# Multi Criteria Decision Analysis for Wicked Risk Problems

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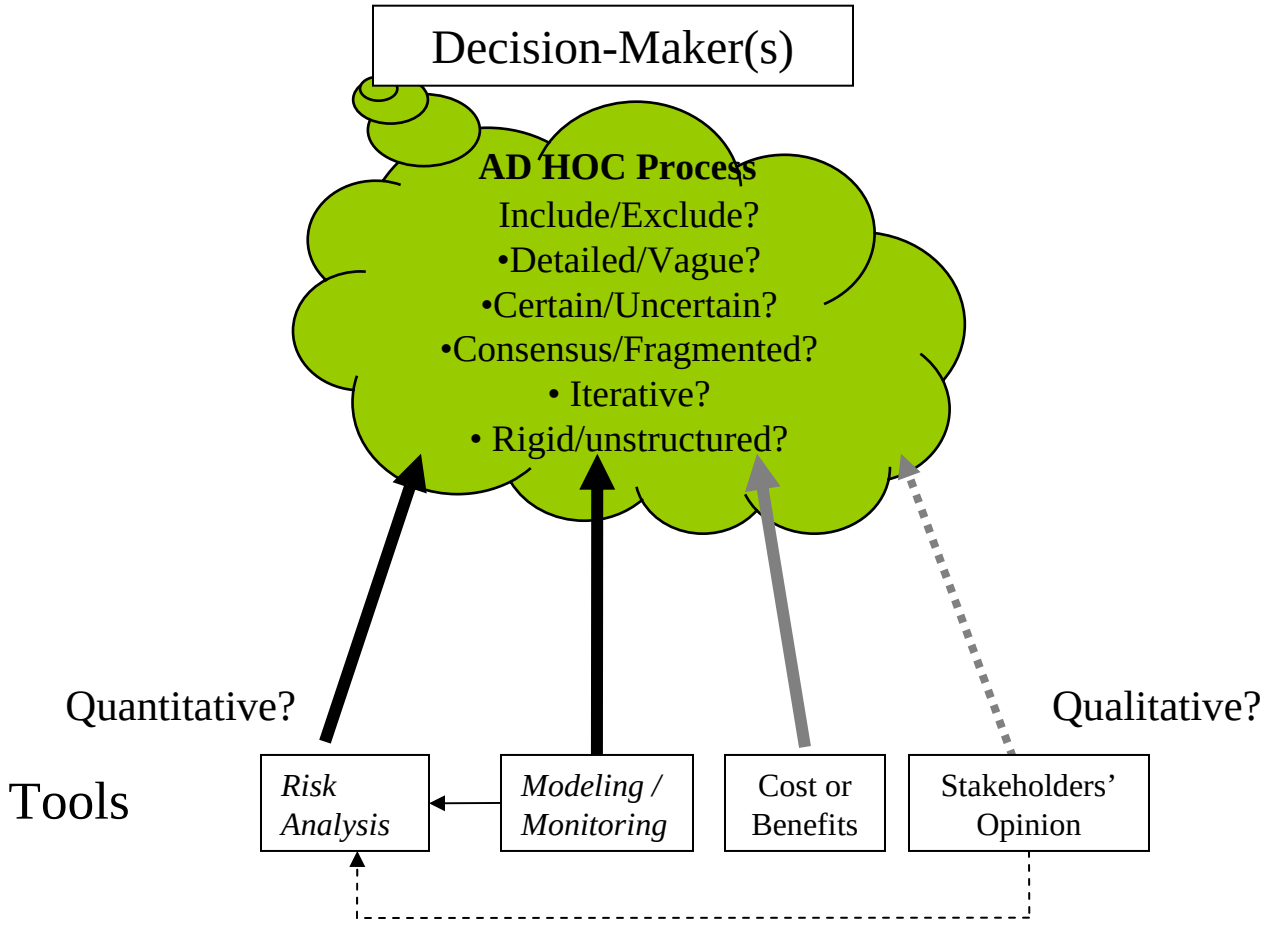
January 2009
USEPA ERAF & TSERAWG Joint Meeting

# Overview

- Environmental assessment and decisions are growing more complex
- Decision analysis methodologies & tools
  - Provide a means of integrating/comparing performance measures and decision criteria with stakeholder and decision-maker values
    - Multi-Criteria Decision Analysis
    - Example: NY/NJ Harbor
  - Provide a means of communicating and comparing trade-offs for planning and further understanding

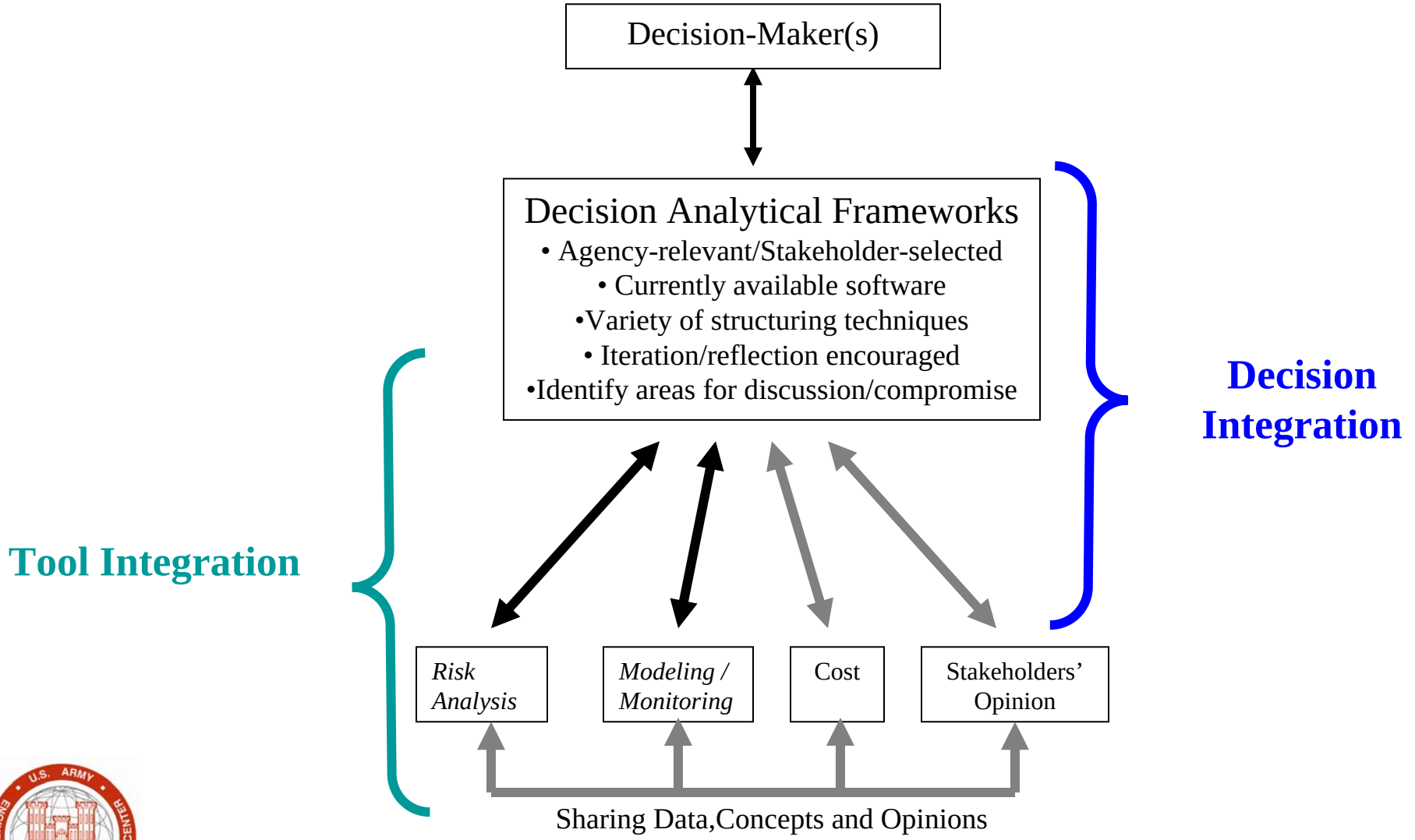
# Challenges in Current Decision-Making Processes



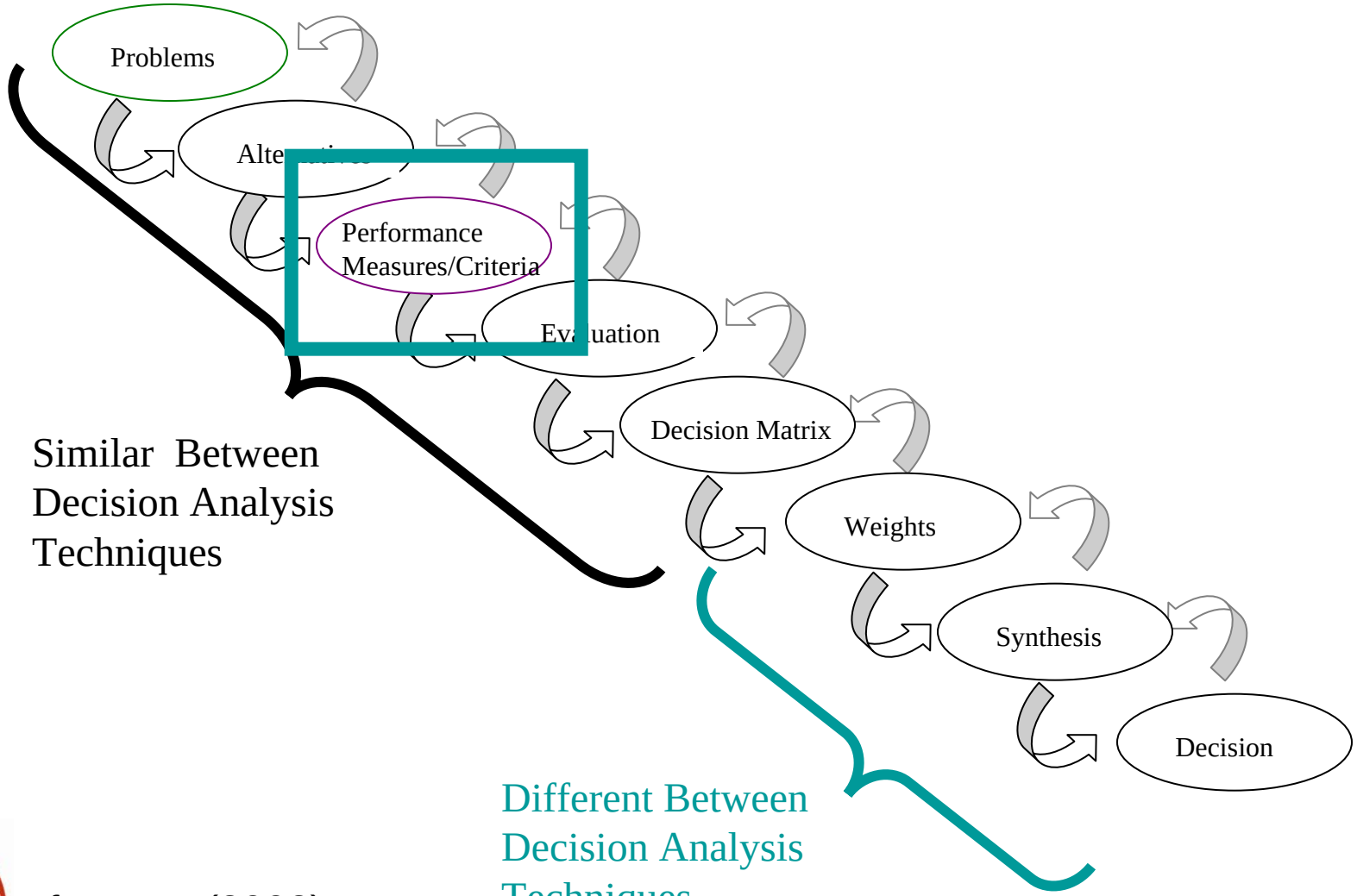
# Challenges to Complex Decision-making

- “Humans are quite bad at making complex, unaided decisions” (Slovic et al., 1977).
- Individuals respond to complex challenges by using intuition and/or personal experience to find the easiest solution.
- At best, groups can do about as well as a well-informed individual if the group has some natural systems thinkers within it.
- Groups can devolve into entrenched positions resistant to compromise
- Do honesty and common sense suffice?

# Evolving Decision-Making Processes



# Multi-Criteria Decision Analysis

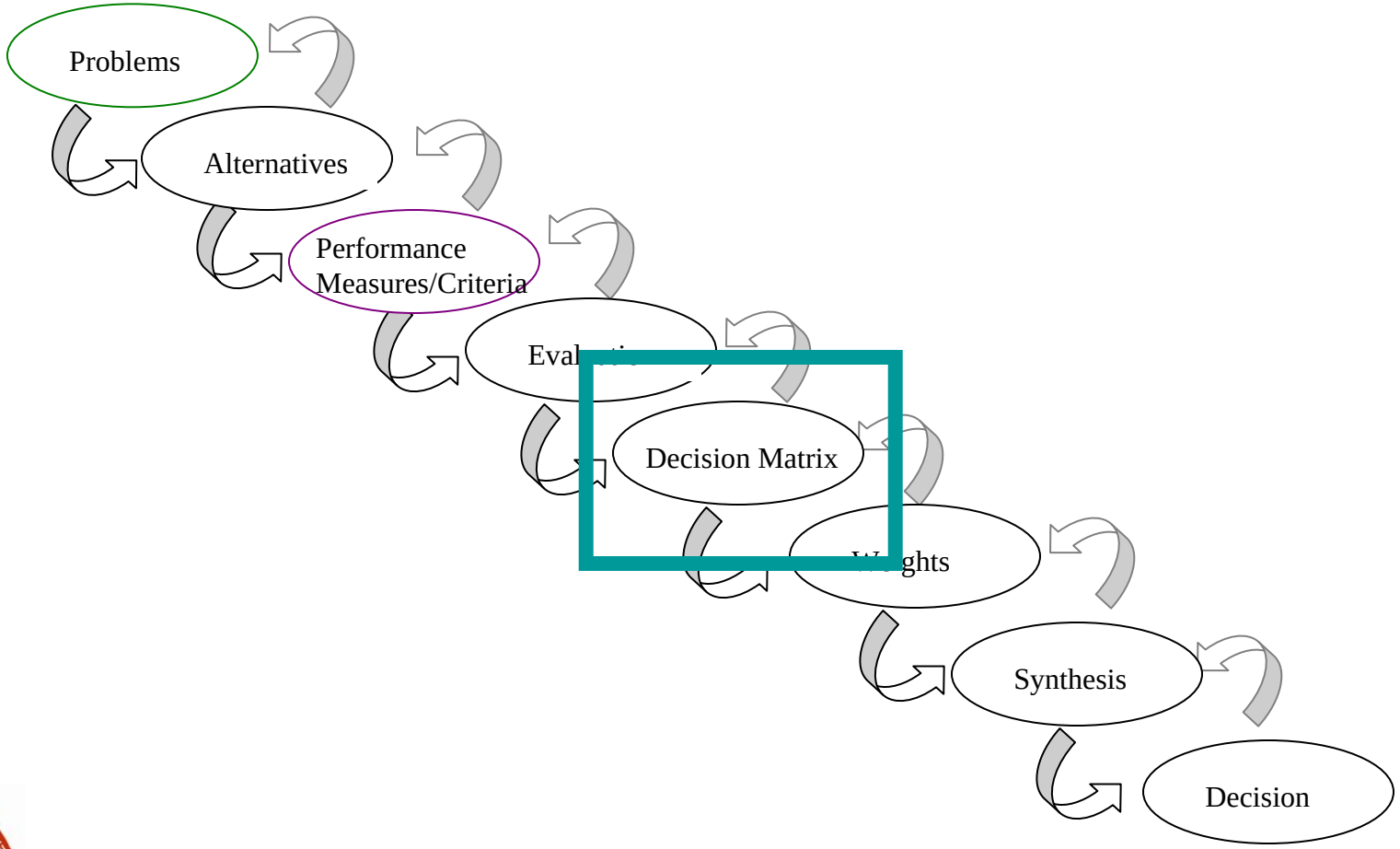



After Yoe (2002)

# Requirements for Decision Criteria

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

# Multi-Criteria Decision Analysis



# Comparing Apples & Oranges (or Fish, Ducks and Money)

| Plan | Cost | Fish | Ducks |
|---|---|---|---|
| A | 100 | 10 | 5 |
| B | 100 | 5 | 10 |
| C | 150 | 10 | 10 |
| D | 150 | 10 | 15 |

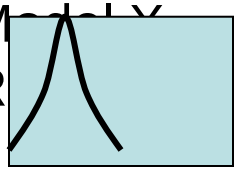
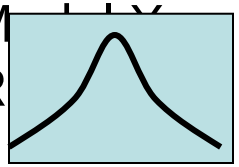
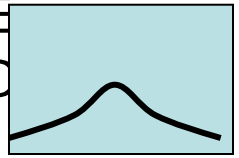
After Yoe (2002)

# Example Decision Matrix

How to combine these criteria?

How to compare these alternatives?

How to combine these results?

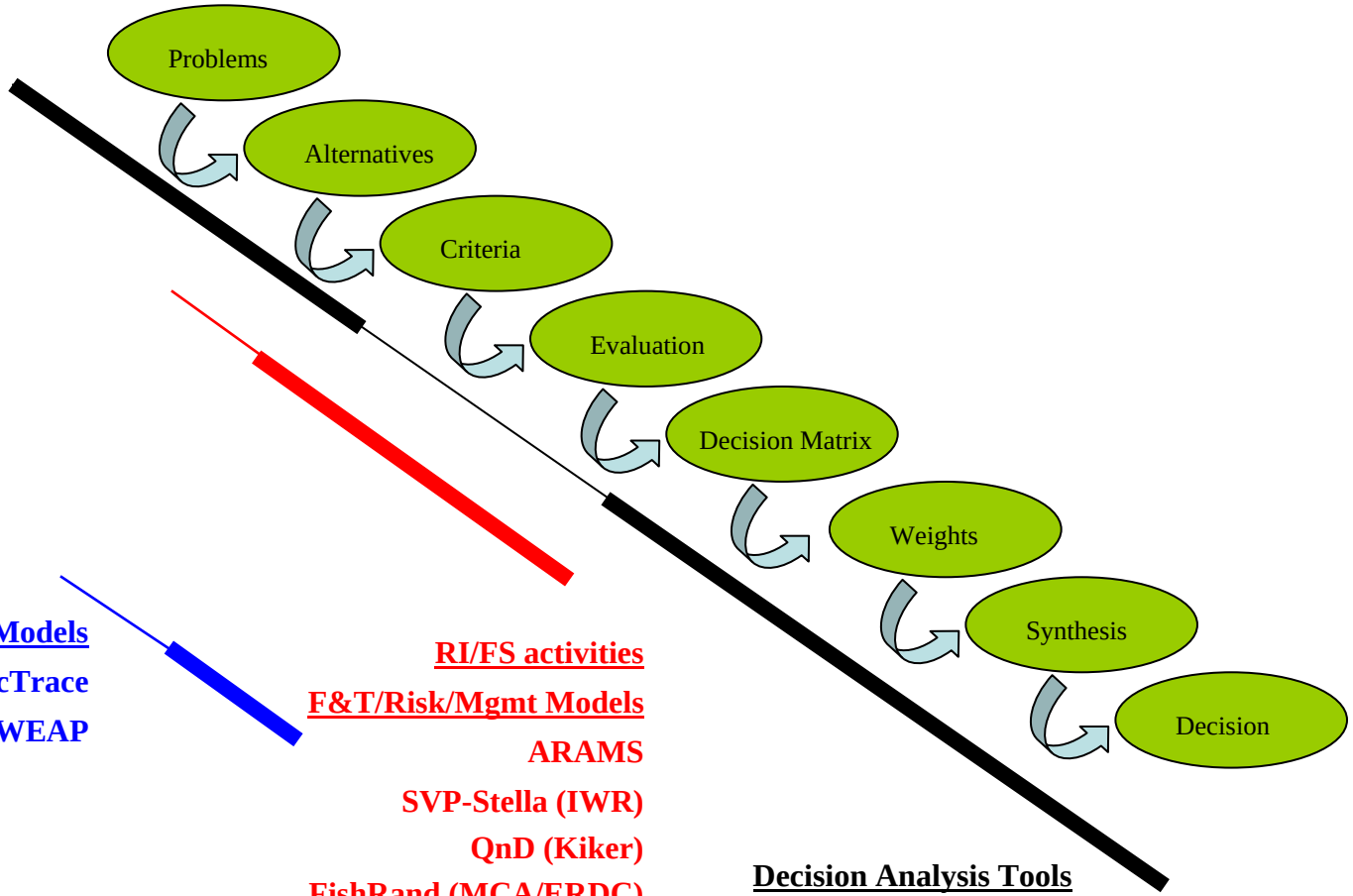
| | Crit. 1 | Crit. 2 | Crit. 3 | Crit. 4 |
|---|---|---|---|---|
| Alt. | Result | Preference | Cost | monetary benefit |
| Alt. | Model X Result | Stakeholder Preference | Economic Cost | Non-monetary benefit |
| Alt. | R  | Stakeholder Preference | Economic Cost | Non-monetary benefit |
| Alt. | R  | Stakeholder Preference | C  | Non-monetary benefit |

# Trade-Offs: Giving up one thing to get another

- **Explicit** trade-offs
  - Risk reduction vs cost
  - More of one means less of the other
- **Implicit** trade-offs
  - “Habitat cohesion” vs “enhancing aquatic ecosystems”
  - Terms of trade are not following physical laws
- **Value** trade-offs
  - 100 acres of woodland vs 100 acres of inaccessible wetland
  - Choice may depend on what each person “values”

- *Good trade-off analysis makes the “implicit” things into “explicit” things*

# Tools for Planning/Decision Analysis




**Risk Models**

**TrophicTrace**

**WEAP**

**RI/FS activities**

**F&T/Risk/Mgmt Models**

**ARAMS**

**SVP-Stella (IWR)**

**QnD (Kiker)**

**FishRand (MCA/ERDC)**

**RiskTrace (Linkov)**

**SEEM (MCA/CHPPM)**

**Decision Analysis Tools**

**Criterium DecisionPlus**

**ExpertChoice**

**DecisionLab**

# Example: NY/NJ Harbor

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## Issues

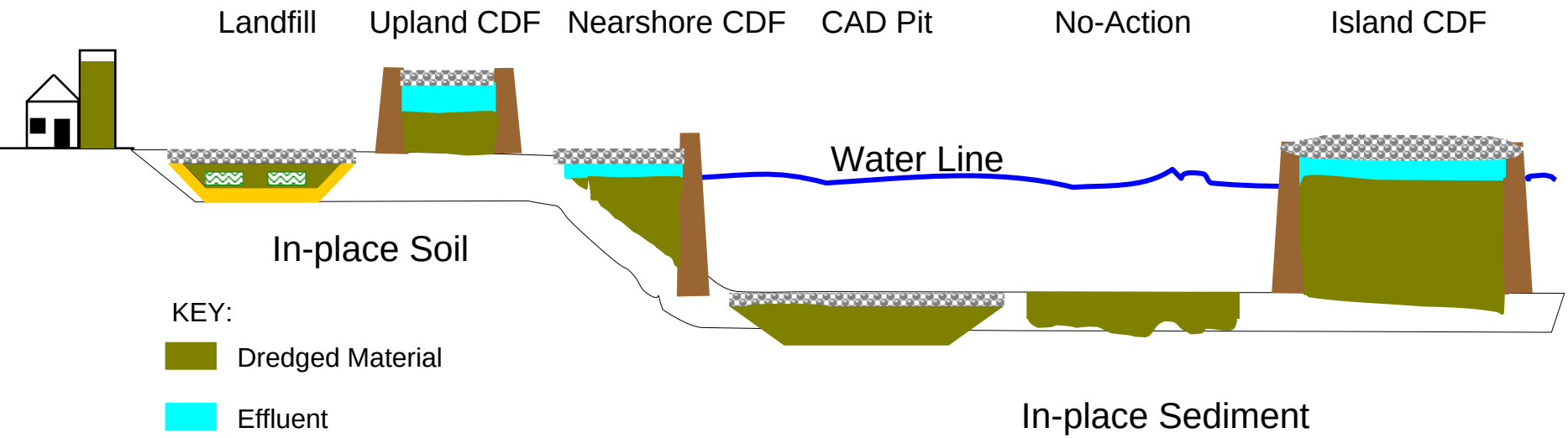
- Harbor among most polluted in U.S.
- >$10^6$ $yd^3$ fail regional criteria for ocean disposal
- Existing disposal site closed
- Proposed deepening

# Example: Decision Methodology

- Proof of Concept Study
- Objectives
  - Integrate comparative risk assessment results with cost and stakeholder decision criteria
  - Use decision criteria/performance measures from published data and proposed costs
  - Test decision tools, methodology and results
- Set contaminated sediment management options
- Set decision criteria/performance measures
- Stakeholder Values / Expert Surveys
  - Selected NY/NJ harbor stakeholders (USACE, EPA, Port Authorities, State, NGOs)

# Illustration of Disposal Alternatives

Manufactured Soil
Cement Lock

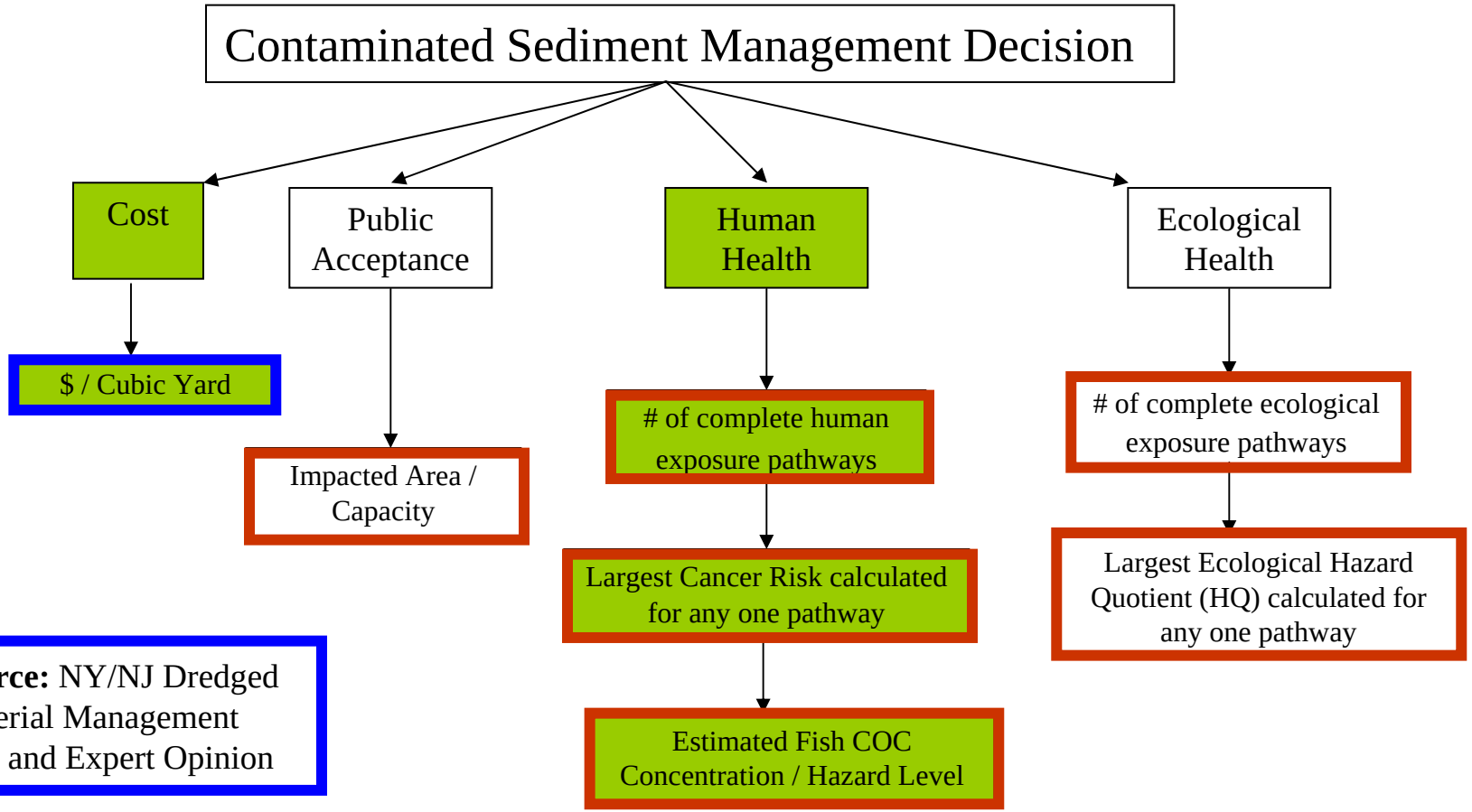



KEY:

- Dredged Material
- Effluent
- Manufactured Liner
- Dike Wall
- Cap
- Standard Landfill Waste

**Kane Driscoll, S.B., W.T. Wickwire, J.J. Cura, D.J. Vorhees, C.L. Butler, D.W. Moore, T.S. Bridges. 2002. A comparative screening-level ecological and human health risk assessment for dredged material management alternatives in New York/New Jersey Harbor. *International Journal of Human and Ecological Risk Assessment* 8: 603-626.**

# Decision Criteria: NY/NJ Harbor



# Criteria Levels for Each DM Alternative

| | *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** |

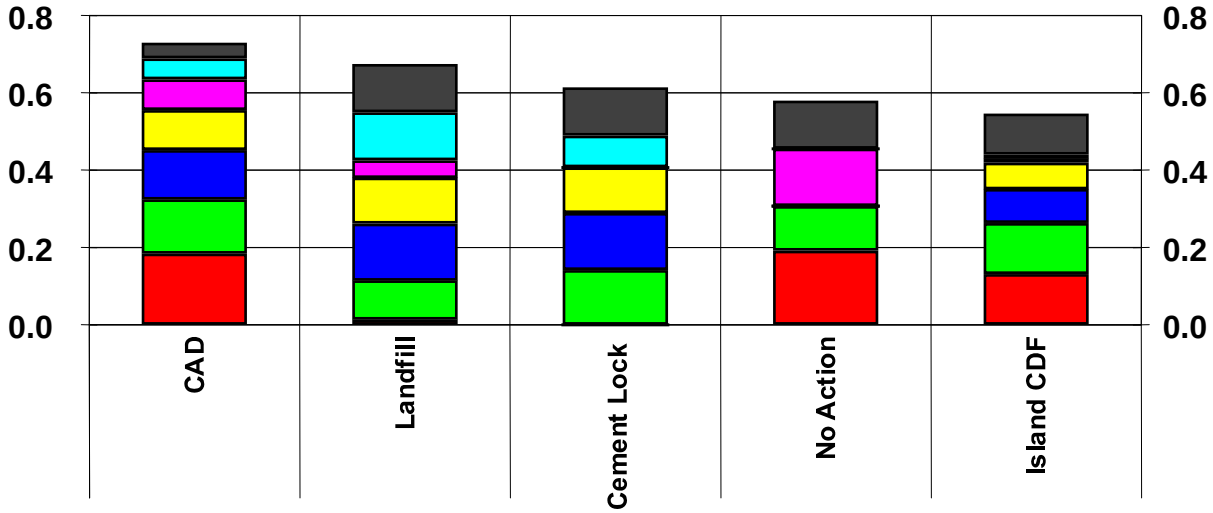
**Red Text: Most Acceptable Value**

**Green Text: Least Acceptable Value**

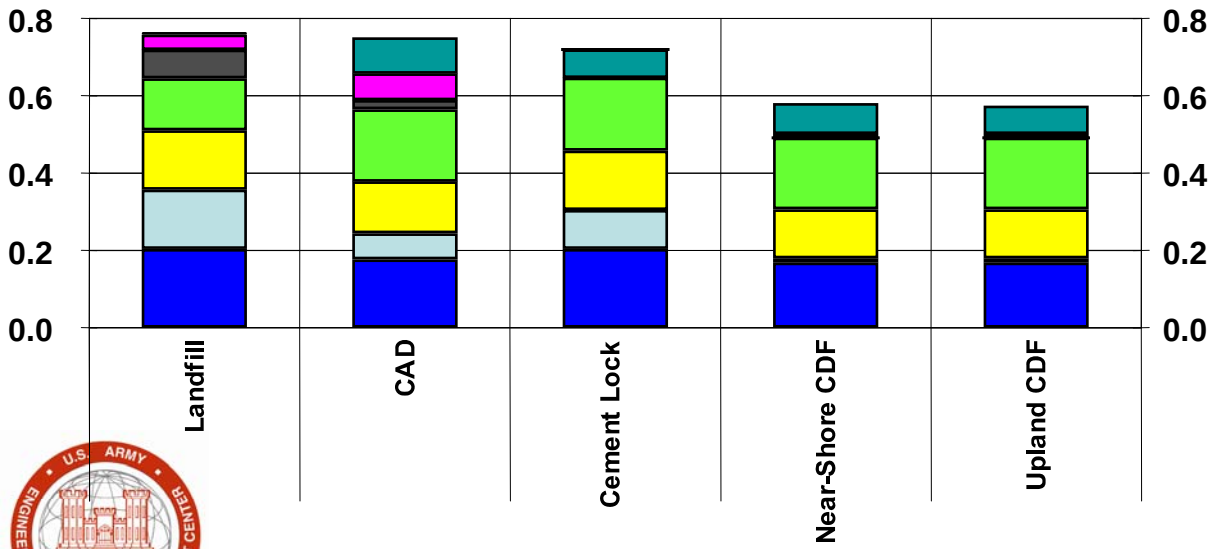
# USACE/EPA Survey Results: Criteria Weights (%)

| | 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 |

# Criteria Contributions to Decision Score




## USACE weighting

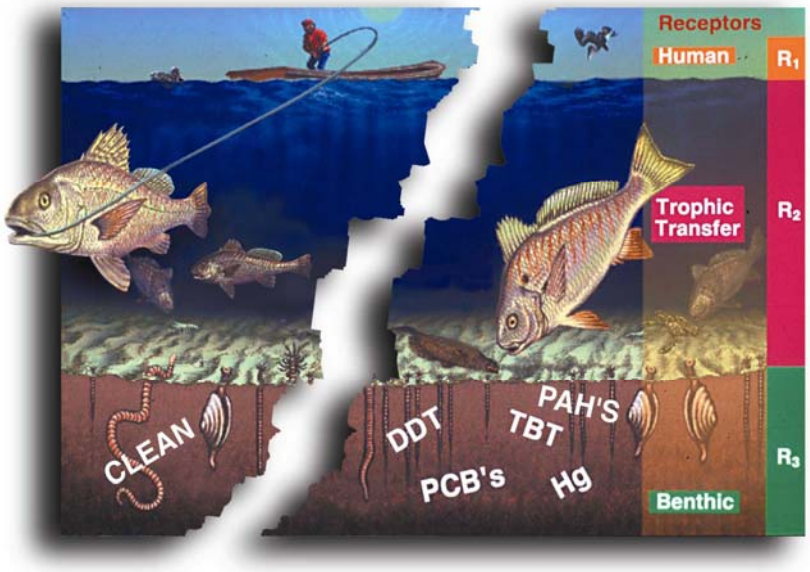



## EPA weighting

- Cost
- Maximum Cancer Probability (Non-Barge Worker)
- Ecological Hazard Quotient
- Est. COC Conc in Fish / Risk-based Conc
- Complete Human Health Exposure Pathways
- Complete Ecological Exposure Pathways
- Ratio of Impacted Area to Facility Capacity

# Risk Assessment: Meeting the Challenge

- Robust methods for analyzing risks and uncertainties
- Sensible methods for comparing risks and uncertainties among alternatives




- Structured and defensible approaches for organizing the decision making process

# Functions and Outputs of MCDA

- Identify, assess, communicate the risks to human health and the environment
- Account for the major uncertainties that could affect the performance of alternatives in the future
- Identify data gaps that could influence decisions
- Provide the basis for ranking the performance of alternatives based on risk metrics and values
- Establish confidence levels for risk decisions and recommendations