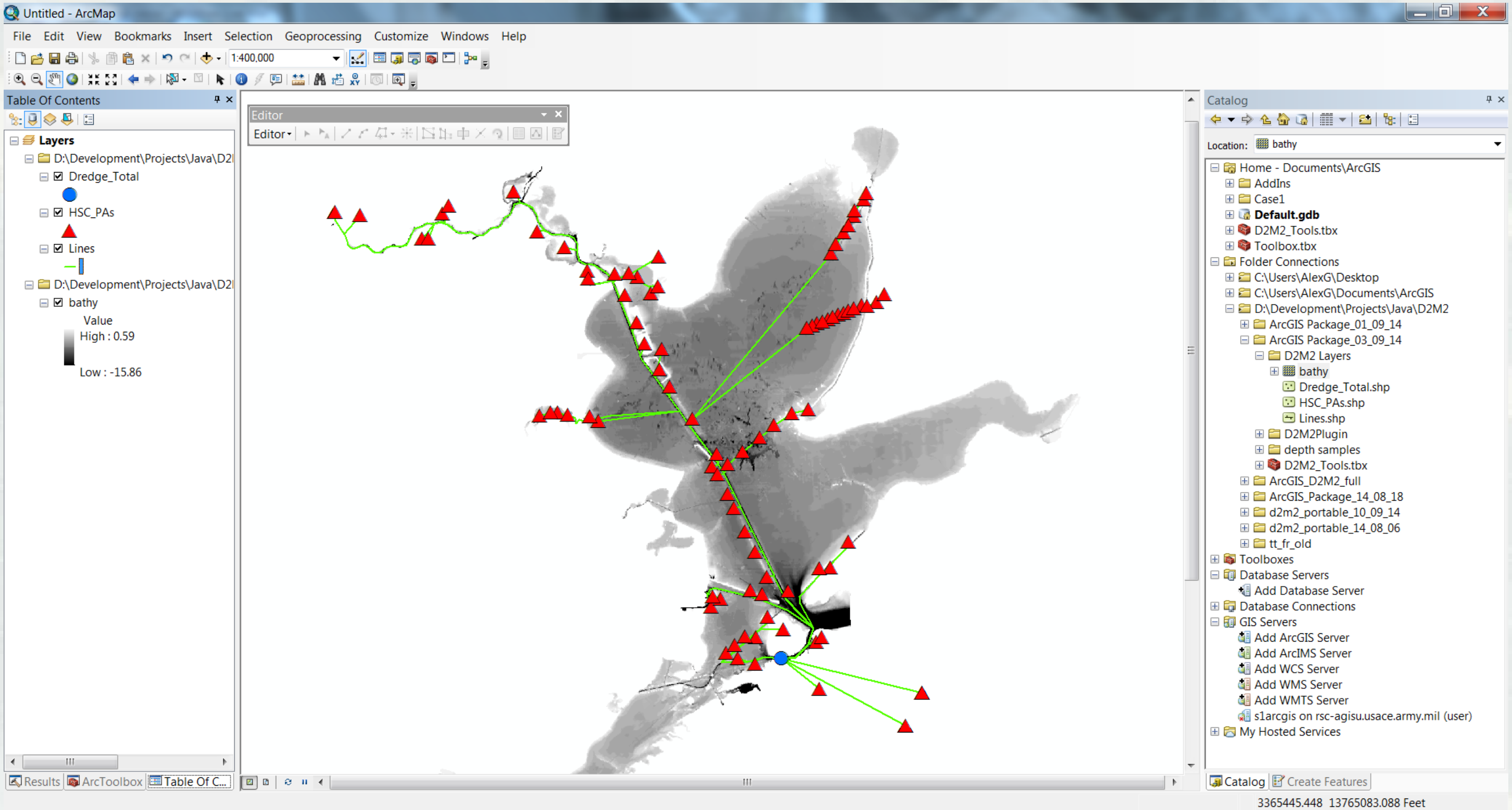


HSC D2M2 Evaluation Criteria

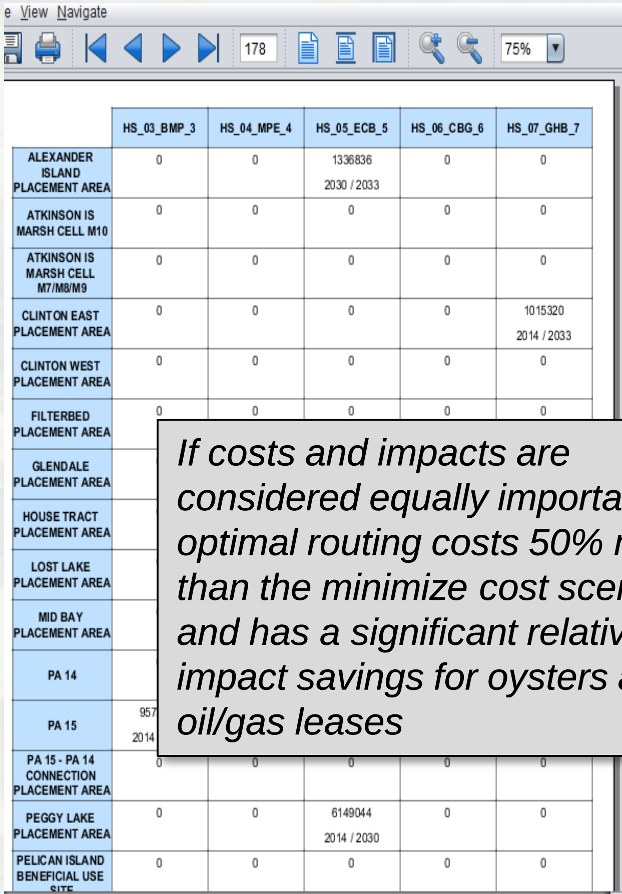


Active Oil and Gas Lease Areas: Proximity to a PA may impact accessibility

HSC D2M2 Site Network



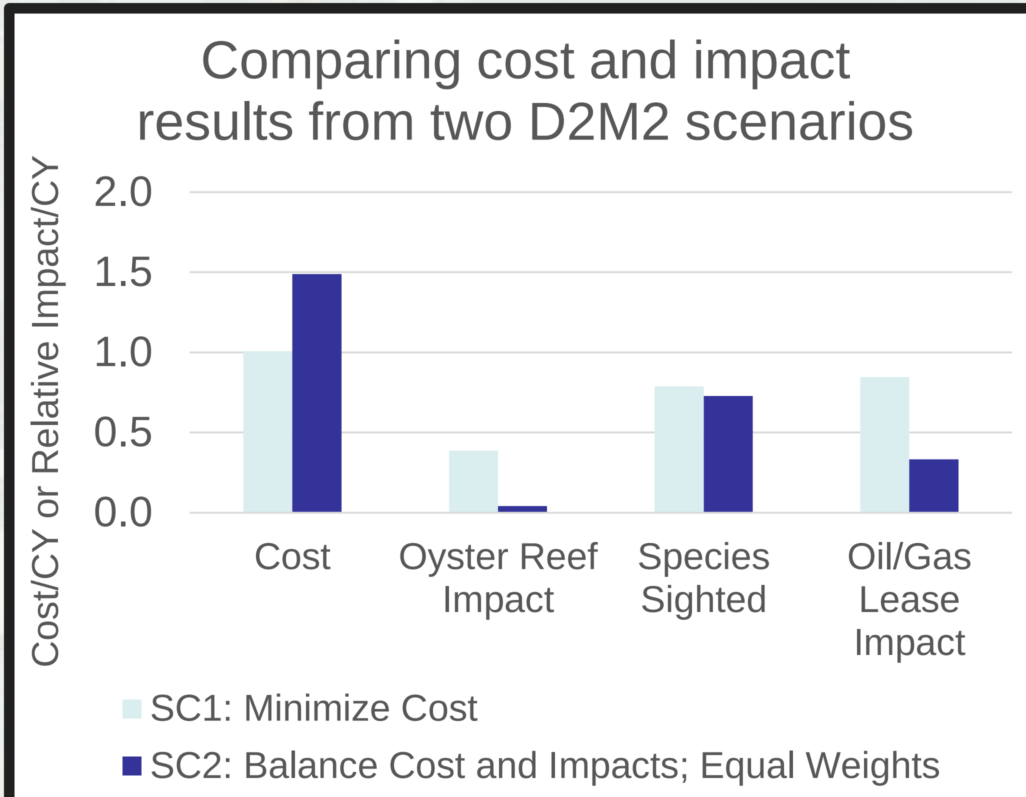
HSC D2M2 Results


e View Navigate

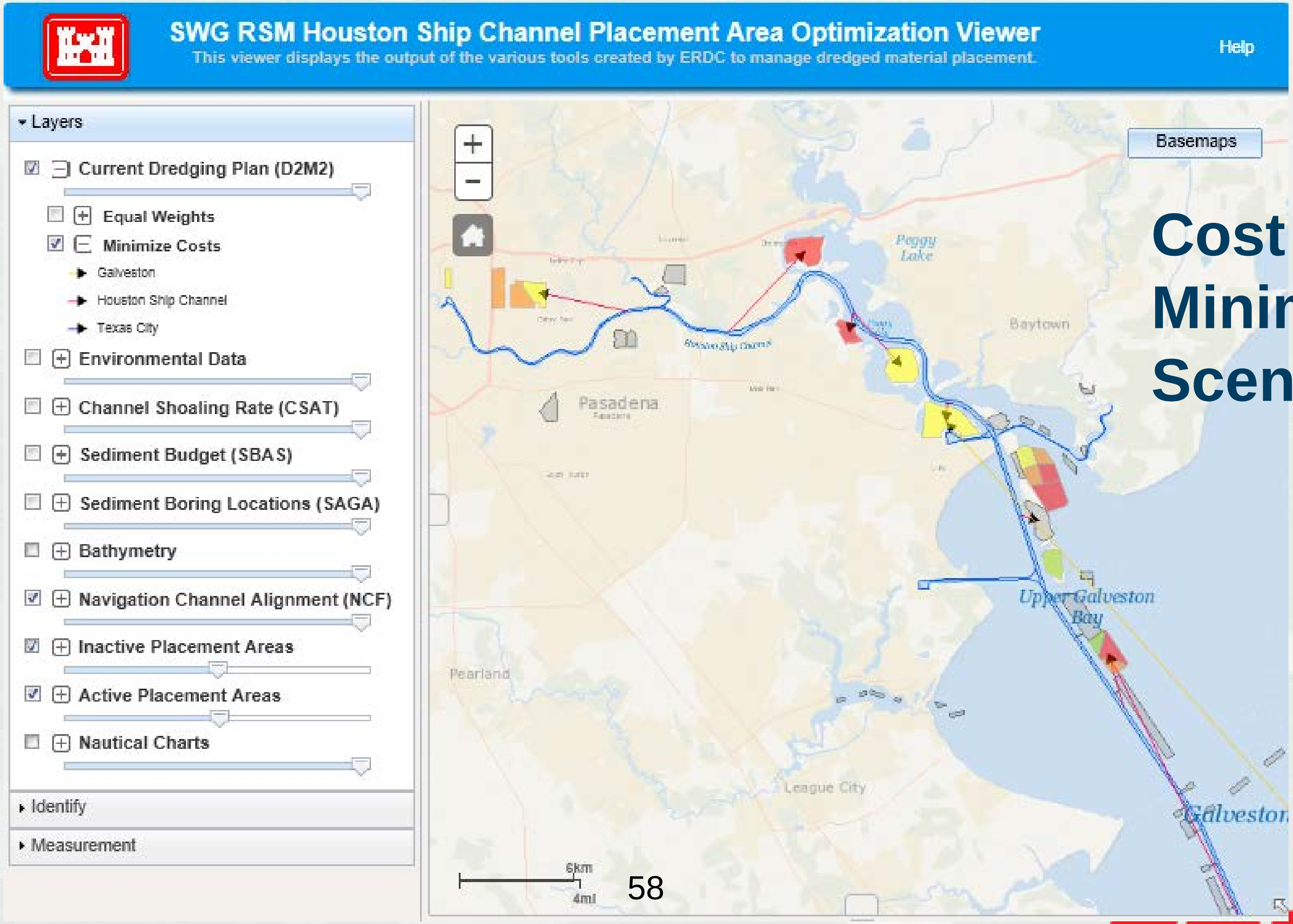
178 75%

	HS_03_BMP_3	HS_04_MPE_4	HS_05_ECB_5	HS_06_CBG_6	HS_07_GHB_7
ALEXANDER ISLAND PLACEMENT AREA	0	0	1336836 2030 / 2033	0	0
ATKINSON IS MARSH CELL M10	0	0	0	0	0
ATKINSON IS MARSH CELL M7/M8/M9	0	0	0	0	0
CLINTON EAST PLACEMENT AREA	0	0	0	0	1015320 2014 / 2033
CLINTON WEST PLACEMENT AREA	0	0	0	0	0
FILTERBED PLACEMENT AREA	0	0	0	0	0
GLENDALE PLACEMENT AREA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HOUSE TRACT PLACEMENT AREA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LOST LAKE PLACEMENT AREA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MID BAY PLACEMENT AREA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PA 14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PA 15	957 2014	[illegible]	[illegible]	[illegible]	[illegible]
PA 15 - PA 14 CONNECTION PLACEMENT AREA	0	0	0	0	0
PEGGY LAKE PLACEMENT AREA	0	0	6149044 2014 / 2030	0	0
PELICAN ISLAND BENEFICIAL USE SITE	0	0	0	0	0

If costs and impacts are considered equally important, the optimal routing costs 50% more than the minimize cost scenario, and has a significant relative impact savings for oysters and oil/gas leases

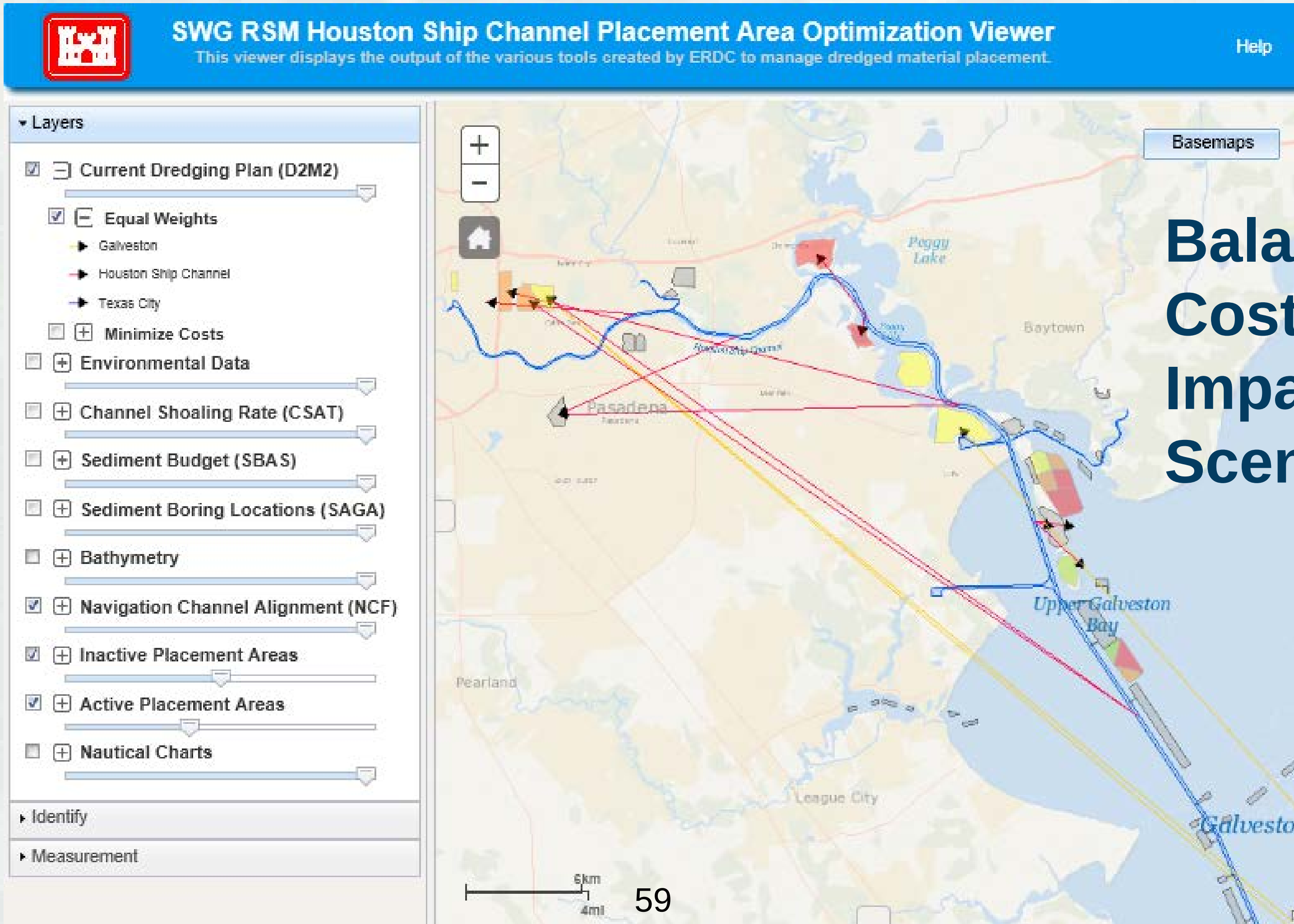


HSC D2M2 Results



Cost Minimizing Scenario

HSC D2M2 Results



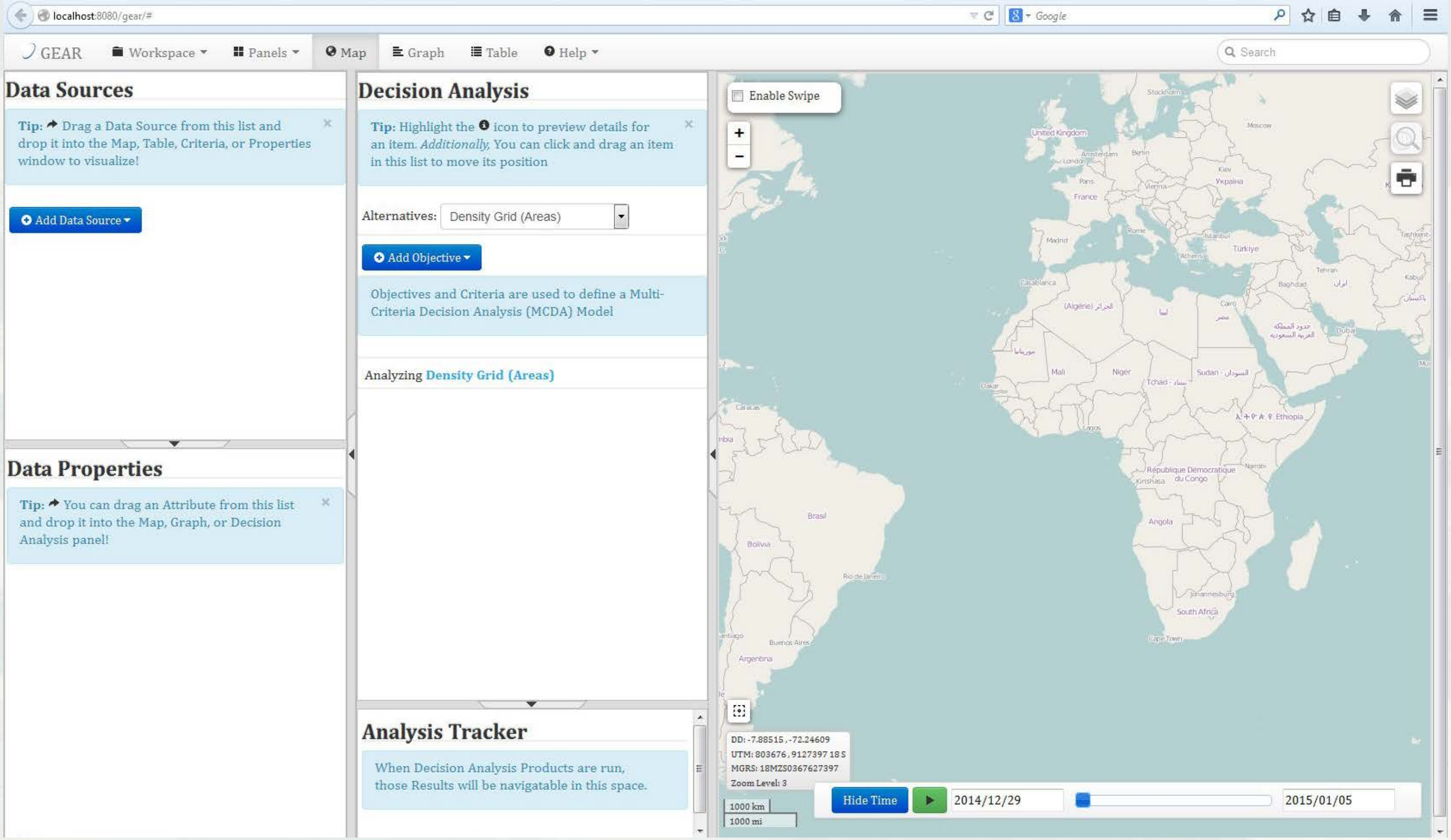
Balanced Costs & Impacts Scenario

Geospatial MCDA

GEAR Summary

- GEAR—“Geo-centric Environment for Analysis & Reasoning”
- R&D prototype of spatial decision analysis software developed over multiple years with millions of dollars of US Government investment.
- GIS-based Multicriteria Decision Analysis (GIS-MCDA) gives users robust capability to efficiently and intuitively assess, analyze, and compare alternative outcomes to generate actionable end products.
- Enables the discovery, retrieval, organization, aggregation, analysis, and visualization of data from heterogeneous sources to transform open data to open analytics.
- Emphasizes a web-enabled software architecture capable of scaling to devices that support modern web browsers (e.g., desktops, tablets, mobile devices). Flexible and interoperable framework facilitates open, participatory, and collaborative analyses.

Screenshot of GEAR Layout

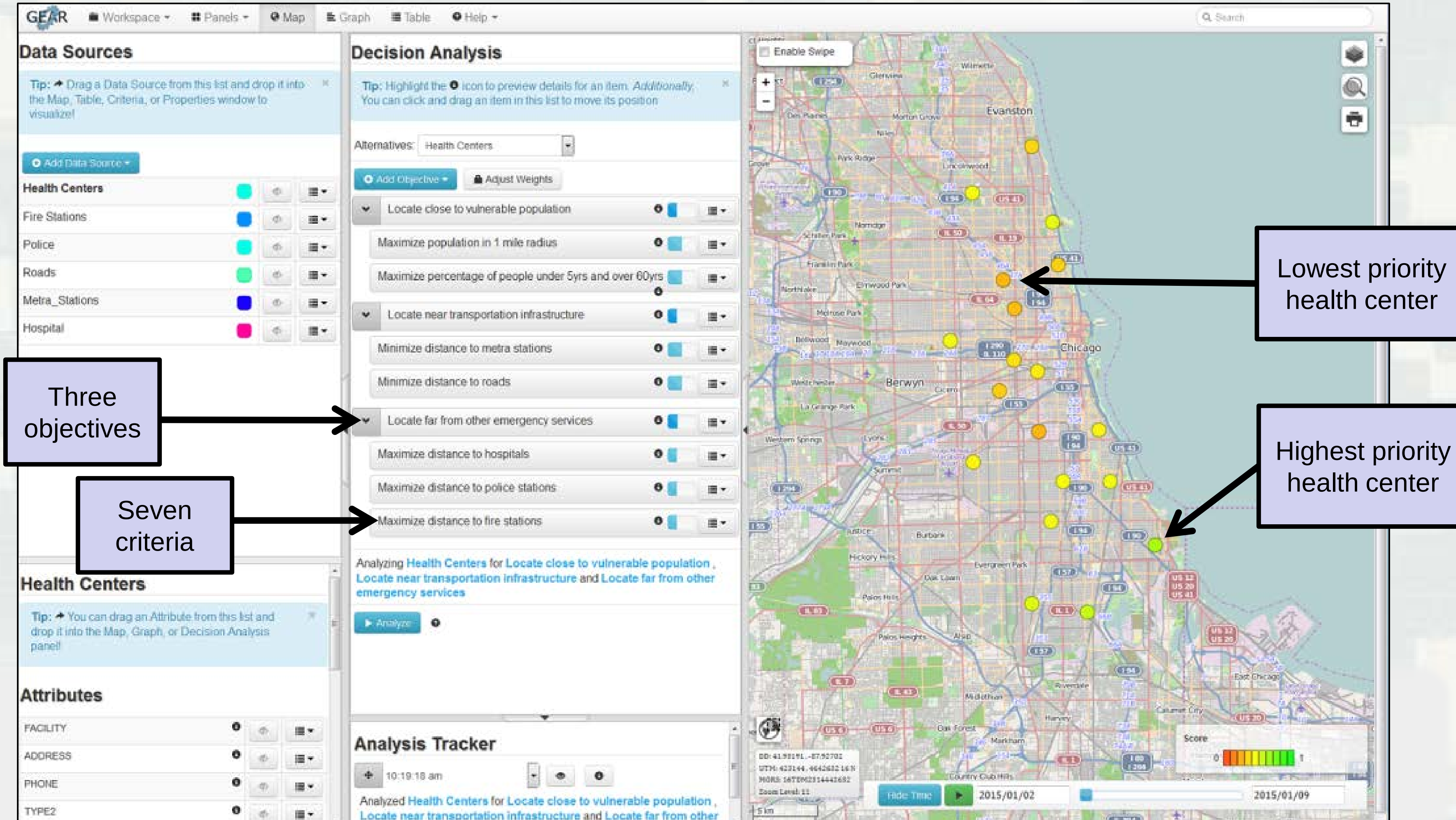


Summary of Core Functionality

- Decision Analysis: GEAR's decision based capabilities allow users to manage and interpret data to answer higher order questions.
- User friendly interface: flexible, scalable, drag and drop capabilities.
- Data sources: GEAR ingests a wide range of data sources for spatial analysis, including uploaded GIS files and dynamic web services.
- Value functions: translate data measured in different units into normalized value scores, then aggregated to evaluate alternatives.
- Analytical power & flexibility: vector analysis of polygons, points, lines, or any combinations thereof; temporally enabled analyses.
- Data modification: edit, add, or remove data fields/entries using math and spatial operators (e.g., +*, -, *, log, spatial join, extract value*).
- Potential applications: many, including humanitarian assistance, disaster response, tactical operations planning, site suitability, environmental analysis, resilience & vulnerability analyses, etc.

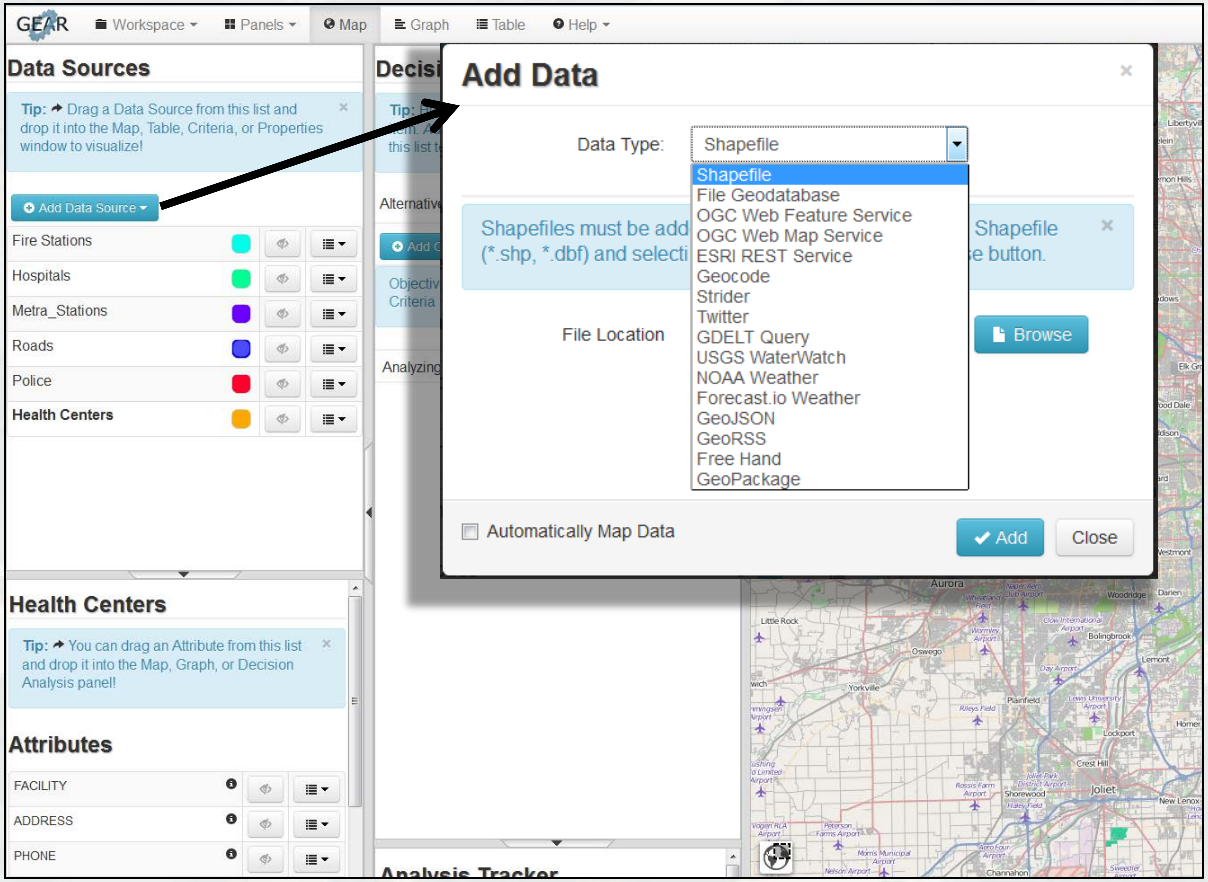
Chicago Demo Summary

Scenario: Infectious disease outbreak in Chicago
Goal: Prioritize existing health centers for logistic and medical response
Assumptions: Ideal locations are central to vulnerable population, near major transportation, and far from other emergency services. Seven criteria used to measure the three objectives.



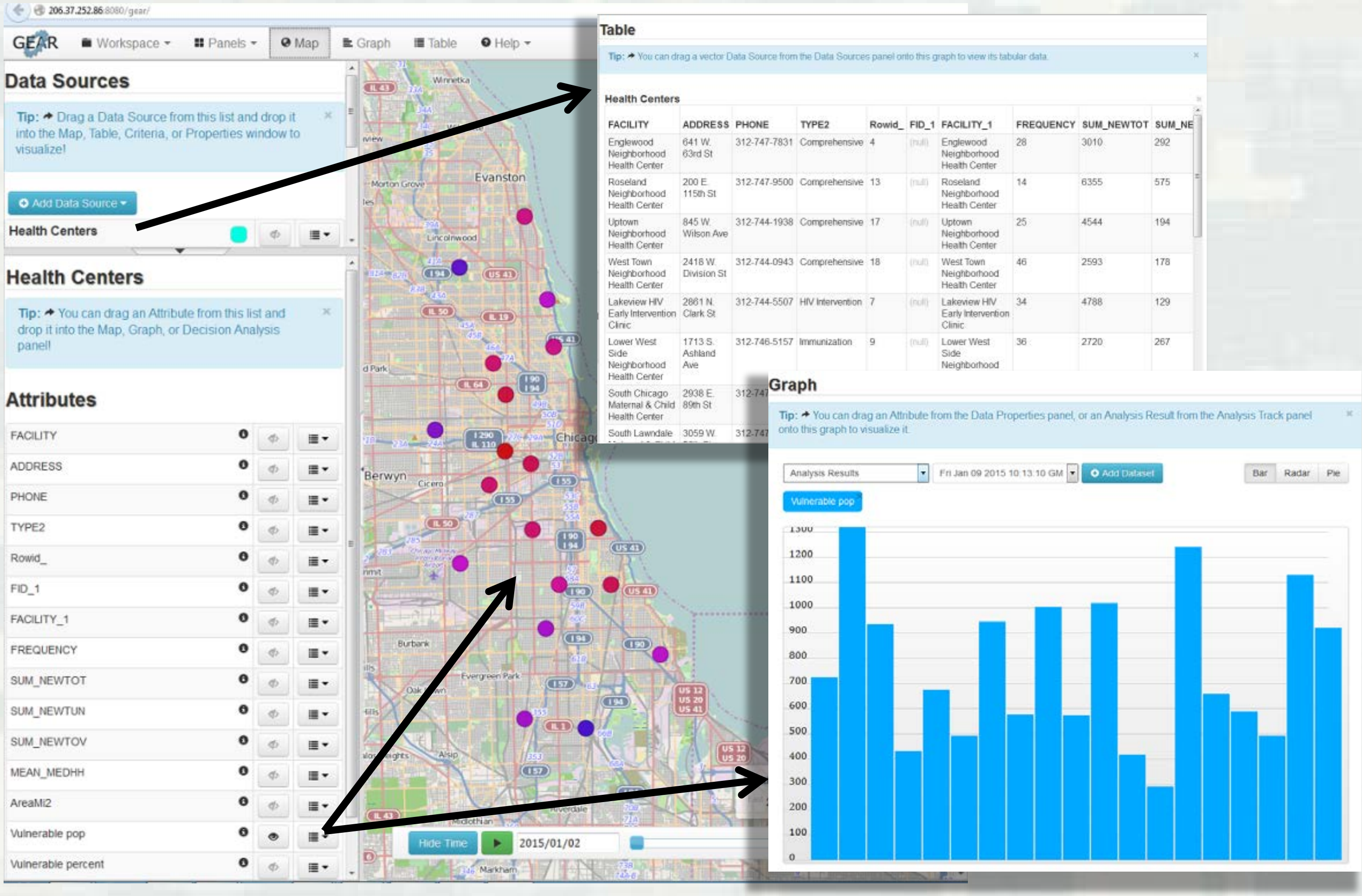
Chicago Demo - Step by Step Walkthrough

Step: Add data sources



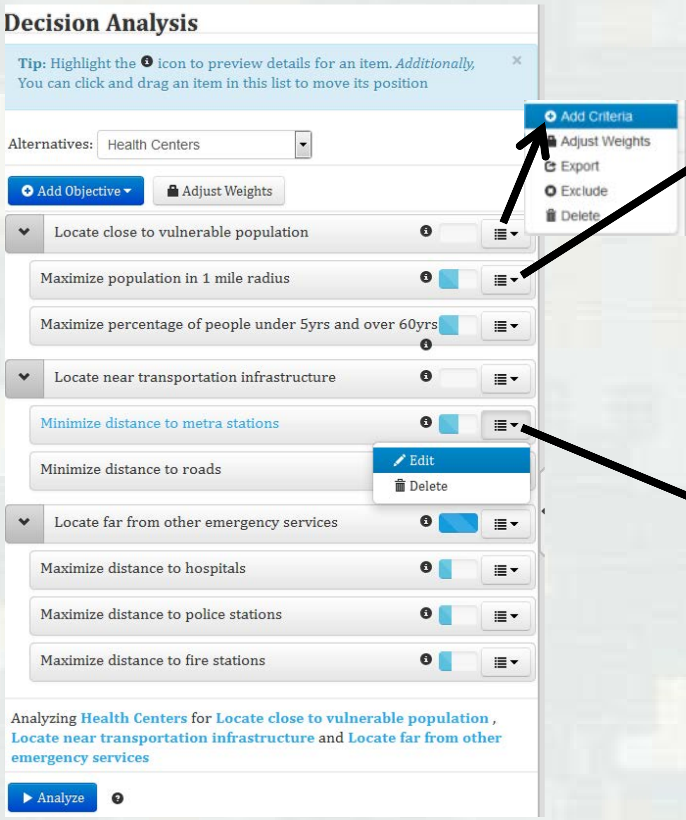
Chicago Demo - Step by Step Walkthrough

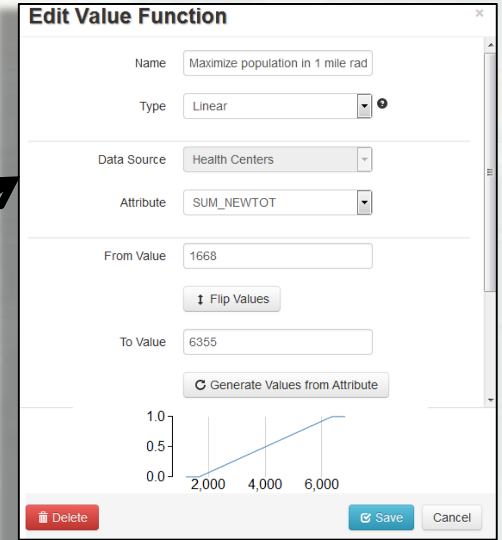
Step: Inspect data sources and attributes in map, table and graph form

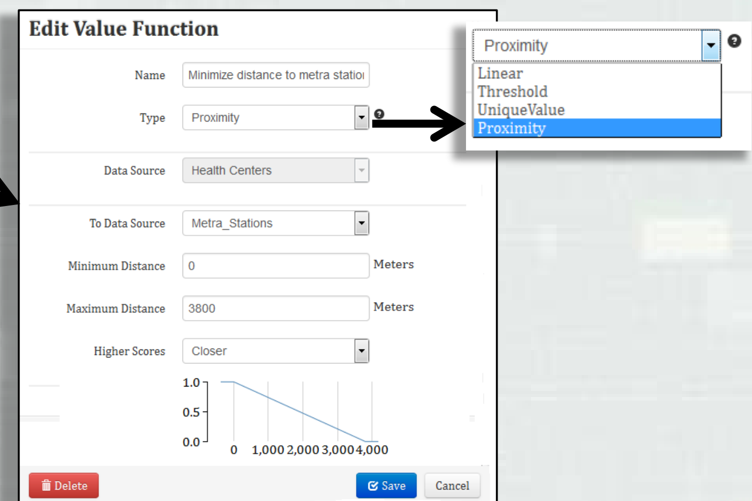


Chicago Demo - Step by Step Walkthrough

Step: Choose decision alternatives and add objectives and criteria

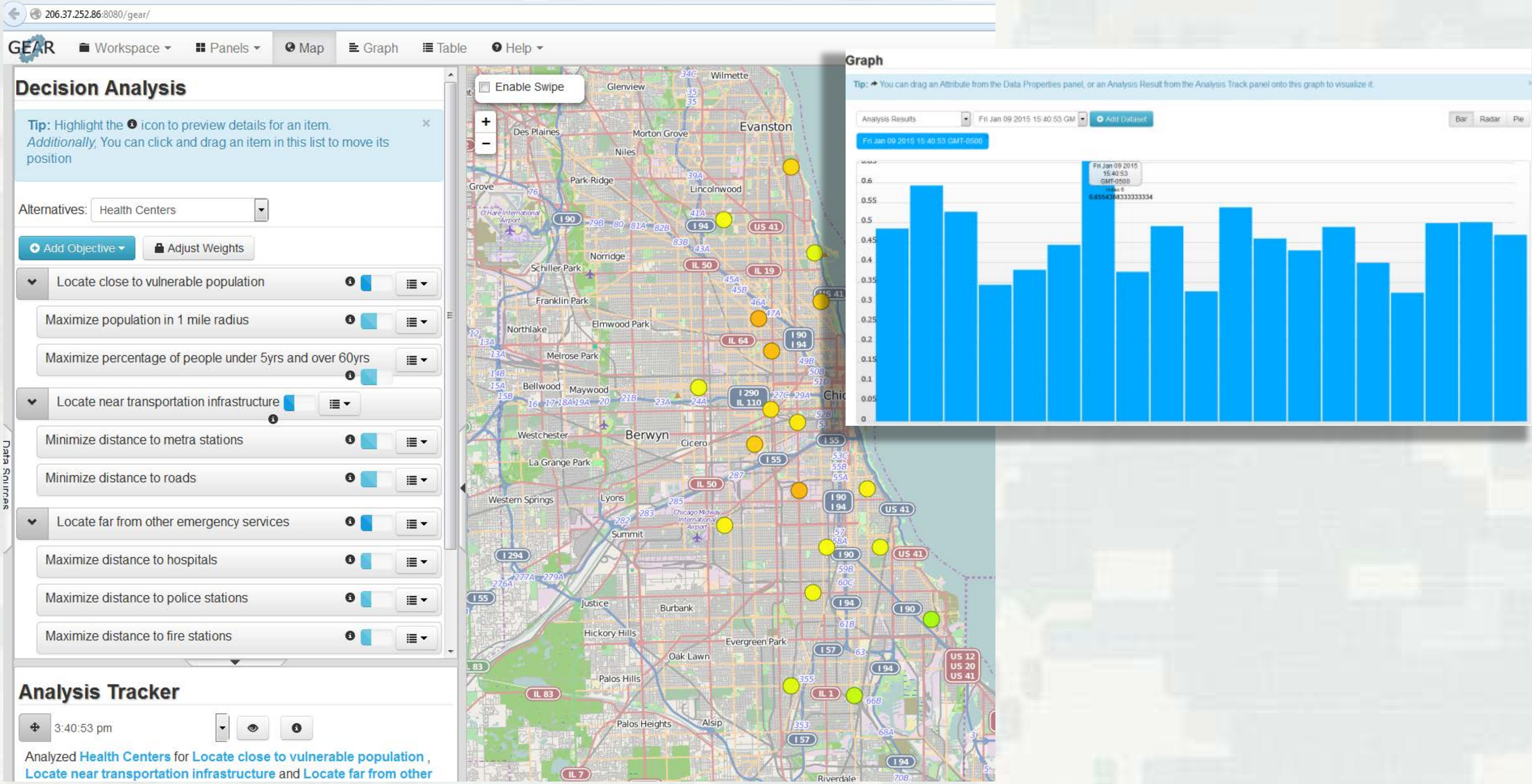






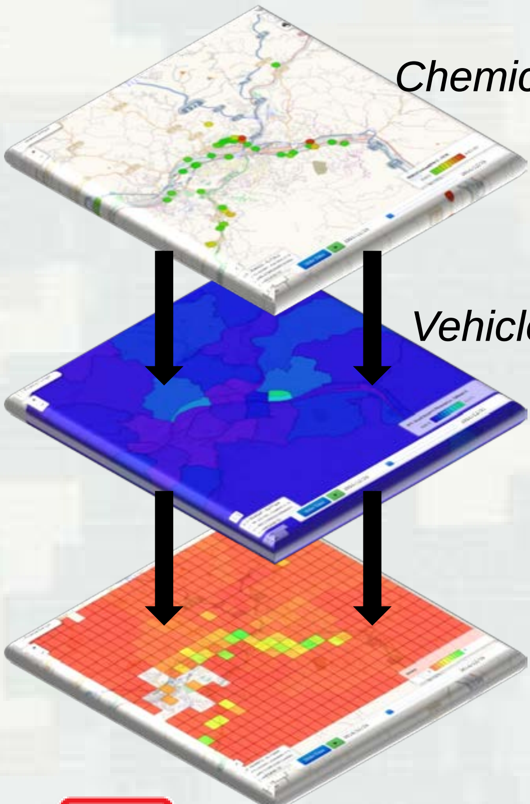
Chicago Demo - Step by Step Walkthrough

Step 6: Select Analyze button and visualize results in map and graph form



Chemical Spill Demo Overview

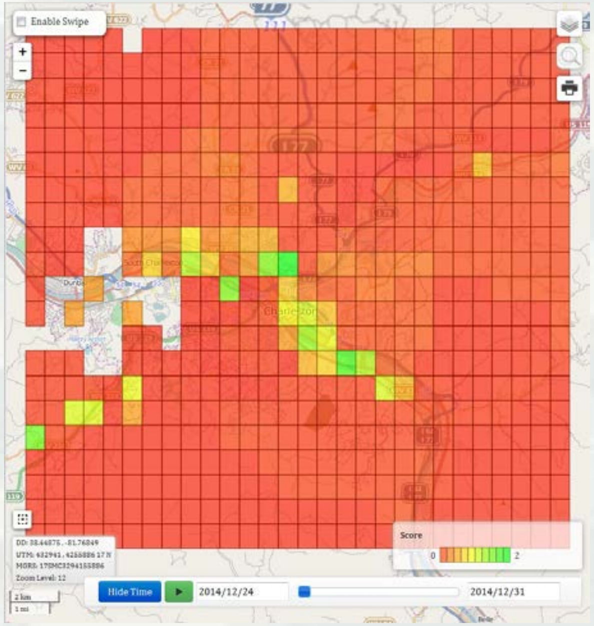
Scenario: Local responders want to identify areas of need after Elk River, WV, chemical spill.
Goal: Evaluate different areas in Charleston, WV, based on anticipated risk & need.
Assumptions: Combine data for chemical spill risk (point data showing chemical concentrations sampled from hydrants) and vehicle access (polygons, representing greater inability to leave).



Chemical concentration

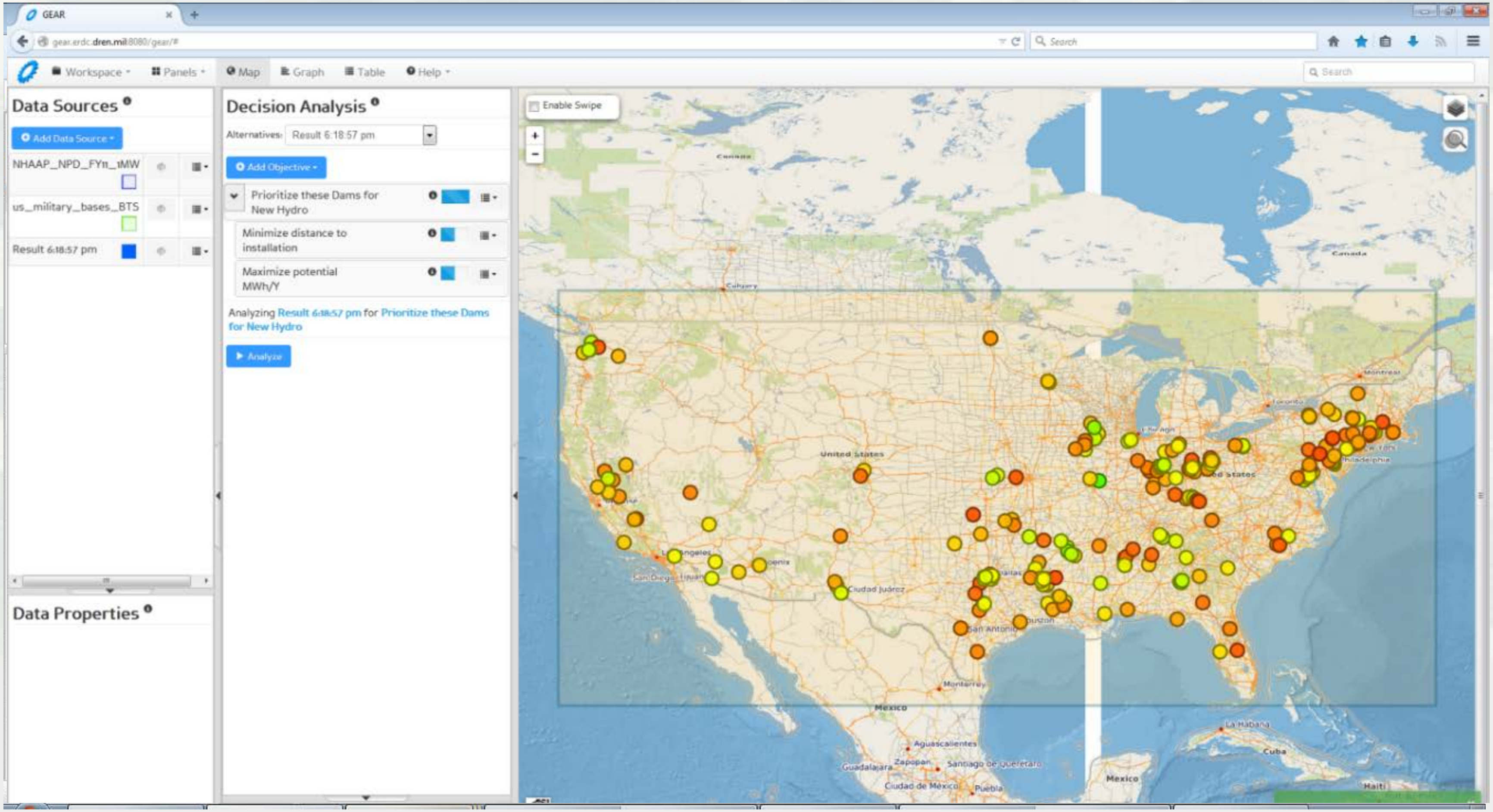
Vehicle access

Light colored grid zones have low vehicle access & high chemical concentrations: Higher priority for response.



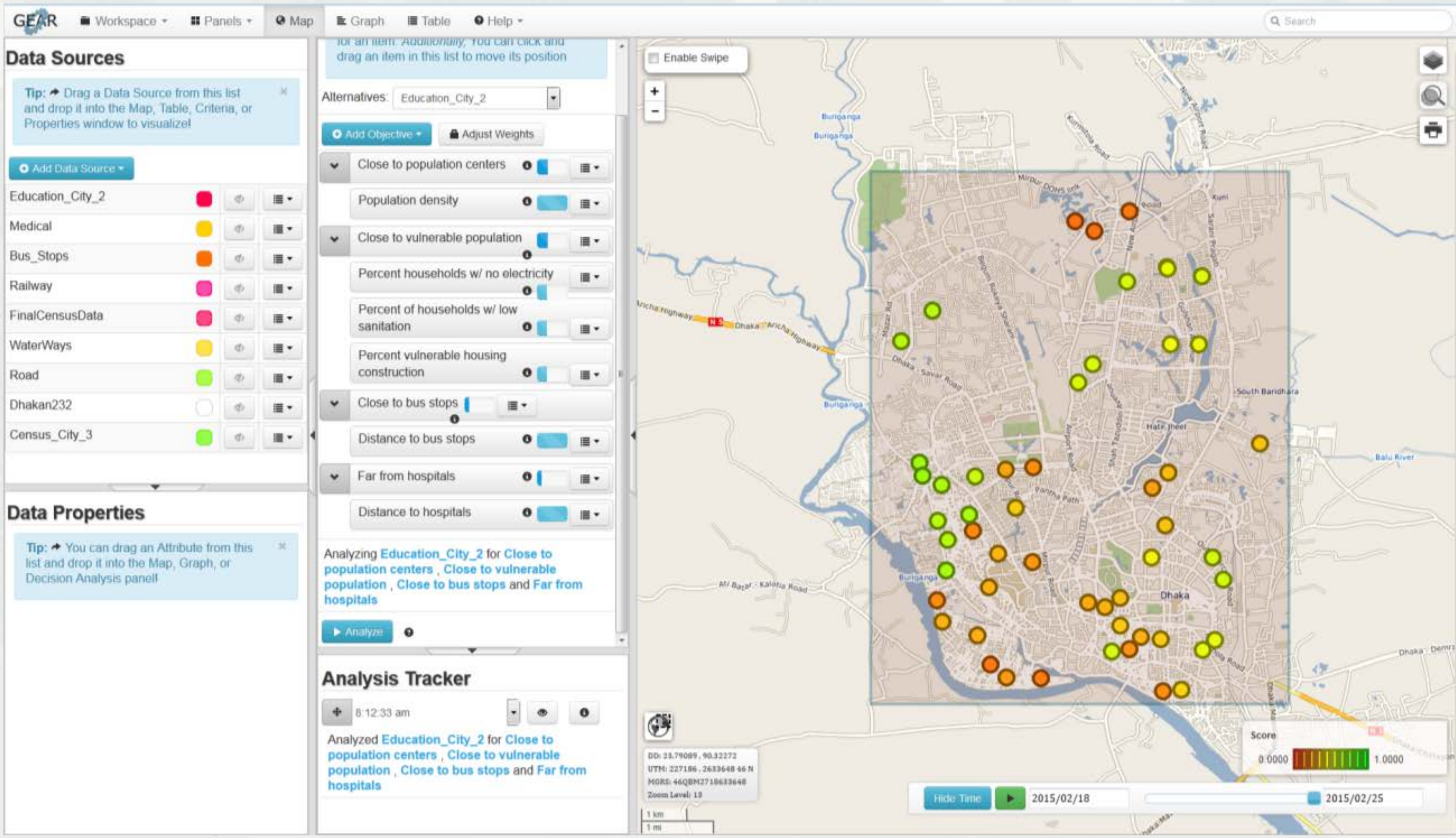
Hydropower Demo Overview

Scenario: US Army wants to invest in hydropower development.
Goal: Screen good locations for new hydro near existing military installations.
Assumptions: Prioritize existing dams based on available hydropower potential and distance from installation (with a threshold based on a maximum of 50km).



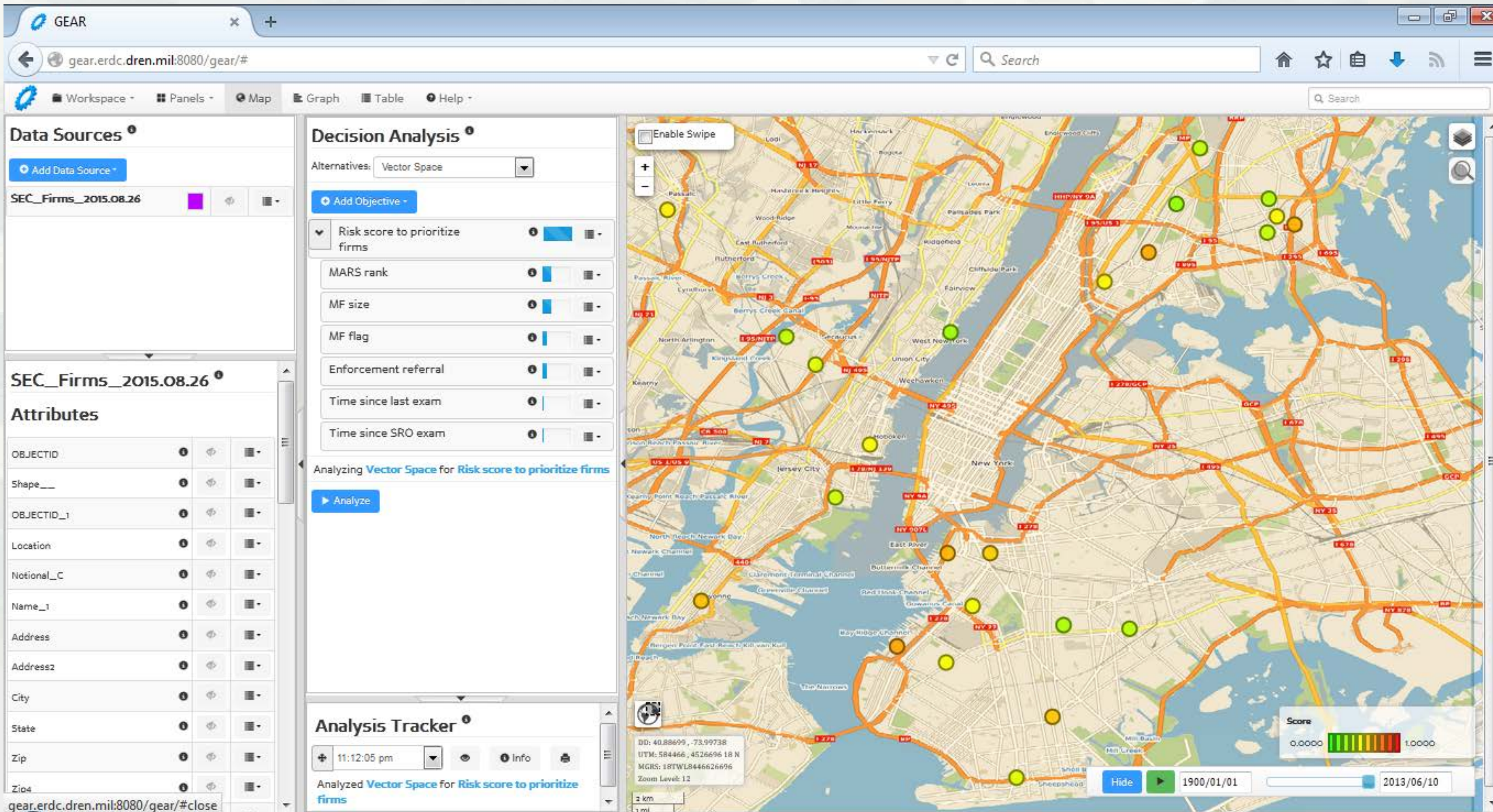
Bangladesh Demo Summary

Scenario: Ebola outbreak in Dhaka, Bangladesh
Goal: Prioritize local schools for temporary medical triage facilities
Assumptions: Ideal locations are central to vulnerable population and population centers, near public transportation, and far from other emergency services. Six criteria used to measure the four main objectives.



Financial Risk Demo Overview

Scenario: US regulatory agency wants to evaluate financial risks with a geographic component
Goal: Screen a large number of financial firms for risky behavior and visualize results.
Assumptions: Identify firms based on their size, whether they have been flagged as suspicions, time since their last regulatory review, etc. (case study is real, data shown here is notional).



Conclusions

- Decision Analytic approaches represent the practical application of analytical tools to support complex decisions, allocation problems and planning processes.
- Benefits include transparency, flexibility, repeatability between decision makers, and responsiveness to multiple planning scenarios.
- Applications are diverse but all require decision maker / stakeholder consideration of multiple criteria/alternatives.
- This can 1) help with integration of methods in tools, and 2) implement some ‘default’ decision models for cases.

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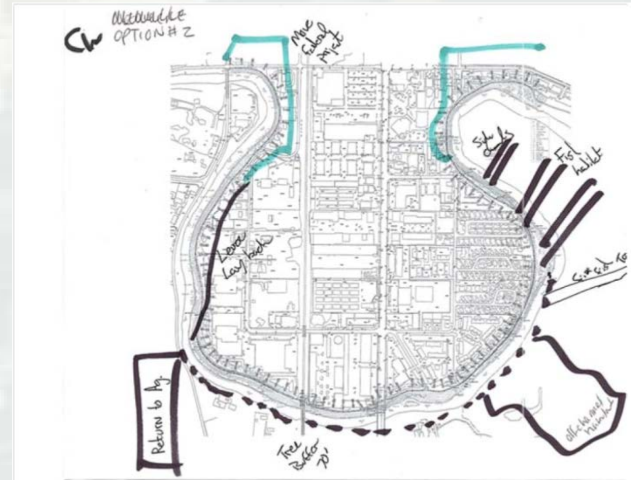
Backup Slides:
Additional Project Snapshots

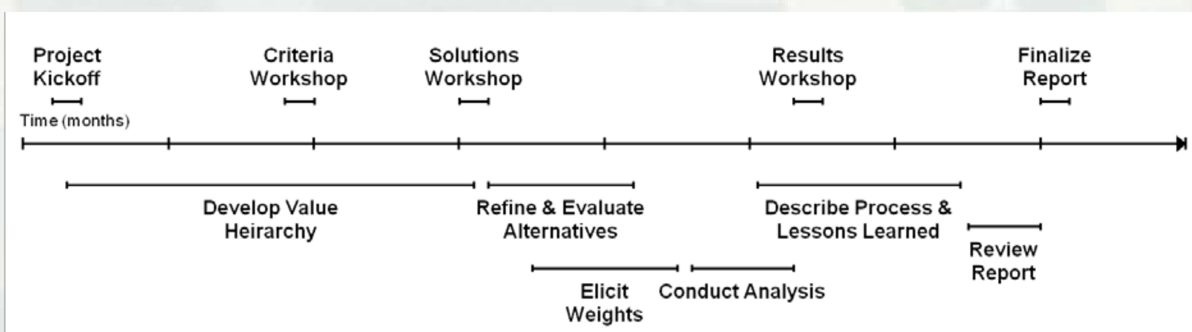
Horseshoe Bend Project

Diverse Stakeholders

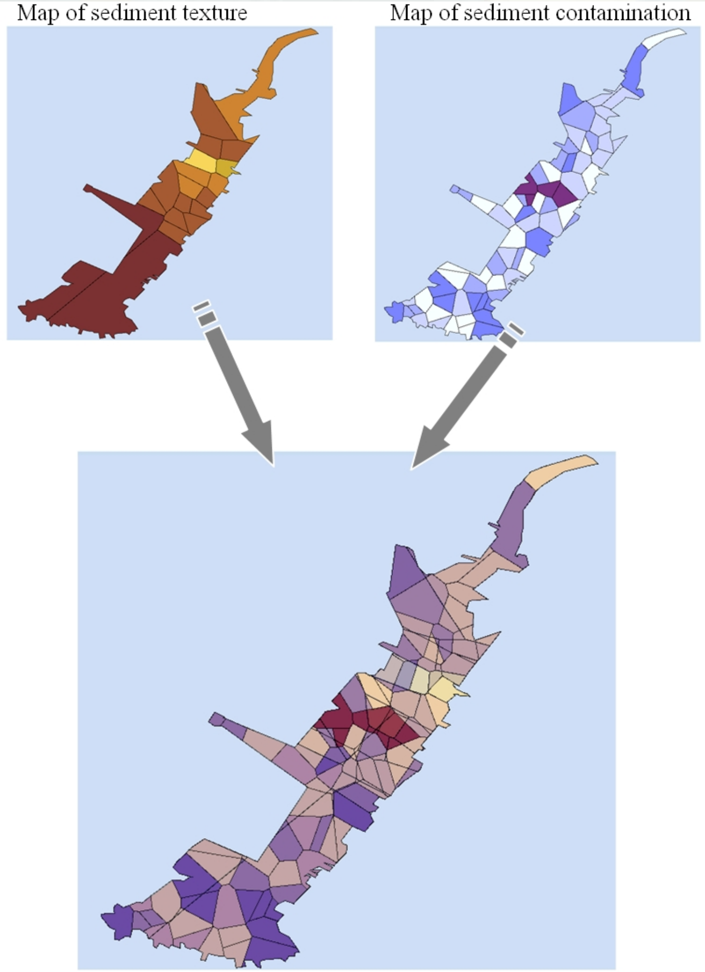
- Flood control
- Environmental
- Tribal interests
- Commercial
- Recreation



Criteria	Ranking (1 - 8)	Score (0 - 100)
Levee Safety / Reliability	1	100
Fish / Salmon Health	2	85
Cost	3	60
Implementability	4	55
Flood Risk Management	5	40
Community Resilience	5	40
Tribal and Public Use	7	22
Water Quality	8	5



NY/NJ Harbor – Multiple Types of Sediment Contamination

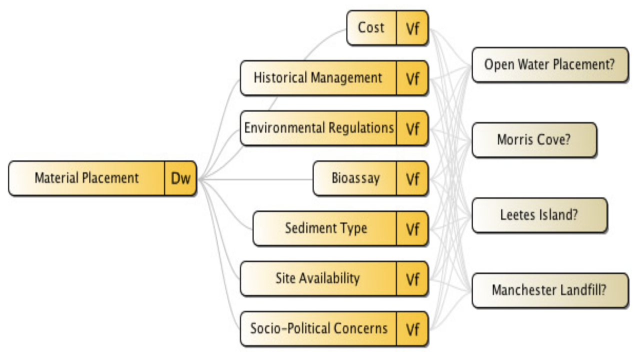


Combined map of sediment texture and contamination

New Haven Harbor

Weight of Evidence Assessment

The support given by various LOEs for site suitability must be interpreted in the context of known metadata about the data source, e.g., its relevance, quality, and resolution.



Morris Cove

Criteria	Relevance	Quality	Resolution	LOE Support
Cost	HIGH: *Budget constraints were required to be met*	HIGH: *Extensive holistic cost analysis*	MED: *3 significant figures used*	MED: *$10.8M= 125% increase*
Hist. Management	MED-LOW: *Historic use is not a required nor limiting factor but is informative*	N/A	N/A	MED: *Not previously used*
Environmental Effects	HIGH: *Federal regulations were required to be met for all project aspects*	MED: *Fairly vague descriptions of environmental surveys for total impact were taken*	N/A	HIGH: *Supporting Essential Fish Habitat Lower emissions*
Bioassay	HIGH: *Contaminants could destroy essential habitat*	HIGH: *3 different in vivo tests*	MED-LOW: *Sample size of 6*	MED: *Low levels of PCBs and DDTs detected*
Sediment Type	HIGH: *Incompatible sediment could destroy essential habitat*	MED: *Vibracore considered 2nd tier*	HIGH: *Sample size of 19*	HIGH: *Compatible*
Site Availability	HIGH: *Key requirement for placement*	MED: *Recent surveys conducted for site availability*	N/A	MED: *Will accept only 75% of total material*
Socio-Political	MED-HIGH: *Public unrest could make an alternative less feasible*	MED-LOW: *Speculation, no known specific polling*	N/A	MED: ▪ *No new infrastructure* ▪ *Longer project timeline*

Portfolio Approach for Cruise Time Allocation

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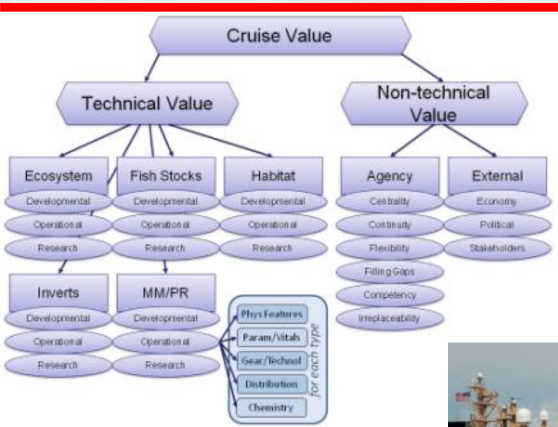

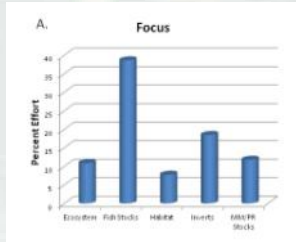

Key Participants

•**Sponsor:** NOAA NMFS

Purpose/Objectives

- The approach can ensure the portfolios of cruises selected meets the NOAA NMFS's goals for its science portfolio.
- Documenting the value of each cruise, whether completed or not completed, allows the agency to argue for increased resources.
- Portfolio decision model is designed to make transparent the current criteria being used in NMFS decisions NOT replace them.

Approach

- New methodology for selecting appropriate portfolios of cruises given the value they deliver, both technically and to the agency and stakeholders
- Technical and non-technical criteria were developed, and the FY13 white boat cruises were scored as a proof-of-concept
- Results presented to the Vessel Coordinators and Science Board
- Science board to determine the scope, complexity and data sources for forward-looking analyses

Results

•Initial proof-of-concept using FY13 White Boat Cruises

•Presented to Vessel Coordinators(May 2014)

•Presented to Science Advisory Board (June 2014)

•White paper for NOAA NMFS Science Board (June 2014)

Resilience Assessment: Jamaica Bay Case Study

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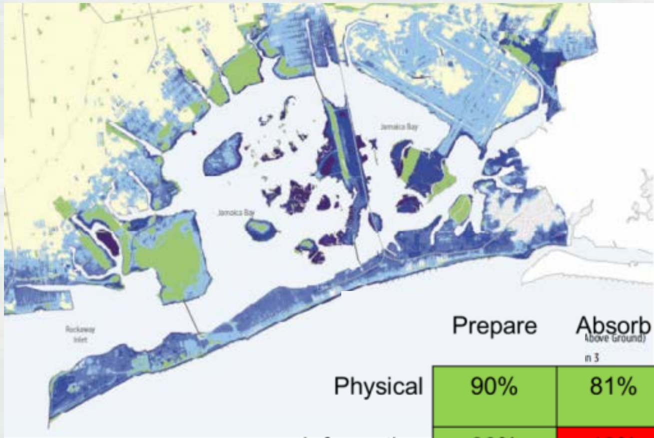

	Prepare	Absorb	Recover	Adapt
Physical	90%	81%	62%	10%
Information	80%	19%	23%	75%
Cognitive	68%	95%	22%	40%
Social	76%	88%	92%	34%

Key Participants

•**Sponsor:** CERB

Purpose/Objectives

- Existing risk management strategy is not sufficient to ensure coastal community safety in the face of climate change and uncertain future events.
- Assessments of coastal community resilience that incorporate the physical, social and information aspects of a community in both the preparation and the recovery from events help responsible agencies, such as USACE, to evaluate the efficacy of proposed projects and identify points of reduce impact without support in other community sectors.
- The goal of the project is to provide a quantitative assessment of resilience that can be incorporated into planning models

Approach

- Use a matrix approach to defining the assessment space for resilience: capacity across the physical-information-cognitive-social domains in the prepare-absorb-recover-adapt stages
- For Jamaica Bay case study, use narrative reports and community/stakeholder interviews to define critical functions of the system and identify relevant metrics for each capacity cell.
- MCDA methodologies can be used to aggregate data into a final score of resilience that provides a baseline to evaluate project proposals against.

Results

- Primary efforts by government agencies occur in the physical and information domain during the prepare stage and in the physical domain of the recovery stage, efforts dictated largely by funding availability and public visibility.
- Continued efforts to improve reliability and robustness of physical structures may result in diminishing returns in the absence of additional efforts to develop capacities in the cognitive (organizational decision structures) and social domains and in the adaptation phase.

•This assessment is not complete; the matrix shown is hypothetical.

Humanitarian Assistance Project Site Suitability

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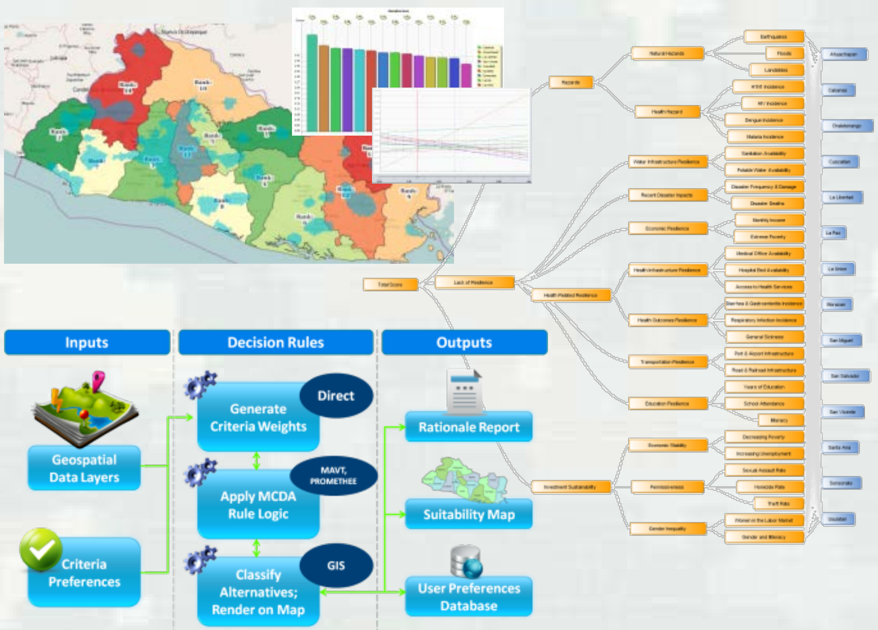

Key Participants

•**Sponsor:** ERDC TEC, Office of Naval Reseach

•**Gov't Contributors:** ERDC TEC & EL, AGC, Pacific Disaster Center

•**Gov't Proponents:** Ike Clark & Steve Carro (SOUTHCOM J45), Kevin Stanley (SOUTHCOM J7), LTC Travis Lindberg (USACE LNO to SOUTHCOM), Tiger Hession (PACOM J45)

Purpose/Objectives

- DOD Humanitarian Assistance and Disaster Response (HADR) managers often face the complex task of prioritizing limited funds for investment across broad regions of varying need.
- The *SHAPE* project presents a framework for HADR project evaluations & site suitability analysis based on spatial and other data via Multi-Criteria Decision Analysis (MCDA)
- Provides a transparent, flexible, repeatable, data-driven and justifiable, analytical approach for evaluating projects.

Approach

- Integrates data across competing objectives via value functions and importance weights.
- Evaluates HADR projects based on local hazard exposure, community resilience, investment sustainability, & agency mission specific criteria.
- Can optimize a portfolio of potential projects based on costs & operational/programmatic constraints.
- Will be integrated into the Pacific Disaster Center's DisasterAWARE web platform, which is already used heavily by SOUTHCOM and others.

Results

- Case study demonstrating approach with risk and vulnerability site screening data from El Salvador.
  - Presented to SOUTHCOM and other COCOM HADR managers.
- In person meeting with SOUTCOM HADR community, where ideas were well received.
- Approach presented at Humanitarian Technology: Science, Systems and Global Impact 2014 conference & printed in conf proceedings.
- Additional journal article in preparation.
- Integration with PDC DisasterAWARE tool planned for FY15.

Value of Information Approach to Prioritize Nanomaterial Research

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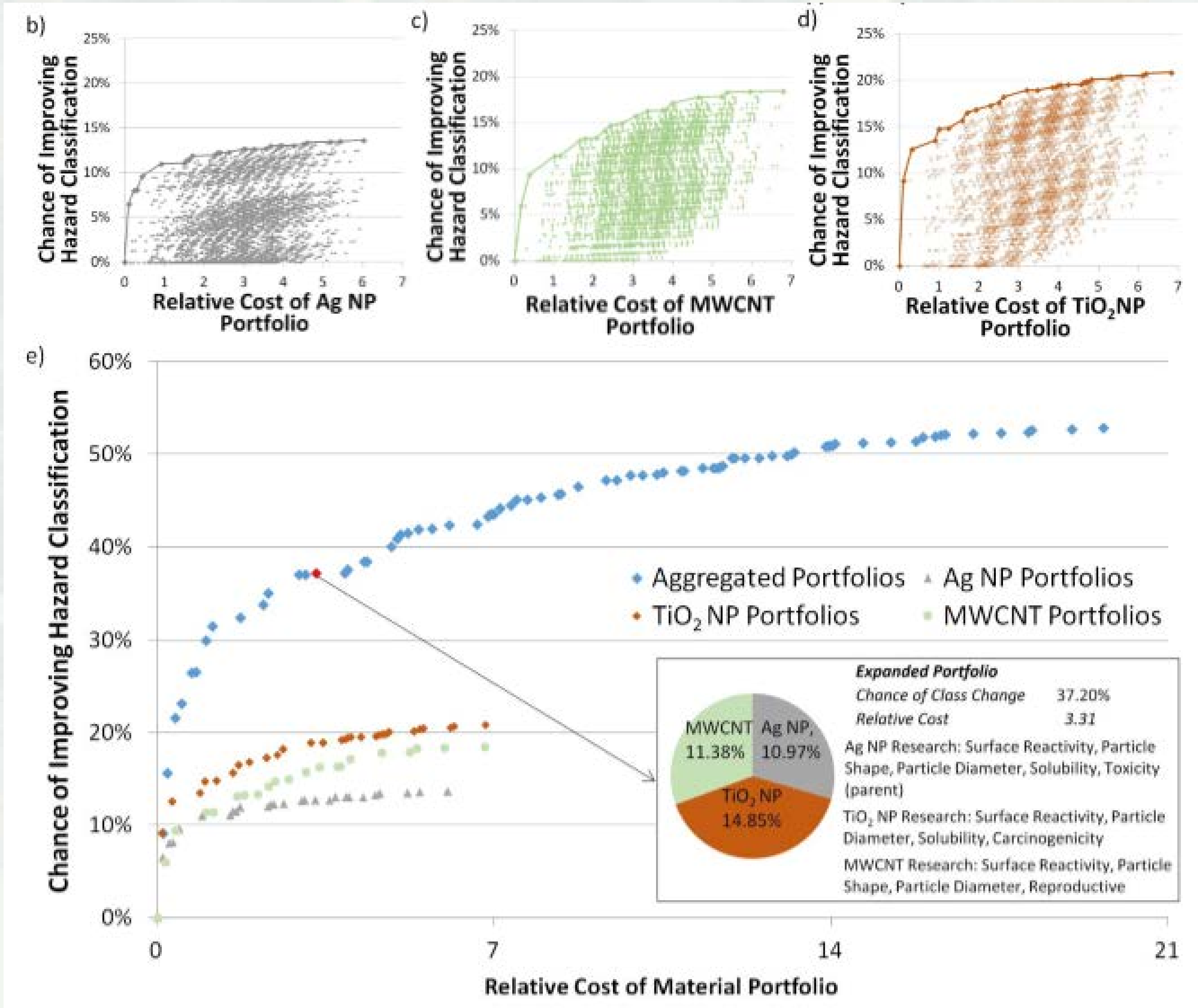

Combined Life-Cycle Assessment and MCDA for Treated Lumber Selection

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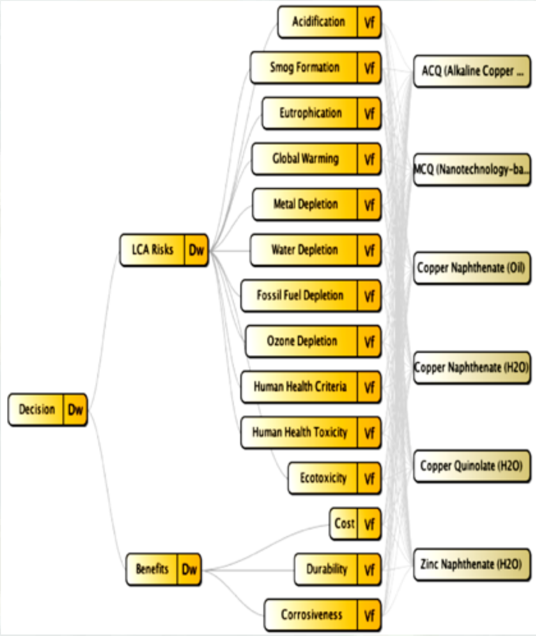

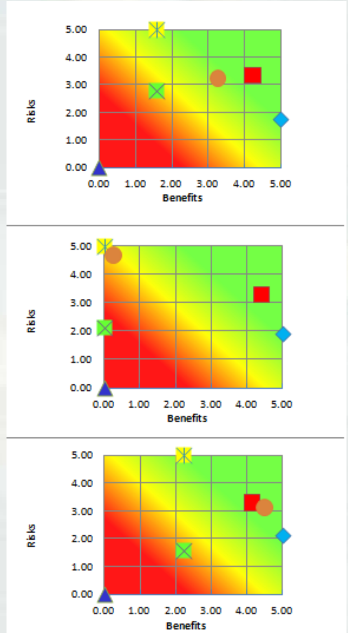

Key Participants

- **Sponsor (s): USACE**
- **Gov't Contributors:**

Purpose/Objectives

- The DOD ships munitions around the world on treated wood pallets. Treatment should ensure that materials are stable in harsh environments and do not degrade munitions, but are also cost effective.
- The DOD currently uses zinc naphthenate (ZN) as a lumber treatment due to its durability but ZN is no longer a registered product with EPA and the DOD must find a suitable replacement.
- The goal of the LCA is to identify environmental and health impacts associated the production of each lumber treatment
- The goal of the MCDA is to weigh the environmental impacts with the performance results and costs to identify preferred lumber alternatives.

Approach

- Develop inventories of life-cycle impacts associated with production of six treated lumber products.
- Compare the environmental and human health impacts (global warming, acidification, ecotoxicity, etc.) between the six alternatives using LCA analysis and tools.
- Use decision analysis methods to assign relative values to the LCA risks as well as the benefits (low cost, durability, and corrosiveness) of each treatment alternative.
- Use preferences for each of neutral, environmental and military decision makers to identify the preferred treatment alternative for each type of stakeholder

Results

- All three stakeholders determined CQ to be the least favorable alterative.
- Military stakeholder determined ZN to be the most favorable alternative; environmental stakeholder found MCQ (Micronized Copper Quaternary) to be preferred. ZN is no longer an acceptable option but the decision matrix shows that MCQ is a nearly equally favorable alternative for military and could be an effective substitute.
- While the MCQ was ranked second for the military stakeholder, the converse was not true for the environmental ranking, where ACQ (Alkaline Copper Quaternary) was the second most favorable alternative.
- In summary, a specific ranking of alternative in terms of preference across all risk and benefit criteria can be determined for any stakeholder. In addition, treatment alternatives ranked highly across all stakeholder can be used to find a globally acceptable alternative.