Decision Analysis and Risk Management

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Presented at PSAM 9

Hong Kong

May 19, 2008

Why decision analysis?

- **A number of decision alternatives must be evaluated (prioritized).**
- **The decision maker must perform tradeoffs among a number of objectives.**
  - **In current practice, we usually deal with a small number of objectives, e.g., the minimization of the frequency of an undesirable event, the maximization of the reliability of a component or system.**
  - **If we include attributes such as cost, image, and other impacts, the choice of the best decision option is not obvious.**
- **Several stakeholders may be involved.**

Formal Analysis

- **What is important to the decision? (*Objectives)***
- **To what extent are the objectives satisfied? (*Performance Measures; Attributes*)**
- **What is the relative importance of the performance measures? (*Weights)***
- **How does the decision option rate with respect to each of the performance measures? (*Utility or Value Functions)***
- **How do I decide? (*Decision Rule*)**

$$\overline{PI}_j = \sum_{i=1}^{N_{PM}} w_i \overline{u}_{ij}$$

Value of Formal Analysis

- **Provides a systematic way to process large amounts of information.**
- **The decision-making process is explicit and communication is enhanced.**
- **Provides formal rules for quantifying preferences.**
- **The results should be input to an integrated decision-making process (deliberation).**

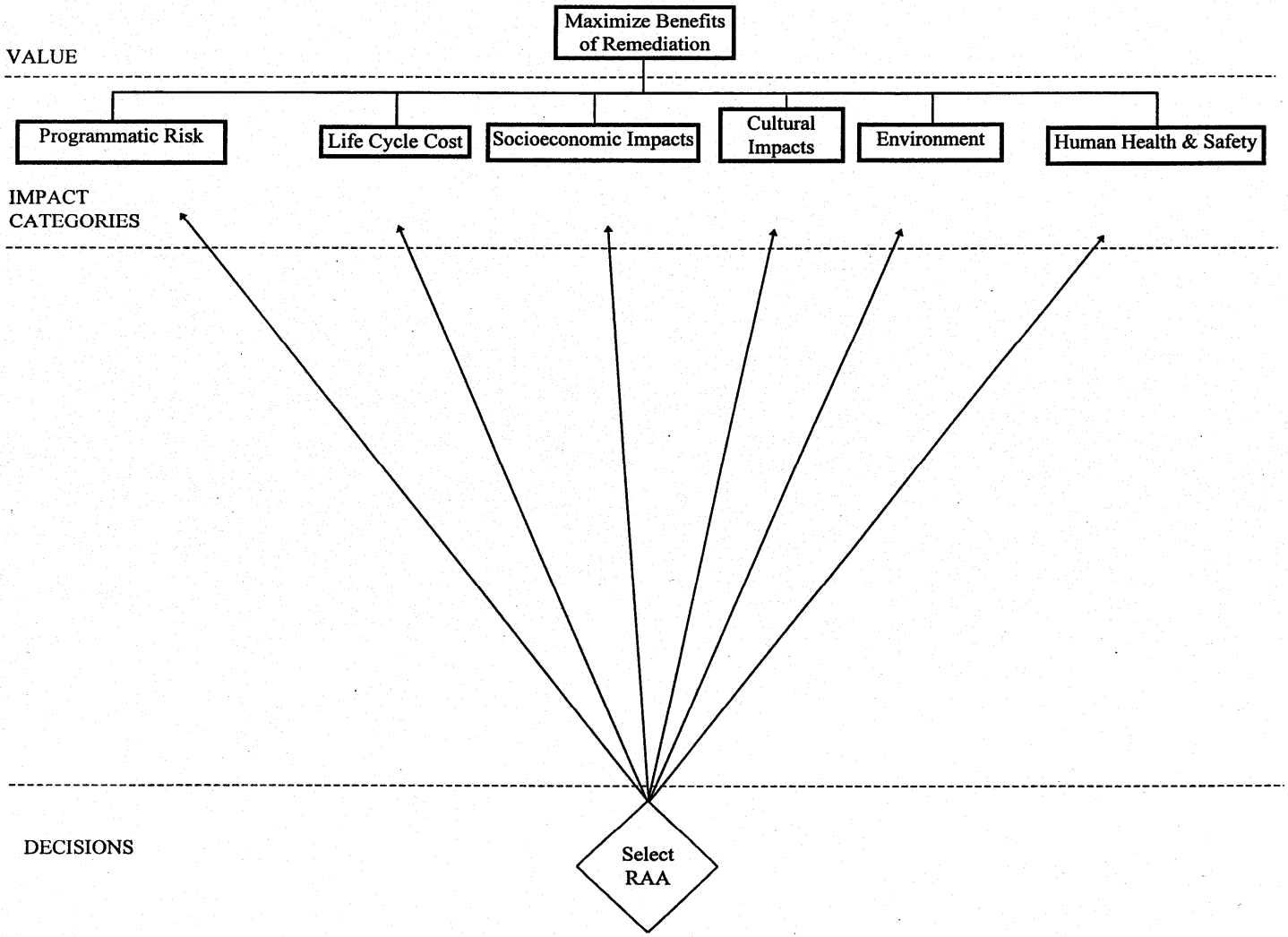
The Analytic-Deliberative Process

- ***Analysis*** **uses rigorous, replicable methods, evaluated under the agreed protocols of an expert community - such as those of disciplines in the natural, social, or decision sciences, as well as mathematics, logic, and law - to arrive at answers to factual questions.**

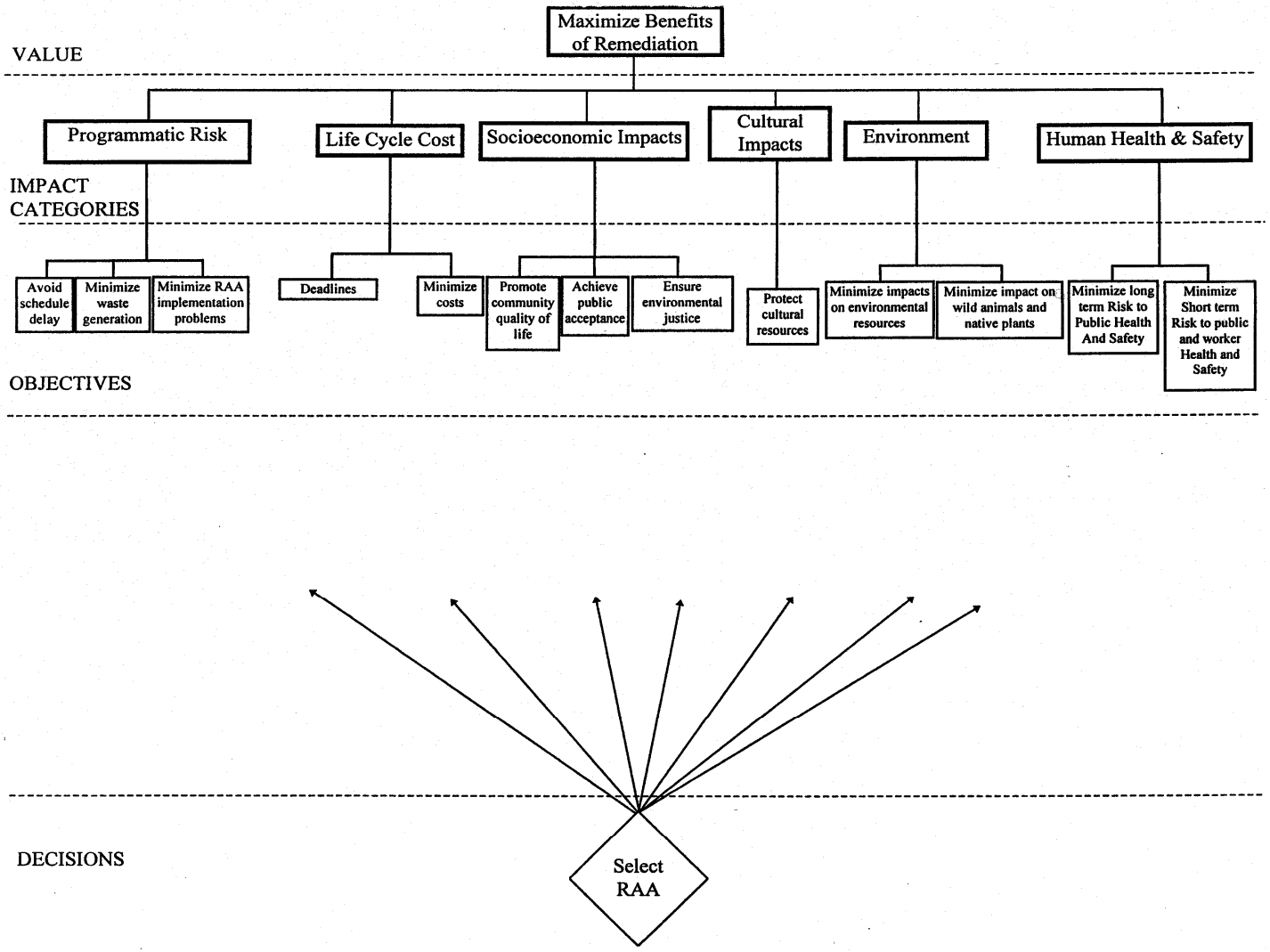
- ***Deliberation*** **is any formal or informal process for communication and collective consideration of issues.**

National Research Council, *Understanding Risk*, 1996.

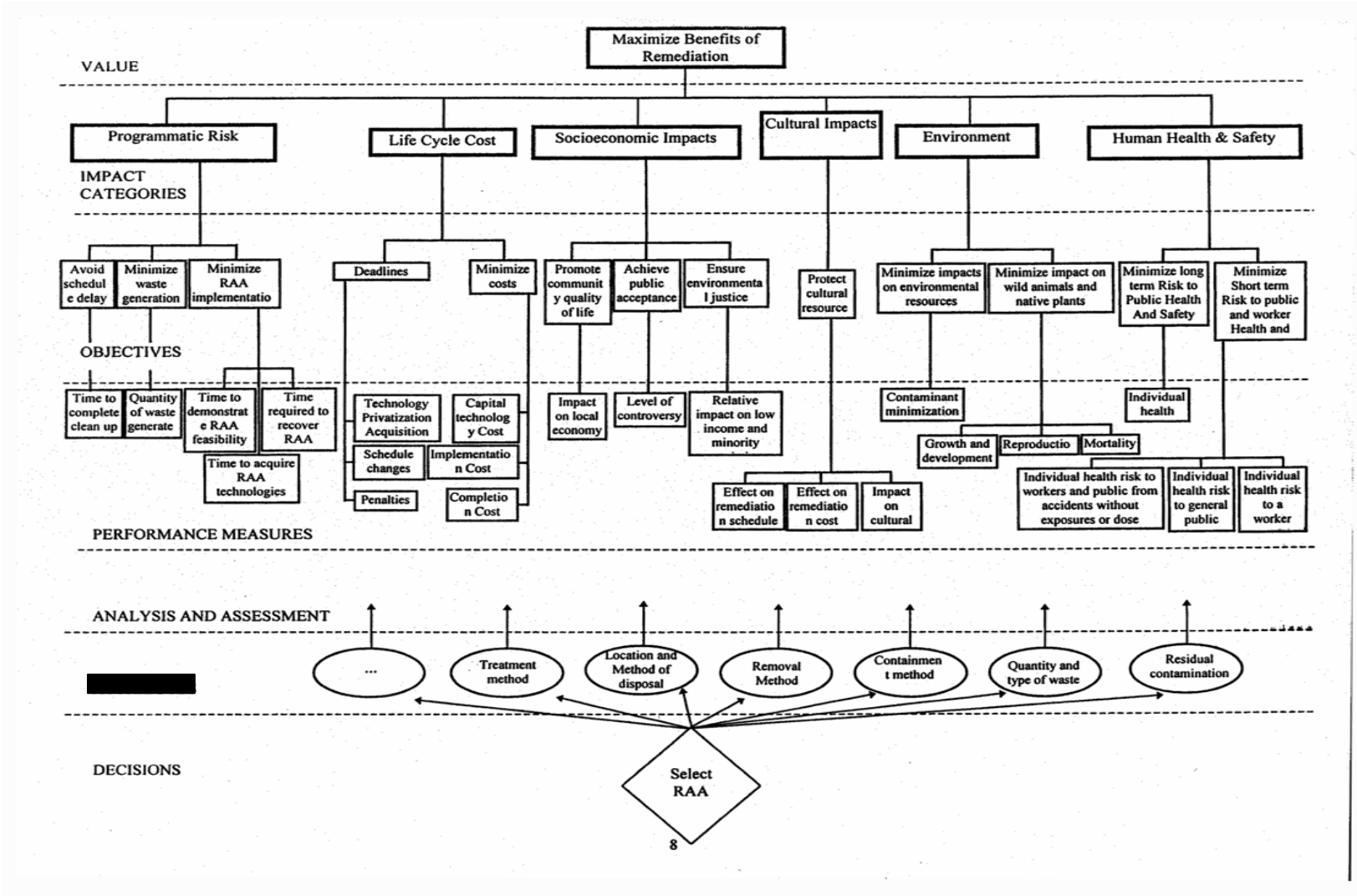
Objectives Hierarchy: Environmental Cleanup, 1



Objectives Hierarchy: Environmental Cleanup, 2

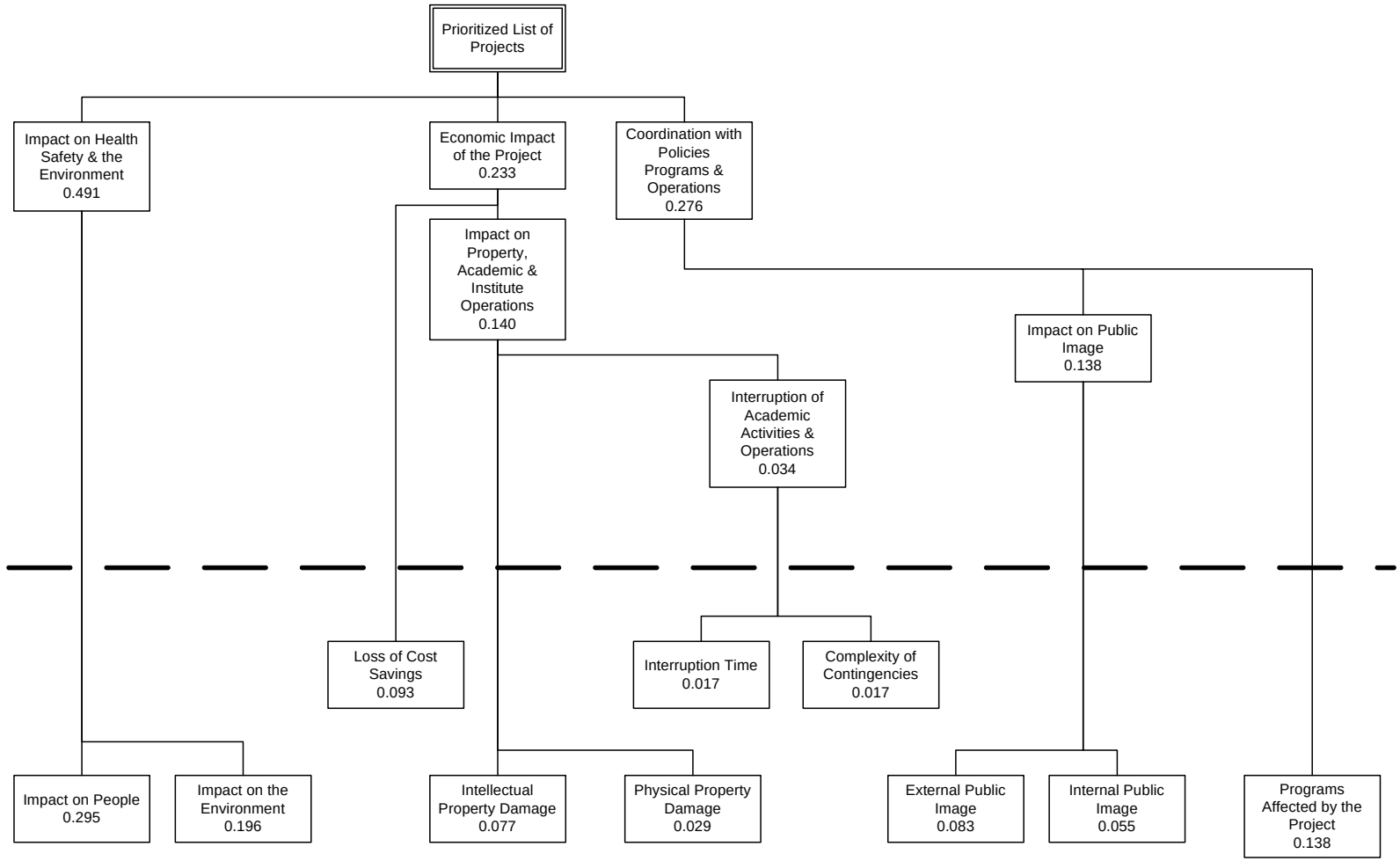


Objectives Hierarchy: Environmental Cleanup, 3



Some stakeholders placed public health & safety under "environment."

Efficient Prioritization of Infrastructure Renewal Projects in MIT's Department of Facilities



Constructed Scales

Interruption of Operations: Interruption Time

Level	***Description***	***Value***
4	Extreme interruption (more than 6 months)	1.00
3	Major interruption (1 to 6 months)	0.57
2	Moderate interruption (1 to 4 weeks)	0.19
1	Minor interruption (less than 1 week)	0.06
0	No interruption	0.00

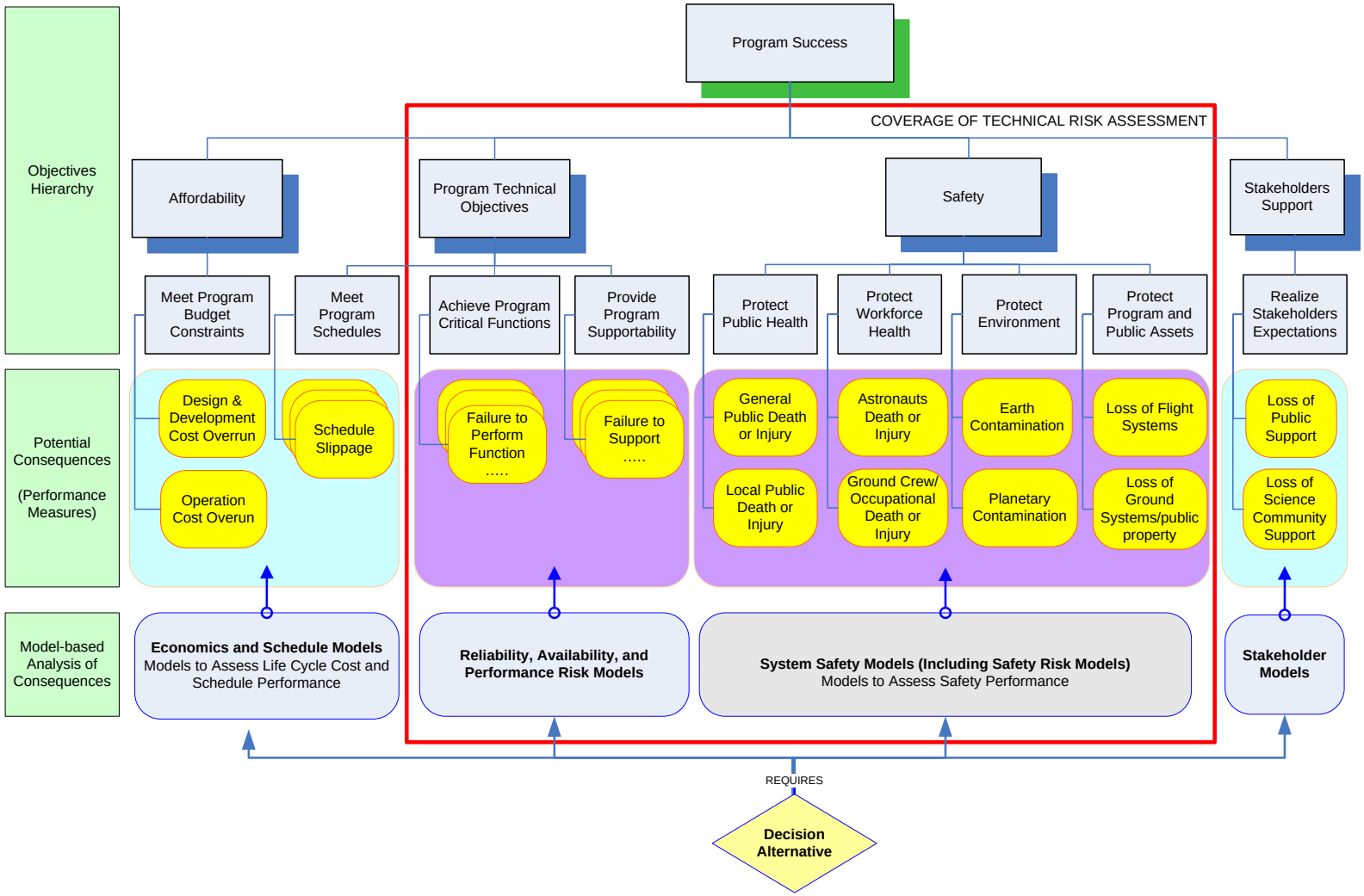
USNRC: Prioritization of Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC)

- **Hundreds of ITAACs over the years.**
- **The ITAACs themselves are not prioritized; rather, the value of inspecting an ITAAC so that the NRC's ability to detect a significant flaw is maximized.**
- **Five Performance Measures are used:**
  - **Safety Significance**
  - **Propensity of Making Errors**
  - **Construction and Testing Experience**
  - **Opportunity to Verify by Other Means**
  - **Licensee (or applicant) Oversight Attention**

A Constructed Scale

- **Propensity of Making Errors**
  - ✓ ***High*** **= A high probability of error in the process or activity due to inherent difficulties**
  - ✓ ***Medium*** **= Some complexity or difficulty of activity that could directly lead to errors**
  - ✓ ***Low*** **= A small probability of error in process or activity as a result of its simplicity or the routine-nature of the activity.**

NASA Procedural Requirements (NPR: 8715.3A, 2006)



Decision Rule

$$\overline{PI}_j = \sum_{i=1}^{N_{PM}} w_i \, \overline{u}_{ij}$$

- The weights are scaling factors that sum to unity

$$\sum_{1}^{N_{PM}} w_i = 1$$

- They represent trade-offs between PMs. They can be assessed directly or using structured approaches, such as SMART and AHP. The DM has the final approval.

STAKEHOLDER RANKINGS AND WEIGHTS

Category / Stakeholder	Programmatic	Life Cycle Cost	Socioeconomic	Cultural	Environment	Human Health & Safety
SH1	4 (8)	3 (11)	6 (4)	6 (4)	2 (34)	1 (39)
SH3	6 (2)	4 (7)	5 (4)	3 (8)	2 (39)	1 (40)
SH4	5 (5)	4 (8)	2 (25)	6 (4)	3 (17)	1 (41)
SH6	4 (12)	6 (5)	3 (13)	5 (10)	2 (27)	1 (33)
SH2	5 (2)	3 (14)	6 (2)	4 (6)	1 (38)	1 (38)
SH5	6 (3)	4 (10)	5 (4)	3 (11)	2 (20)	1 (52)

RAA	STAKEHOLDERS 1	2	3	4	5	6
A	.094 (6)	.048 (6)	.071 (6)	.053 (6)	.050 (6)	.130 (5)
B	.205 (4)	.172 (3)	.154 (4)	.111 (5)	.091 (2)	.159 (2)
C	.216 (3)	.128 (4)	.177 (3)	.122 (3)	.091 (3)	.155 (3)
D	.183 (5)	.115 (5)	.179 (2)	.120 (4)	.082 (5)	.139 (6)
E	.223 (2)	.185 (2)	.132 (5)	.135 (1)	.107 (1)	.114 (4)
F	.258 (1)	.205 (1)	.181 (1)	.128 (2)	.089 (4)	.194 (1)

Performance Indices and RAA rankings for all stakeholders.

Stakeholder 1	Stakeholder 2	Stakeholder 3
RAA F is preferred *Does not employ workers, no worker health risk* *Does not generate waste* *Leaves contaminant in the ground* **RAA C and RAA E are less preferred than RAAF** *B and C have substantial reduction in groundwater contaminant risks* *RAA F performs better in Worker health risk* *C has higher completion costs* *E transports more wastes off-site* **RAA B is slightly less preferred than C & E** *Yields a higher amount of contaminant in the groundwater* **RAA D is less preferred than B** *Transports more waste off site* *RAA D has a higher completion cost* **RAA A is inferior to other RAAs** *High completion cost* *High worker health risk* Uncertainty analyses on performance output indicates that the rankings of RAA B, C, and F are not significantly different. RAA F and B indicate a lower uncertainty & perhaps less likely to fluctuate in the deliberation. E and A appear stable (quantitatively).	**RAA F is preferred** *No short term public accident risks* *Strong concern for public health* **RAA E performs worse than RAA F** *E has more transported wastes* *lower performance on implementation costs,* *due to the number of workers and trucks involved* *E is better than F in removal of contaminant yet poor performance in short term health due to transportation of waste* **RAA B is similar to E in preference** *B is on-site and thus lower costs and less transported waste* *B has higher long term public risk of cancer* **RAA C and D are less preferred** *higher completion cost due to technology (thermal desorption) and the cost of the disposal of the treatment of the residuals.* **D transports wastes off-site which leads to higher costs** *RAA A is least preferred* *Poor performance under worker and public health risks* *High completion cost.*	**RAA F is slightly preferred over the other RAAs** *No worker injuries unlike the other RAAs yet leaves the contaminant in the ground* *Transportation of waste is the performance measure which adversely affects the other RAAs in comparison to F* **RAA C and RAA D perform closely with RAA F** *The tradeoff here is that they remove the contaminant which counteracts their poor performance in regards to worker health* **RAA B is average** *B performs worse than C and D in contaminant removal since the contaminant remains on site* *B has a lower Completion Cost than C and D* **RAA E is less preferred** *High Implementation Cost* *Significant ER and Transported Waste compared to C and D* *Higher volume of transported waste, therefore E is more costly* **RAA A gives substantially lower performance** *In-situ Vitrification which yields high worker health risks* Uncertainty analyses on the performance output of the RAAs show that these preferences are rather stable and that F, D and C are not markedly different.

Major Contributors to Individual Stakeholder Preferences

Deliberation

Role of the stakeholders

- Influence the decision maker's choice
- Communicate concerns, interests, and ideas
- Listen actively

Role of the Analysts

- Provide clarification on technical questions
- Provide technical data on the impacts of each RAA

Role of the Mediator

- Guide deliberation
- Promote understanding of all viewpoints
- Facilitate discussion
- Promote a fair and wise process
- Identify major reasons for agreement and disagreement

Points of Agreement

- **Dislike of in-situ vitrification of RAA A.**
- **Dislike of "no action" alternative F.**
- **Dislike of RAA E; do not transport waste to other communities.**
- **Cr is not a primary concern for long-term health, consequently, the stakeholders are willing to tradeoff more CR left in the ground for less TCE left in the ground.**

Final Consensus

Hybrid RAA	Changes from original	Description
C^+	Off-site, rather than on-site, disposal of organics (TCE).	Excavation and thermal desorption of organics to be disposed of off-site. Soil stabilization of metals (Cr) with on- site treatment.
A^+	No in-situ vitrification.	Soil vapor extraction for TCE . In-situ stabilization for Cr.
F^+	Added action of focused soil vapor extraction for TCE.	Continue with Voluntary Correction Measures, with the addition of focused soil vapor extraction for TCE. No action for Cr.