Remedy Optimization and Adaptive Management

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Our *Systems*

- Navigation system:
  - locks, dams, channels
- Reservoir system:
  - structures and operating procedures
- Flood risk reduction system:
  - Structural, nonstructural, ecosystem features
- The components of a sediment remedy and the encompassing watershed and its uses

We need help to resolve our decision problem

- The complexity of the system
  - Intuition is an unreliable guide
- Sediment clean-up projects are “wicked problems” (Rittel and Webber, 1973)
  - no definitive formulation of the problem
  - no right or wrong solutions, only better or worse solutions
  - a broad diversity of values and opinions that are germane to defining solutions
  - no ultimate test of a solution to the problem

How to Manage the Risks

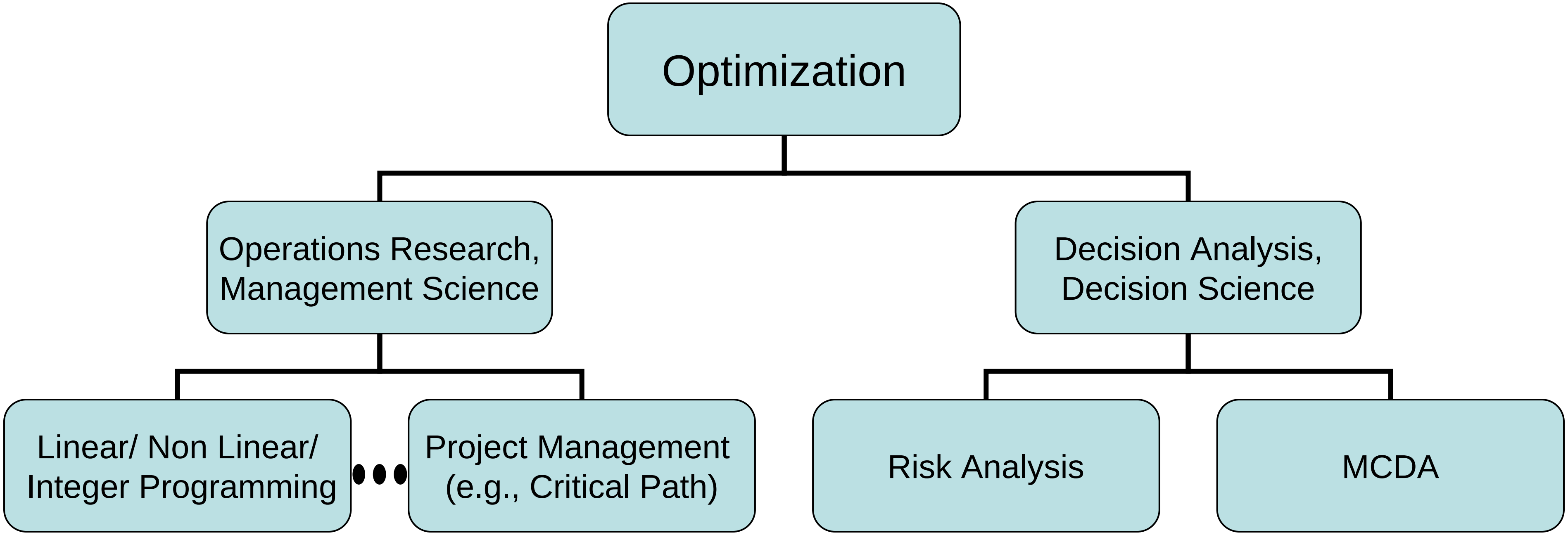
- Navigation vs. Cleanup
  - Do the sediments have to go?
- *In situ* alternatives
  - Monitored Natural Recovery (MNR)
  - Capping
  - Treatment
- *Ex situ* alternatives
  - Dredging
    - Containment
    - Treatment
- What combination of technologies is optimal?
  - Satisfy your objectives hierarchy

What are the objectives and decision criteria?

- 9 NCP criteria
  - Threshold Criteria
    - Overall protection of HH and E
    - Compliance with ARARs
  - Balancing Criteria
    - Long-term effectiveness/permanence
    - Reduction of TMV thru treatment
    - Short-term effectiveness
    - Implementability
    - Cost
  - Modifying Criteria
    - State (or support agency) acceptance
    - Community acceptance
- Other/Imbedded Criteria
  - Consistency with current uses of the waterbody
    - Recreation, navigation
  - Consistency with objectives for the waterbody
    - Restoration
  - Compatibility with other ongoing remediation or restoration activities
  - Compatibility with other activities in the watershed
  - Etc.

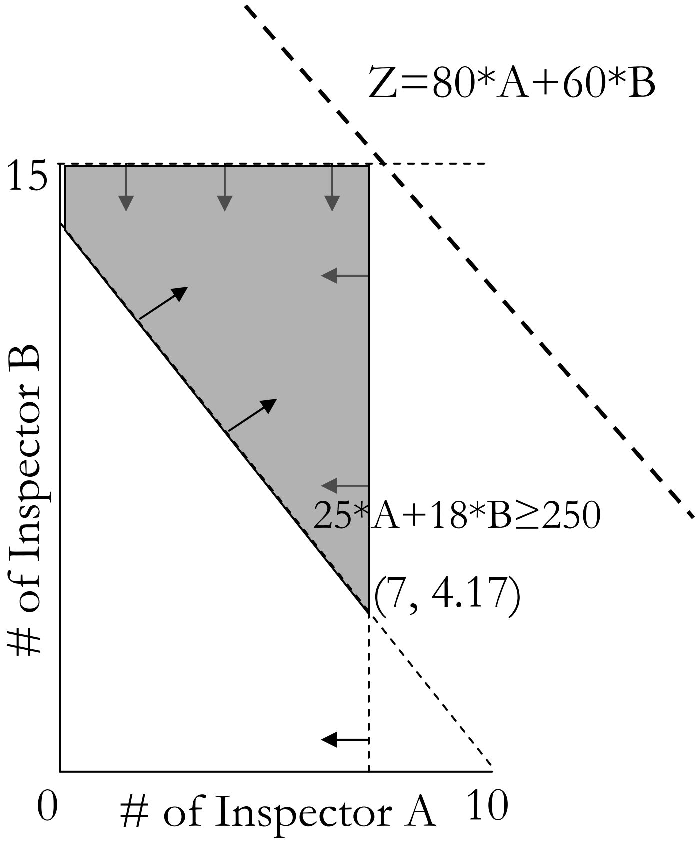
Optimization

- History: Operations research arose during WW II to support logistics and training schedules. Later applications within industry
- OR aims to improve the quality of decisions about the management of limited resources
  - How to allocate limited resources efficiently
  - Applicable to capital investments, quality of life/environment, etc.



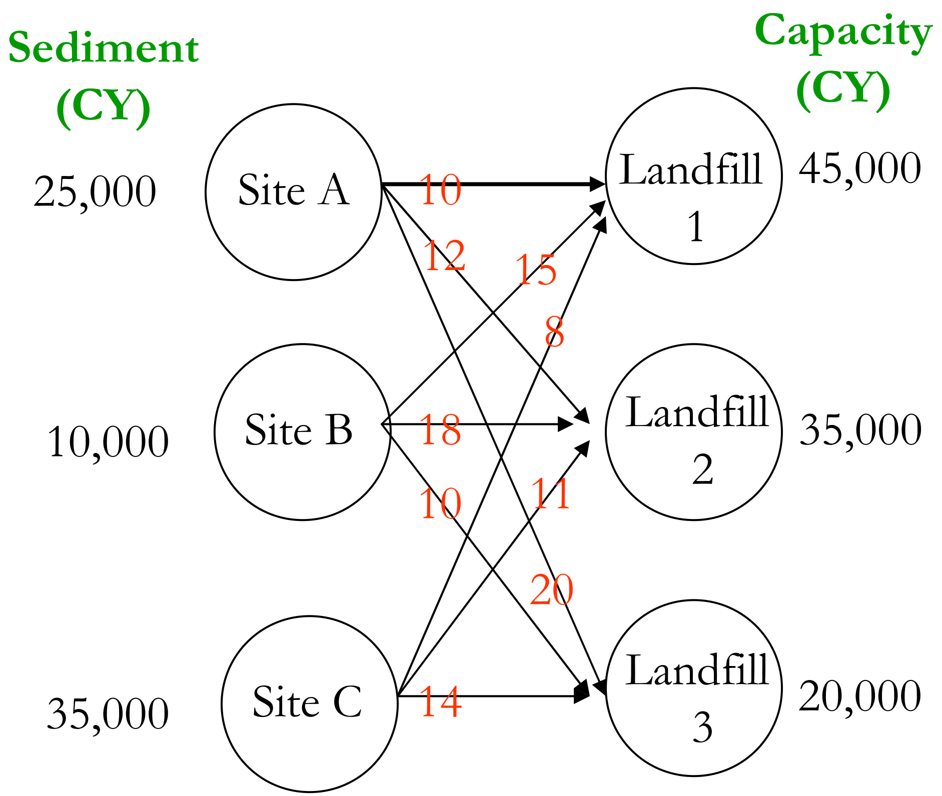
Simple Optimization Problem

- Inspect at least 250 points per day
- Two grades of inspectors, A and B
- 7 grade A and 15 grade B inspectors are available
- Inspector A can check 25 points and B can check 18 points per day
- Wage of Grade A is $80 and $60 for Grade B per day
- What is optimal assignment of inspectors?



Transporting Dredged Material to a Landfill

- You want to determine how much sediment to go from each dredging site to each landfill in order to minimize the total cost
  - Cost can include not only $, but also other non-monetary impacts
- Can consider multi-period planning



OR Success Stories

- FAA Ground-Delay Program
  - To reduce congestion and improve flow of air traffic into airports
    - Determine which aircraft/ how long to delay departures
    - Between 1998 and 2000, 90,000 hours of schedule delays were avoided at a cost savings of more than $150 million
- NYC
  - To improve the deployment of street cleaner, garbage trucks, and inspectors
    - Productivity increased 17%
- GM
  - To identify the optimal way to ship 300 types of components to 30 assembly plants.
    - Cut cost by 26%, saving $2.9 million a year

Multi-Objective Optimization

- Problem: Allocating remedial approaches across a spatially diverse site
  - Site divided into three areas
  - 3 remedial technologies available
  - What is the optimal allocation?
- Objectives:
  - Minimize Cost
  - Minimize incidental harm/risks
  - Minimize time to achieve acceptable risk reduction
- Constraint
  - Each area can use only one of the 3 options
  - Only remedial option 1 or 2 are applicable to Area 1
  - Only remedial option 2 or 3 are applicable to Area 3
  - The total suspended concentration from two adjacent areas must be less than 8

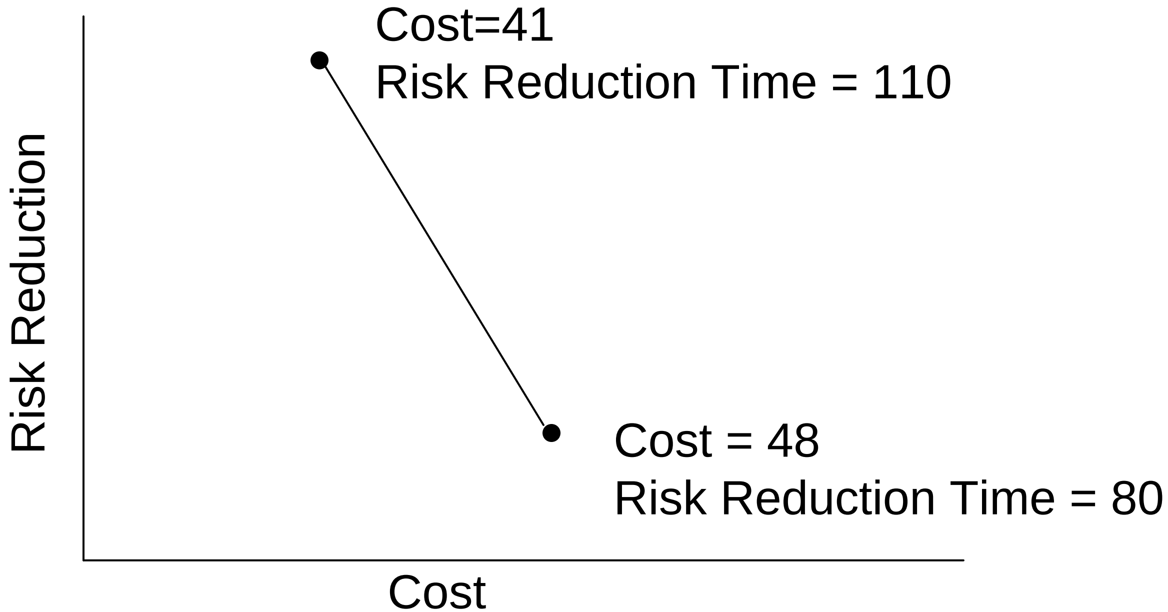
Characteristics

Characteristic	Area 1			Area 2			Area 3		
	Option 1	**Option 2**	**Option 3**	**Option 1**	**Option 2**	**Option 3**	**Option 1**	**Option 2**	**Option 3**
Cost per cubic yard	10	13	14	11	15	17	13	14	18
Risk reduction time (mos.)	60	45	30	45	30	20	50	30	15
Incidental harm/risk	13	10	14	9	7	12	14	8	17
Suspended conc.	4	2	3	7	3	2	6	2	2

Results

Optimal Decision & Performance \ Objective		When minimize		
		Cost	**Risk reduction days**	**Environmental impact**
Optimal technique	Area 1	1	2	2
	Area 2	3	3	2
	Area 3	2	3	2
Performance	Cost	**41**	48	42
	Risk Reduction Time	110	**80**	105
	Incidental Harm/Risk	33	39	**25**

Trade-offs



- Optimal solution depends on the relative importance of each objective
  - E.g., Two extreme points are (W_{cost}, W_{risk})=(1,0) or (W_{cost},W_{risk})=(0,1)
  - With multiple objectives, can use Z= W_i*f(i)+ W_j*f_j(j)+…+ W_t*f(t) where f(i) is a function of various objectives

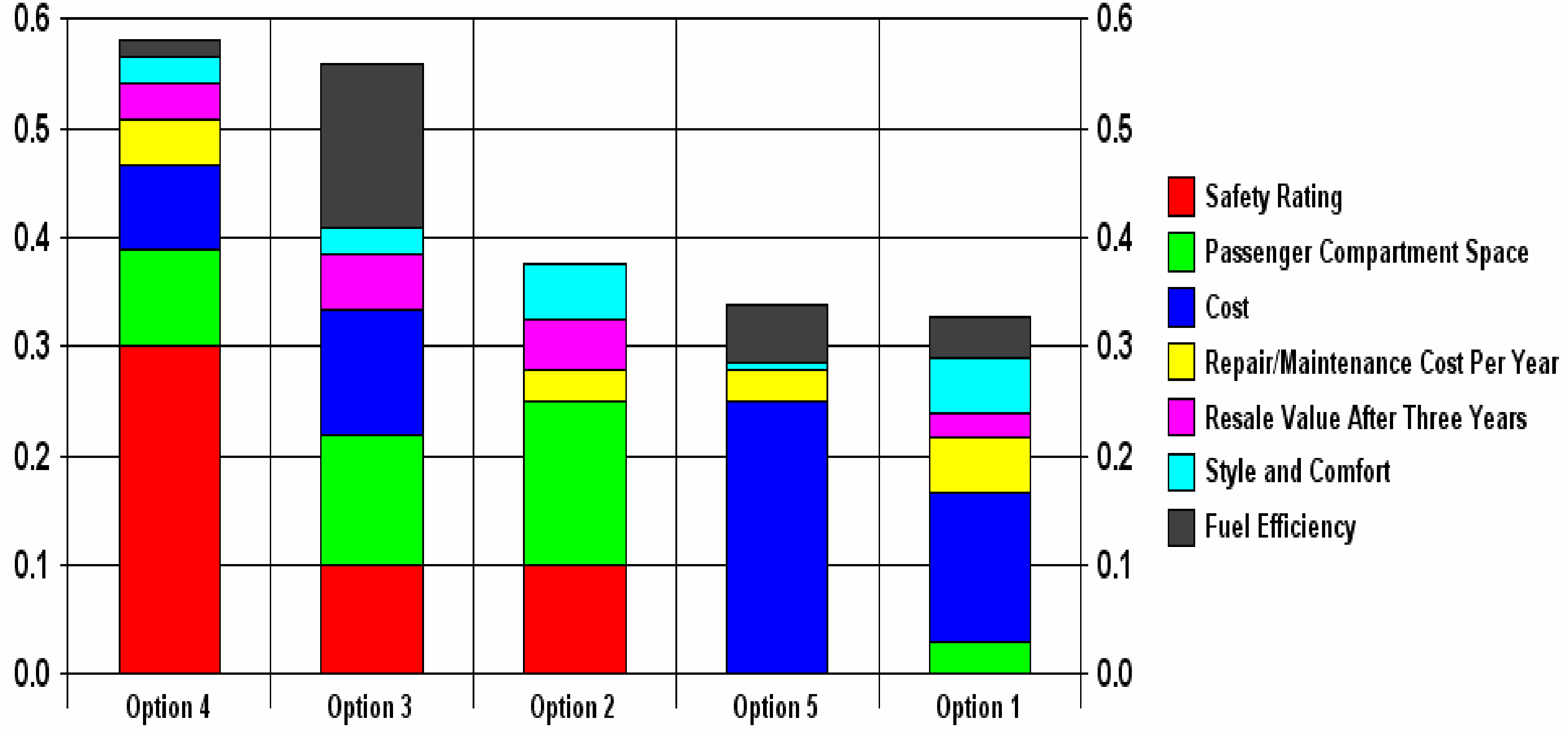
Multi-Criteria Decision Analysis

- An approach for structuring and analyzing decision problems
- Emphasis given to:
  - Defining the problem
  - Establishing explicit objectives
  - Defining metrics for evaluating alternative solutions/plans
  - Incorporating human values and risk attitudes
    - Through weighting and utility functions
  - Ranking plans based on quantitative scores derived from metrics
    - Using multi-attribute utility theory

Data Matrix

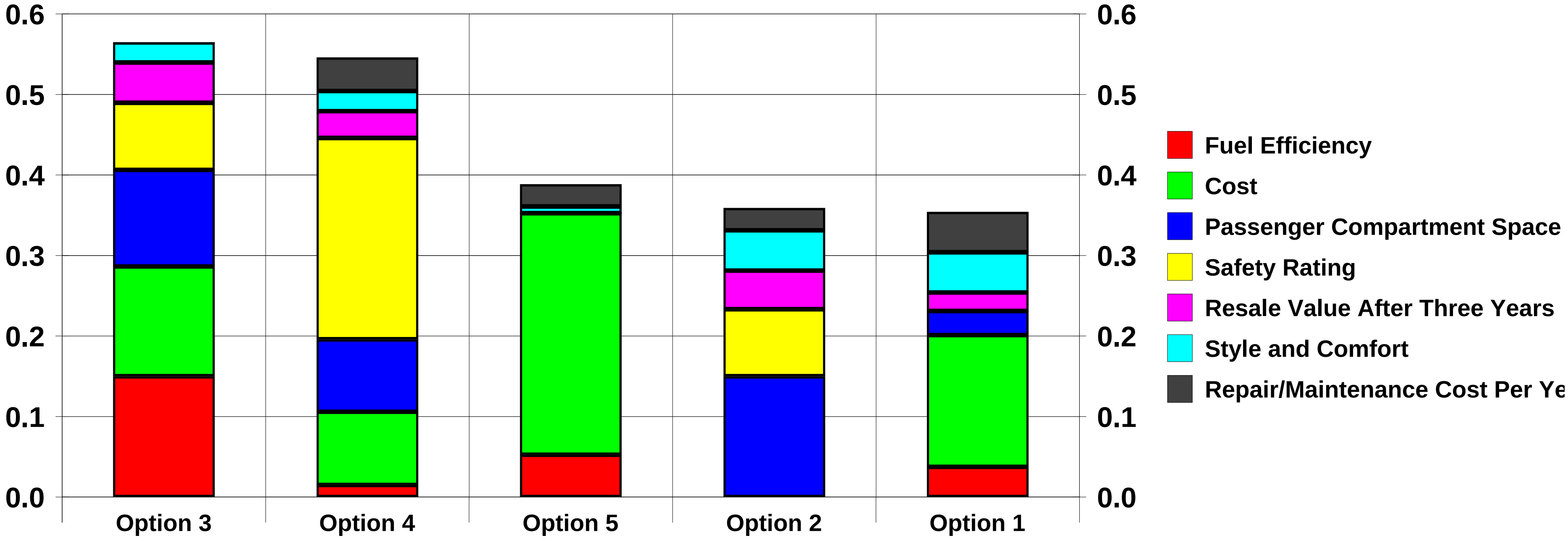
Metric (Weight)	Units	Cars				
		Option 1	Option 2	Option 3	Option 4	Option 5
Cost (25)	Dollars	27,000	45,000	30,000	35,000	12,000
Resale Value After Three Years (5)	% of Original Value	44	56	57	49	33
Repair/Maintenance Cost Per Year (5)	Dollars	100	500	1,000	250	500
Fuel Efficiency (15)	MPG	30	25	45	27	32
Passenger Compartment Space (15)	ft^3	150	170	165	160	145
Style and Comfort (5)	Qualitative	Finest	Finest	Average	Average	Poor
Safety Rating (30)	NHTSA Safety Rating	2	3	3	5	2

Ranking and Contributions by Metric



Ranking Sensitivity to Weight Allocation

Cost: 25 to 30   Safety: 30 to 25



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

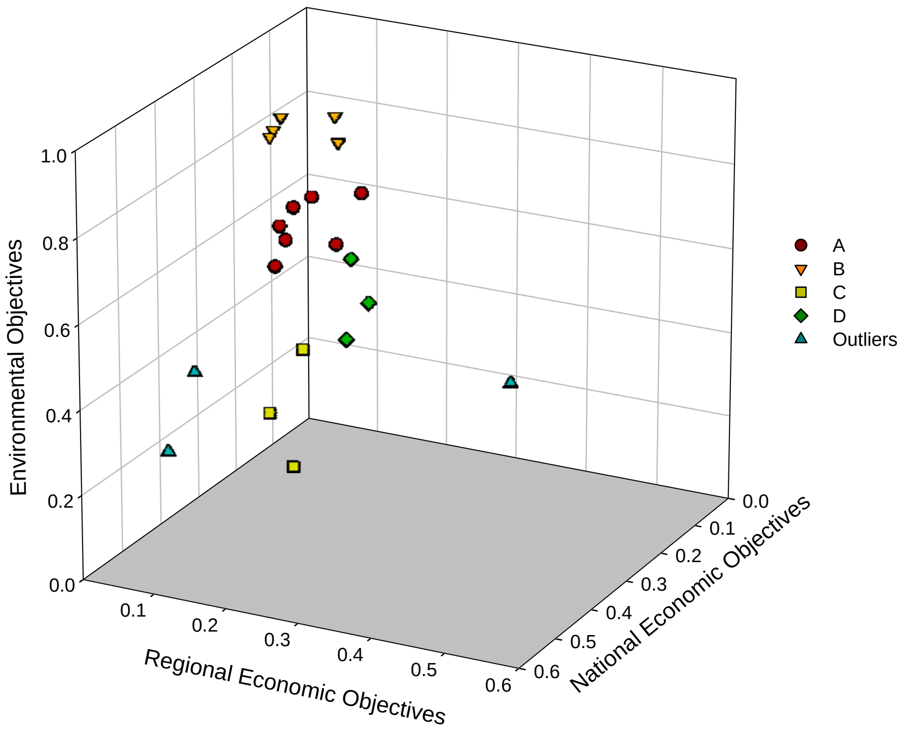
Risk Metrics

- 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

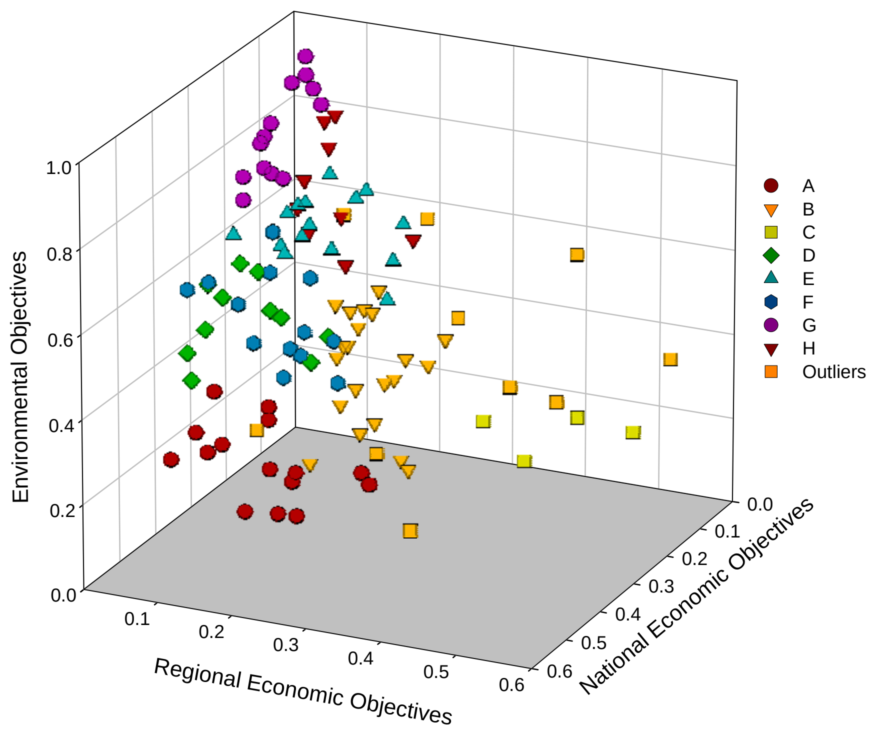
LaCPR Weightings Results

Weight allocation for gov't agencies (a) and all stakeholders (b)

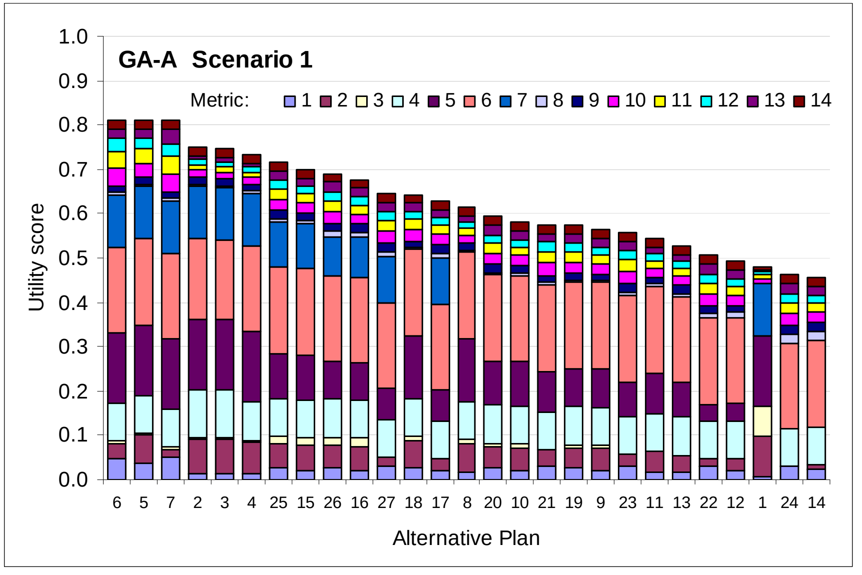
(a)

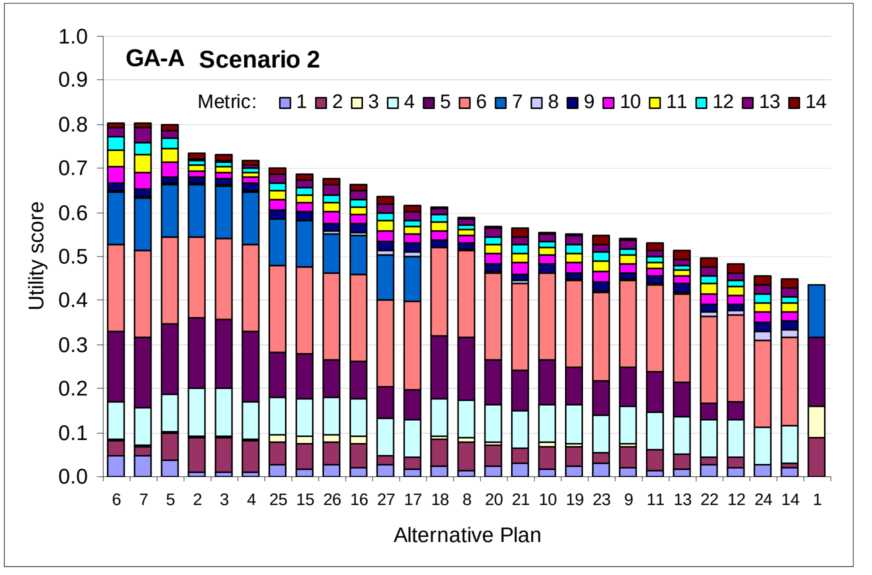


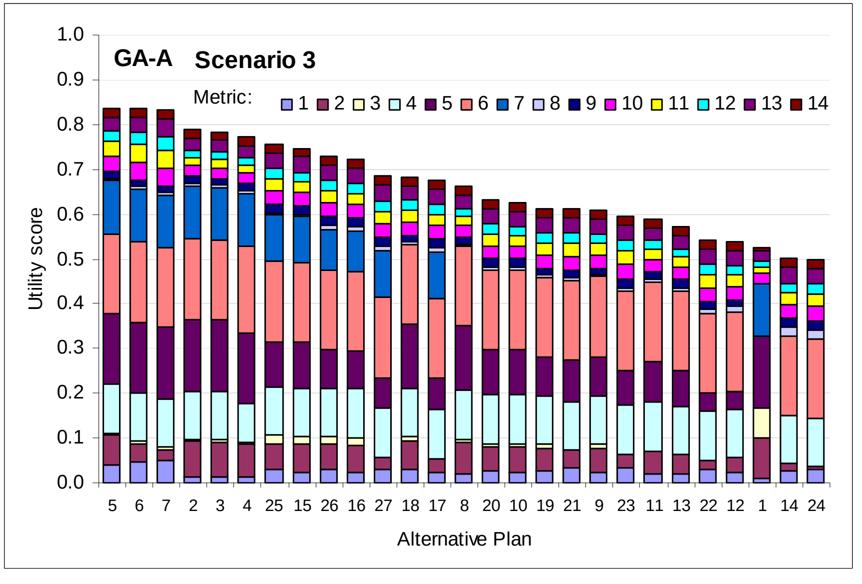
(b)

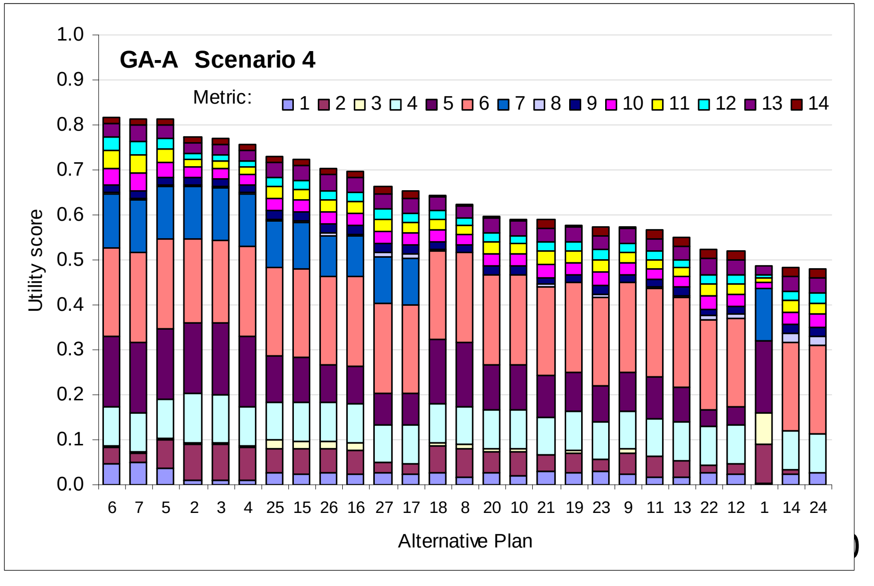


Example Plan Rankings

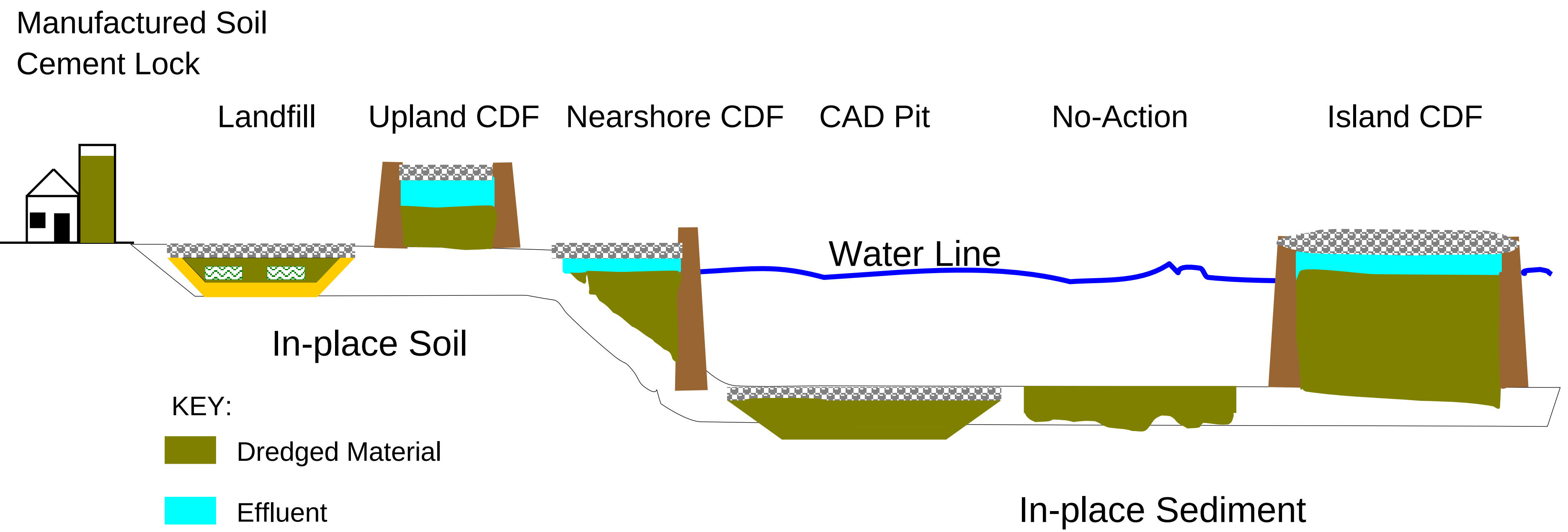








A Sediment Example



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.

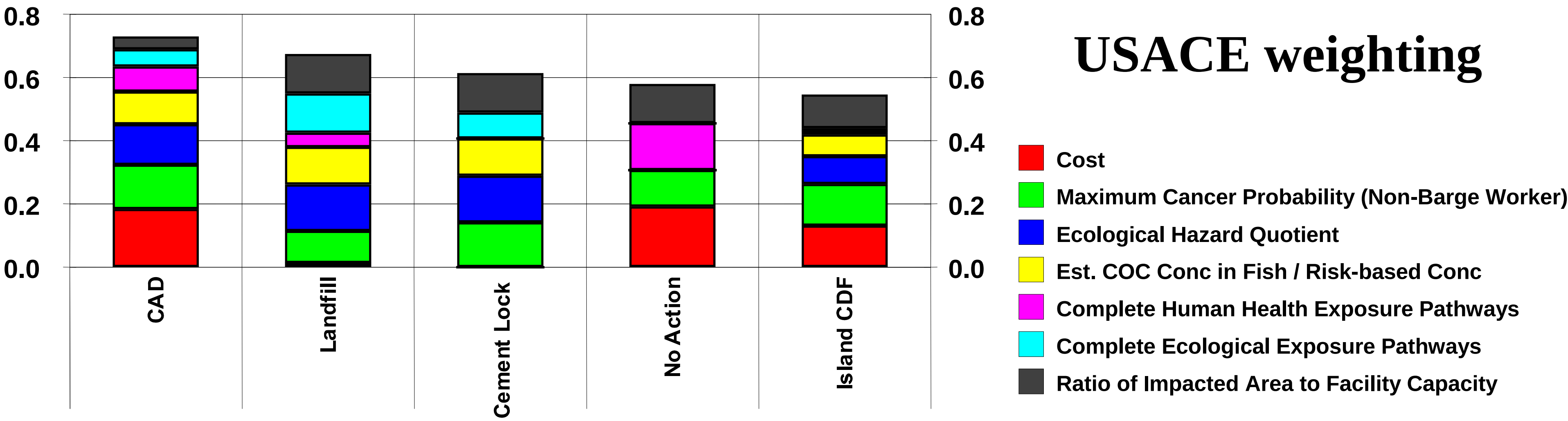
Criteria Levels for Each NY DM Alternative

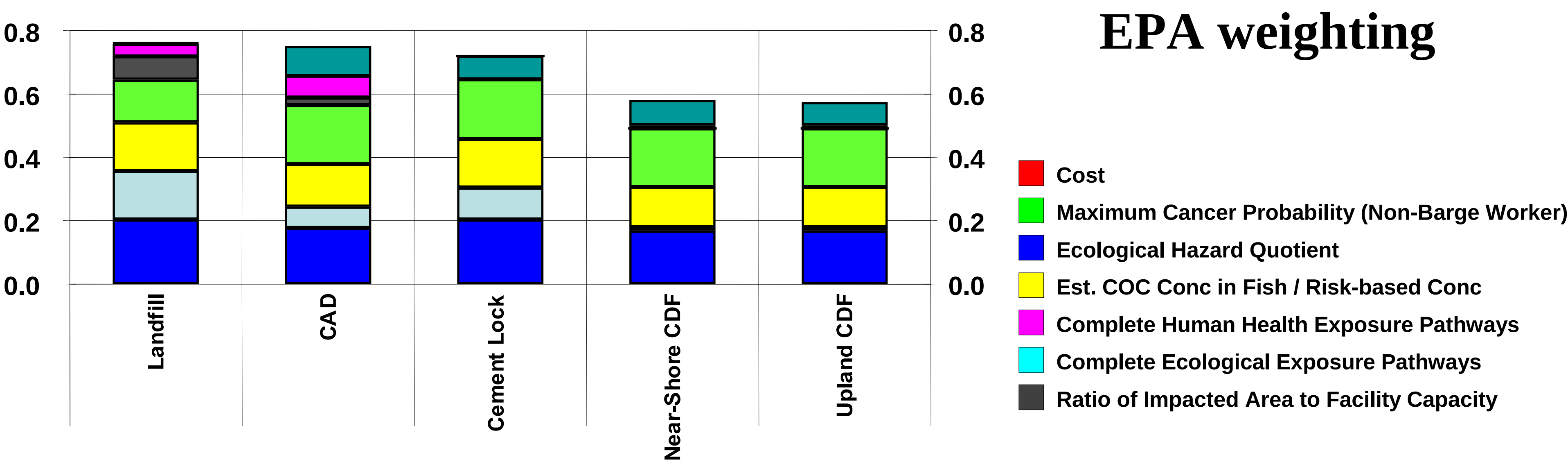
	Cost	Public Acceptability	Ecological Risk		Human Health Risk		
DM Alternatives	($/CY)	Impacted Area/Capacity (acres / MCY)	Ecological Exposure Pathways	Magnitude of Ecological HQ	Human Exposure Pathways	Magnitude of Maximum Cancer Risk	Estimated Fish COC / Risk Level
CAD	5-29	4400	23	680	18	2.8 E -5	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

Blue Text: Most Acceptable Value

Red Text: Least Acceptable Value

Criteria Contributions to Decision Score

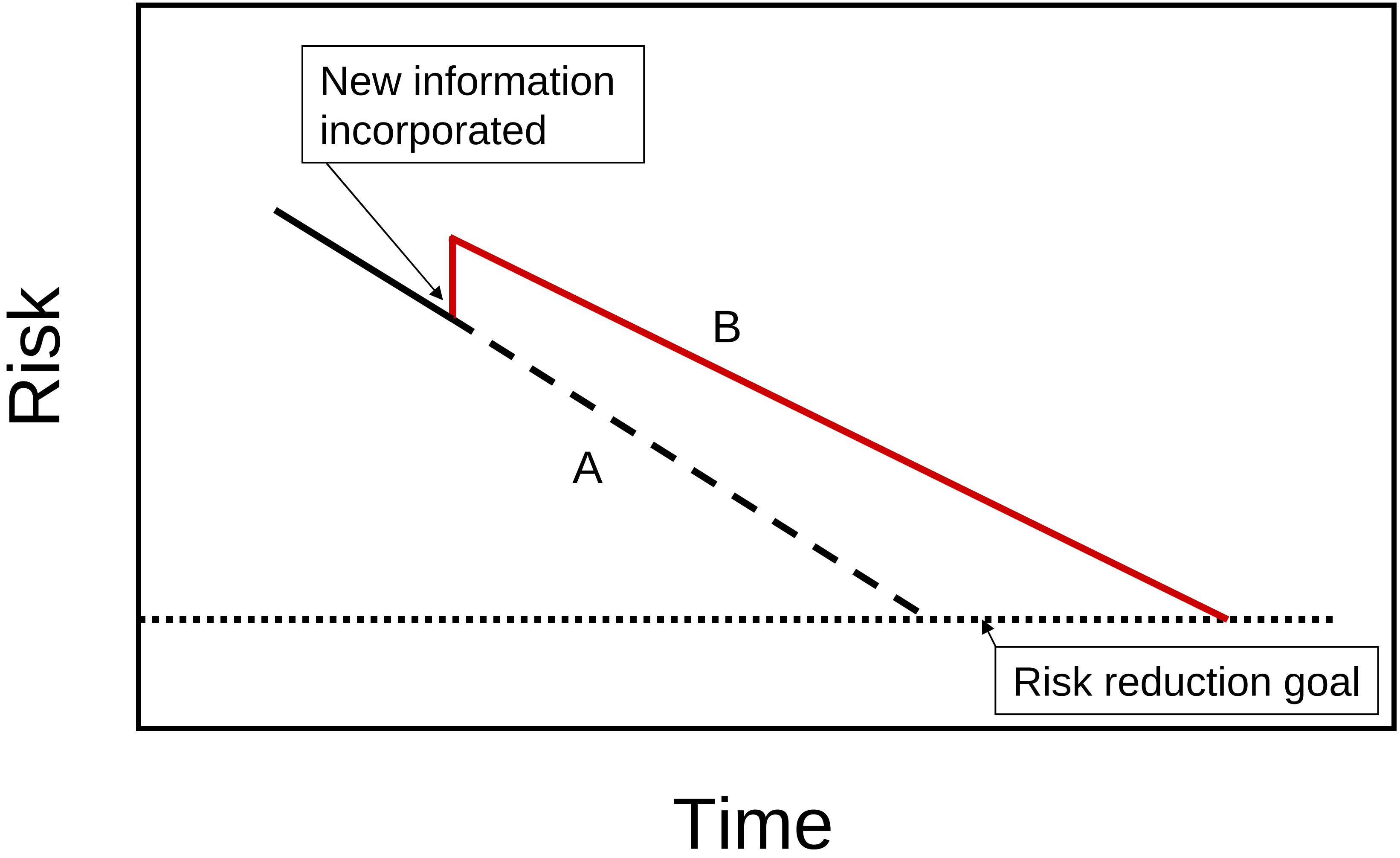




Adaptive Planning and Engineering

- Uncertainty is inherent to planning, design, construction, and O&M
- Adaptive management requires a framework for collecting and using information that results from:
  - Implementing a plan
  - Monitoring the performance of the plan
  - Learning
- The OR and MCDA provide suitable approaches

Risk Reduction Trajectories



The Path Forward

- 3 principles relevant to transforming practice
  - Sediment remedial projects should be addressed as decision problems
  - Deliberation is essential to the successful resolution of risk-decision problems
  - Transforming practice requires commitment to change, experimentation, and learning