Structured Decision Making: A Tool for Applying NUREG-1757 ALARA Analysis

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As Low As Reasonably Achievable – ALARA

- The very statement of ALARA implies the need for optimization through decision analysis.

  This was the early intent of ALARA (UK, ICRP) – and it is used that way in the US under NRC's License Termination Rule (LTR) for decommissioning.

  - License Termination Rule – NRC 10 CFR 20, NUREG-1757 Appendix N.

  However, in health physics and DOE practice, ALARA evolved to emphasize procedural and cultural dose reduction, often without formal quantitative analysis

  - Limited utility and missing the original point (optimization).

Decision Analysis is about *optimization* based on utility and probability (value systems and science models), not only on probability.

ALARA and Compliance

- Typical US approach to remediation – Compliance 1st, ALARA 2nd perhaps.
  - This is not ALARA as originally intended.
  - The underlying decision analysis process has been short-circuited with a possible implication that various decision attributes are rolled up in a way that says that cost-benefit must be at least where the compliance metrics are.
- NRC's LTR (10 CFR 20, Subpart E) is an exception.
  - **NRC's NUREG-1757, Appendix N for a CBA approach to ALARA.**
  - Approach consistent with OMB's cost-benefit analysis guidance.

Note: ALARA and the LNT

The linear no-dose threshold (LNT) model is inherent in the ALARA approach.

- A “cost per person-rem” is associated with ALARA analyses (NUREG-1530).
- Today’s cost is about $7,500 per person-rem.
  - Based on the value of a statistical life and risk of cancer fatality.
- Compliance objectives for the public are often 25 mrem/yr.
- This corresponds to less than $200 for a person in a year – which is unlikely to play a significant role in a CBA.
  - Need lots of receptors or lots of years to have an effect in most remediation decisions.
- This is a tacit acknowledgement of the low “value” of a 25 mrem/yr dose.
  - And yet, ”we” regulate to these low levels.
- ALARA/CBA assumes the LNT, so this applies to even very low doses.

The LTR and NUREG-1757 Appendix N – ALARA

- Describes a simple decision analysis approach to ALARA.
  - We can do better!
- Different targets for performance in the License Termination Rule
  - Unrestricted release (<25 mrem/yr)
  - <25 mrem/yr under institutional control (IC), and <100 mrem/yr if IC is lost
  - <25 mrem/yr under IC, and <500 mrem/yr if lost
  - Alternative criteria.
- NUREG-1757 describes how to select the best alternative based on CBA.
  - “simplified method ... to estimate when a remedial action is cost-effective using generalized estimates for the remedial action”

Table N.1 Possible Benefits and Costs Related to License Termination or Decommissioning

Possible Benefits

- Collective Dose Averted
- Regulatory Costs Avoided
- Changes in Land Values
- Esthetics
- Reduction in Public Opposition

Acknowledgement by NRC that some attributes are not easy to measure monetarily

Possible Costs

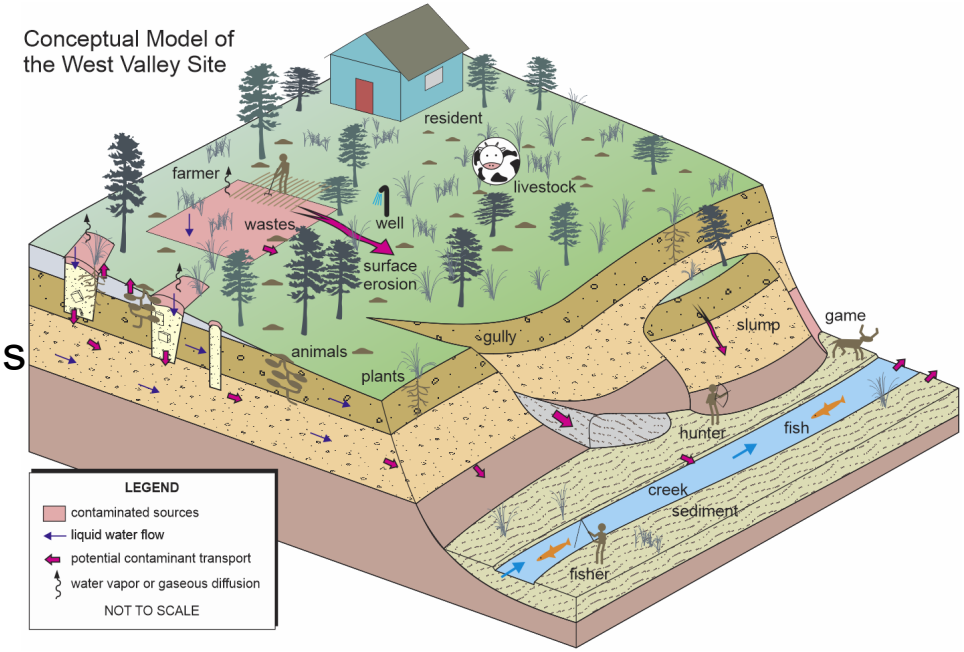
- Remediation Costs (including waste disposal costs)
- Additional Occupational/Public Dose
- Occupational Non-radiological Risks
- Transportation Direct Costs and Implied Risks
- Environmental Impacts
- Loss of Economic Use of Site/Facility

Decision Science Implementation of ALARA

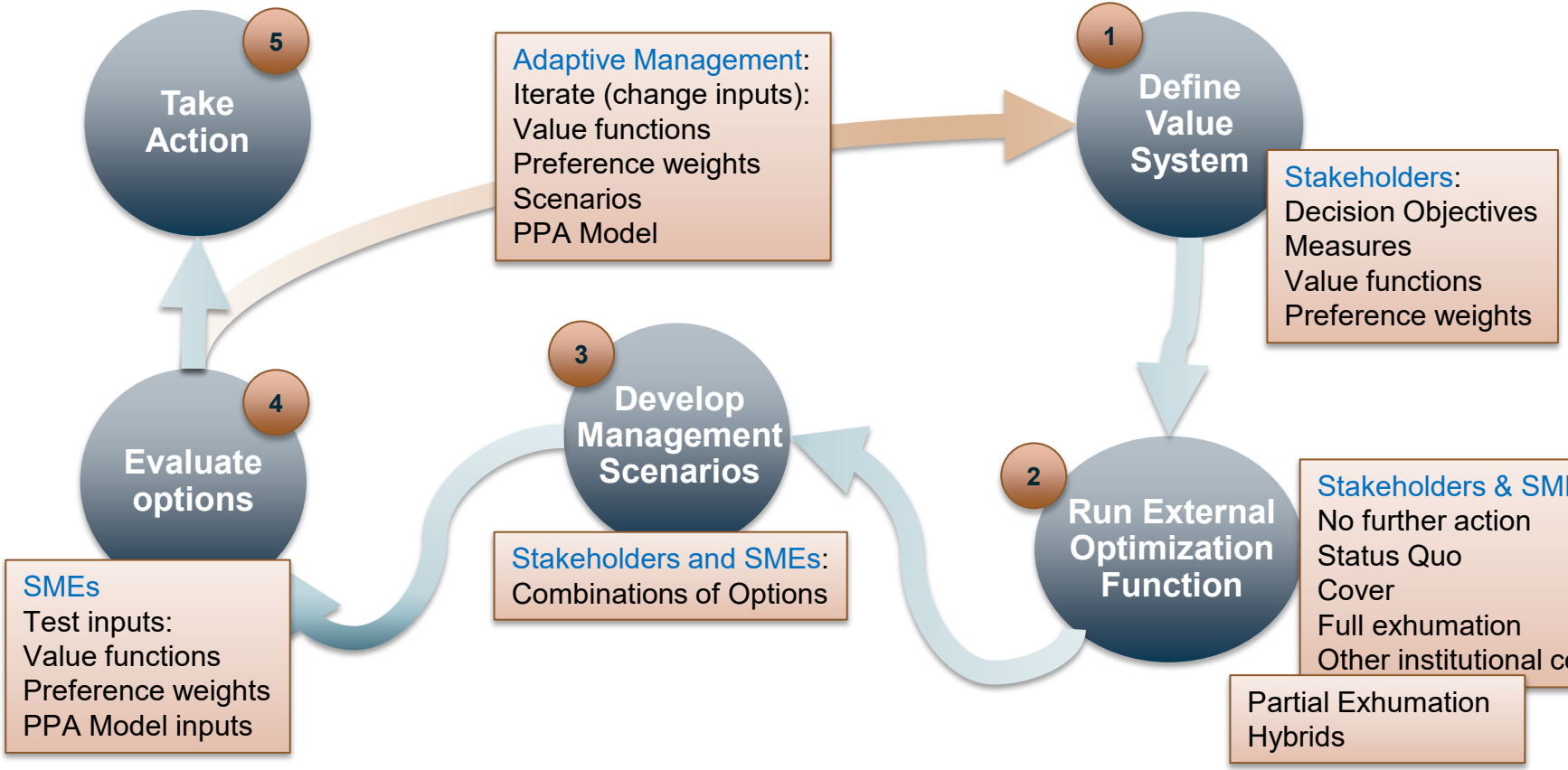
- Decision science provides tools to consider costs and benefits beyond collective averted dose benefit and exhumation cost.
- Structured Decision Making (SDM) is a decision analysis approach that combines Value Focused Thinking, Probabilistic Consequence Modeling, and Multi-attribute Utility Theory in a rigorous "formalized common sense" framework that is defensible and transparent.
- Neptune's Guided interactive Statistics and decision Tools (GiSdT© – pronounced "gist") is a software application designed to facilitate SDM.
  - GiSdT© provides tools to facilitate discussions prompted by Values Focused Thinking. SDM with GiSdT© can facilitate quantifying and integrating values either through valuation/monetization or through constraints.

Application: West Valley Site

- Probabilistic Performance Assessment (PPA) Model is used to evaluate the long-term safety of disposed waste at West Valley
- Coupled Processes
  - air, water, erosion, plants, animals, …
- Receptors
  - onsite resident farmer
  - onsite and offsite populations
  - ingesting, inhaling, external
- ~20k stochastic parameters
- 415 decision units
  - A very complex model !!

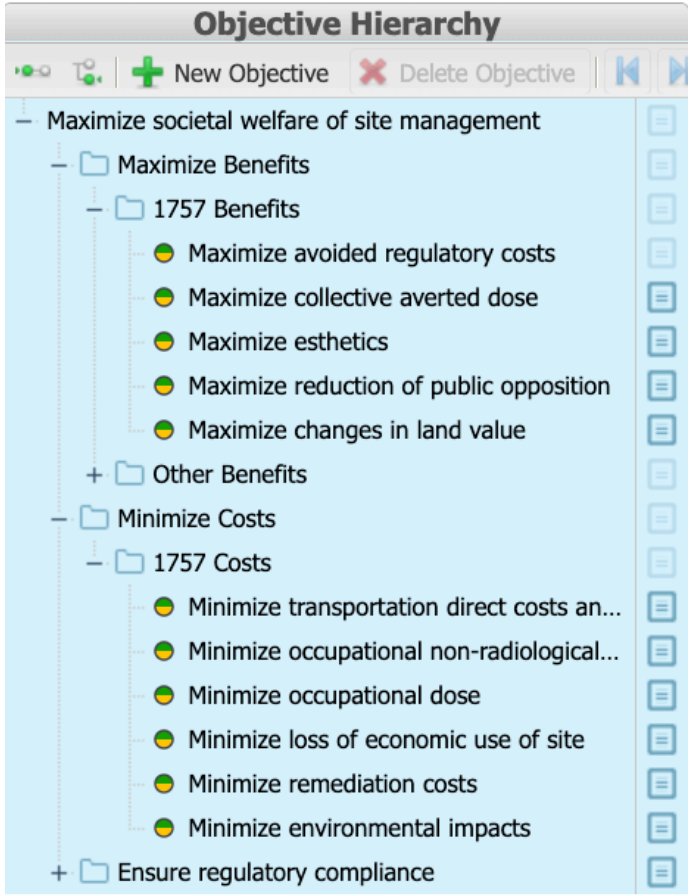


GiSdT SDM Framework for West Valley



NUREG 1757 Objectives

- Under this step, preferences and values are organized into an Objectives Hierarchy.
- An Objectives Hierarchy structures the issues into an outline.
- The Fundamental Objectives, are situated at the top.
- Tiered sub-Objectives that refine and provide more specifics or meaning on the Fundamental Objective are listed below this.
- In this example, the objectives are structured around the NUREG 1757 possible list of objectives (attributes).

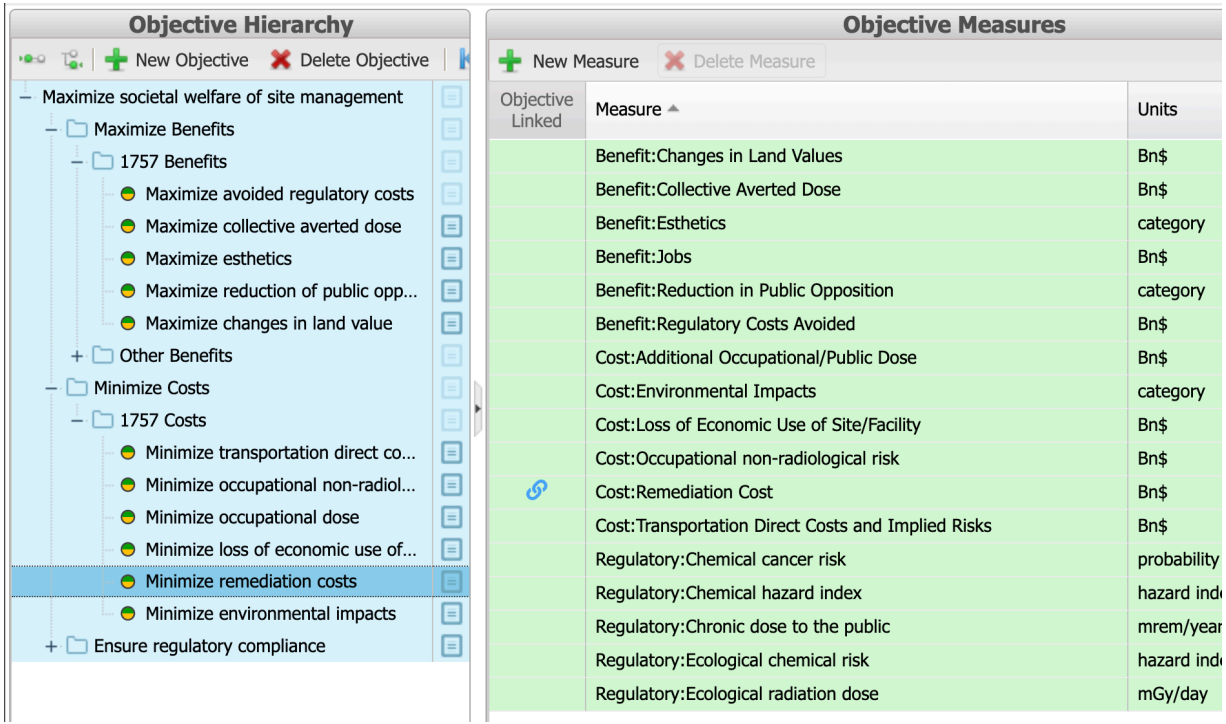


NUREG 1757 potential Costs & Benefits

Measures should be Interpretable, Measurable, Quantifiable, and Meaningful.

This is relatively easy for monetized objectives – less so perhaps for non-monetized objectives.

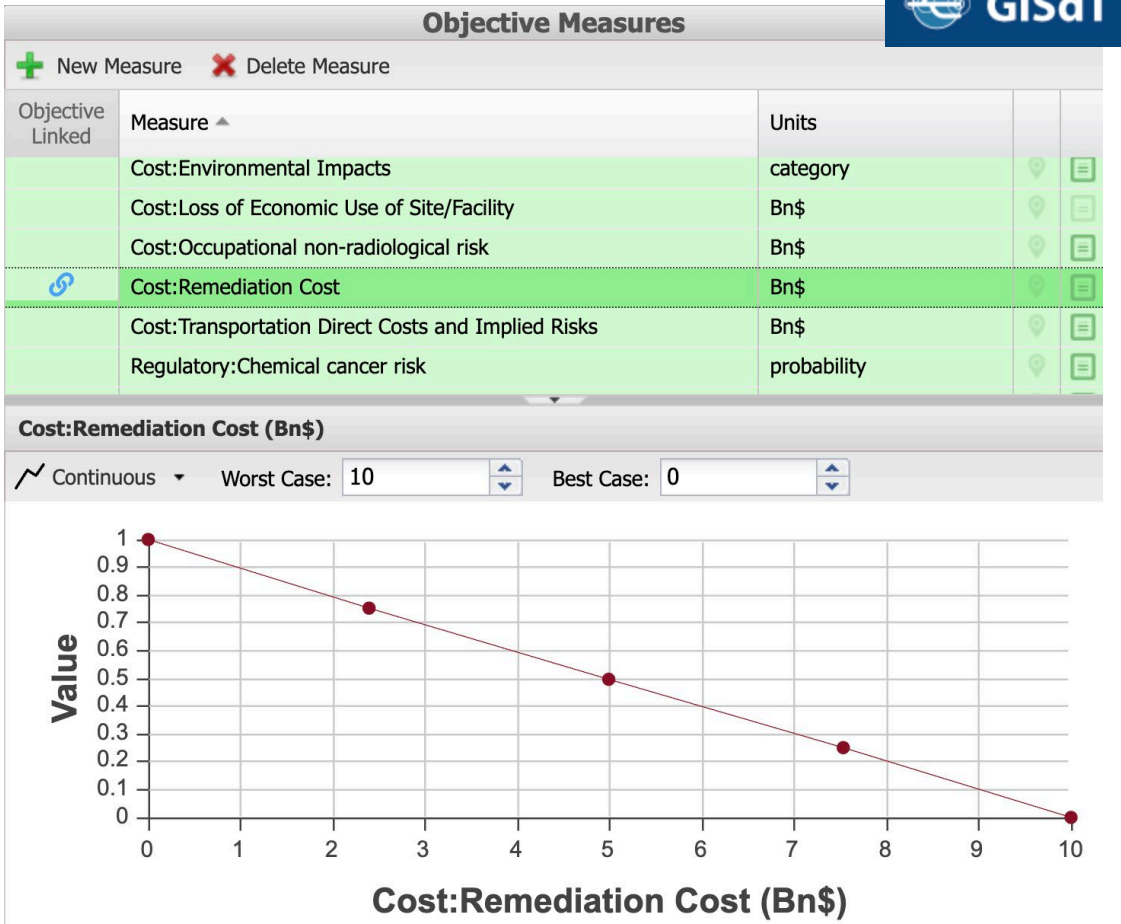
For example, the objective “Minimize remediation costs” has a measure in dollars that is labelled “Cost: Remediation Cost”.



Value Functions

A normalized value function is associated with each Measure, which allows all Measures to be comparable on the same 0-1 scale.

- Measures in dollars are relatively straightforward.
- Methods usually exist to value non-market-based benefits & costs.
- Derived Measures can be valued through stakeholder & decision maker elicitation.

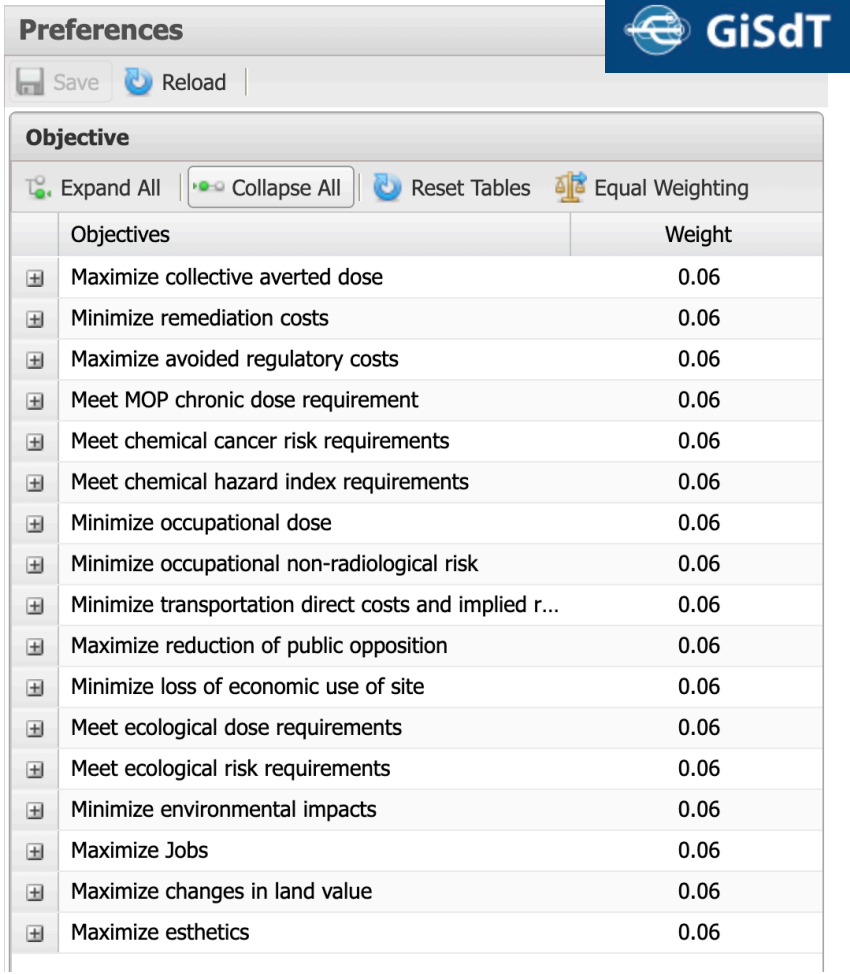


Preference Weights

Each Objective is assigned a preference weight through a ”swing weighting” tool.

Preference weights are implicit in any decision regardless of how large (WV selected exhumation) or small the decision (house purchase). SDM facilitates acknowledging, discussing and potentially quantifying these weights.

The illustration on the right simply shows the initial weights. Swing weighting is employed to develop project-specific weights. This involves ranking the objectives and then assigning relative weights to each successive pair of objective.



Objectives	Weight
Maximize collective averted dose	0.06
Minimize remediation costs	0.06
Maximize avoided regulatory costs	0.06
Meet MOP chronic dose requirement	0.06
Meet chemical cancer risk requirements	0.06
Meet chemical hazard index requirements	0.06
Minimize occupational dose	0.06
Minimize occupational non-radiological risk	0.06
Minimize transportation direct costs and implied r...	0.06
Maximize reduction of public opposition	0.06
Minimize loss of economic use of site	0.06
Meet ecological dose requirements	0.06
Meet ecological risk requirements	0.06
Minimize environmental impacts	0.06
Maximize Jobs	0.06
Maximize changes in land value	0.06
Maximize esthetics	0.06

West Valley Options Might Include….

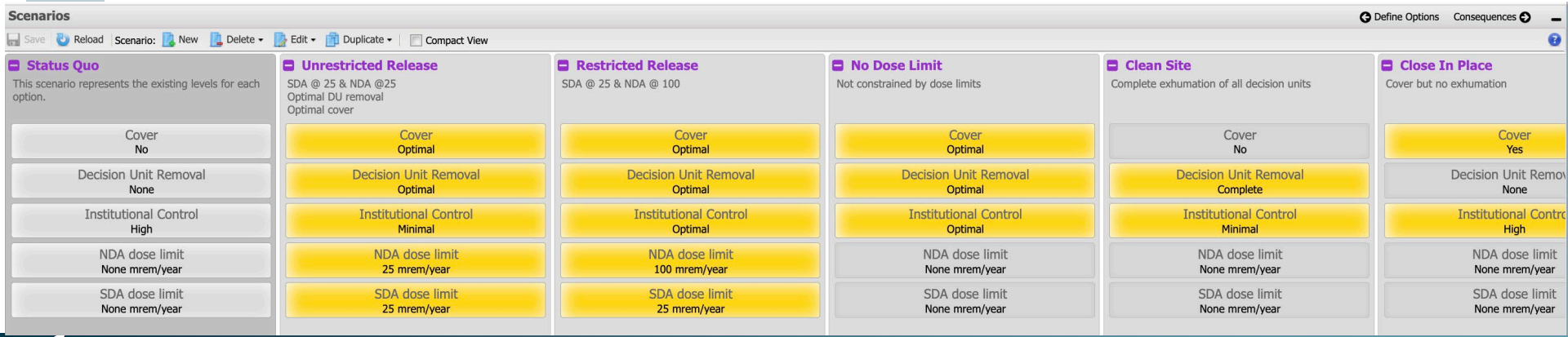
- No further action (walkaway).
- Continued Institutional Control (IC), Status Quo.
- Closure in place (capping the site).
- Exhume all waste.
- Partial Exhumation
  - HYBRID 1 – target 25 mrem/yr for all Facilities
  - HYBRID 2 – target 25 mrem/yr for the SDA and 100 mrem/yr for all other Facilities
  - HYBRID 3 – optimal scenario (see Optimization function)
- Other scenarios could be considered, such as land reuse as a State Park

Combinations of some of the above are possible.

Options and Scenarios

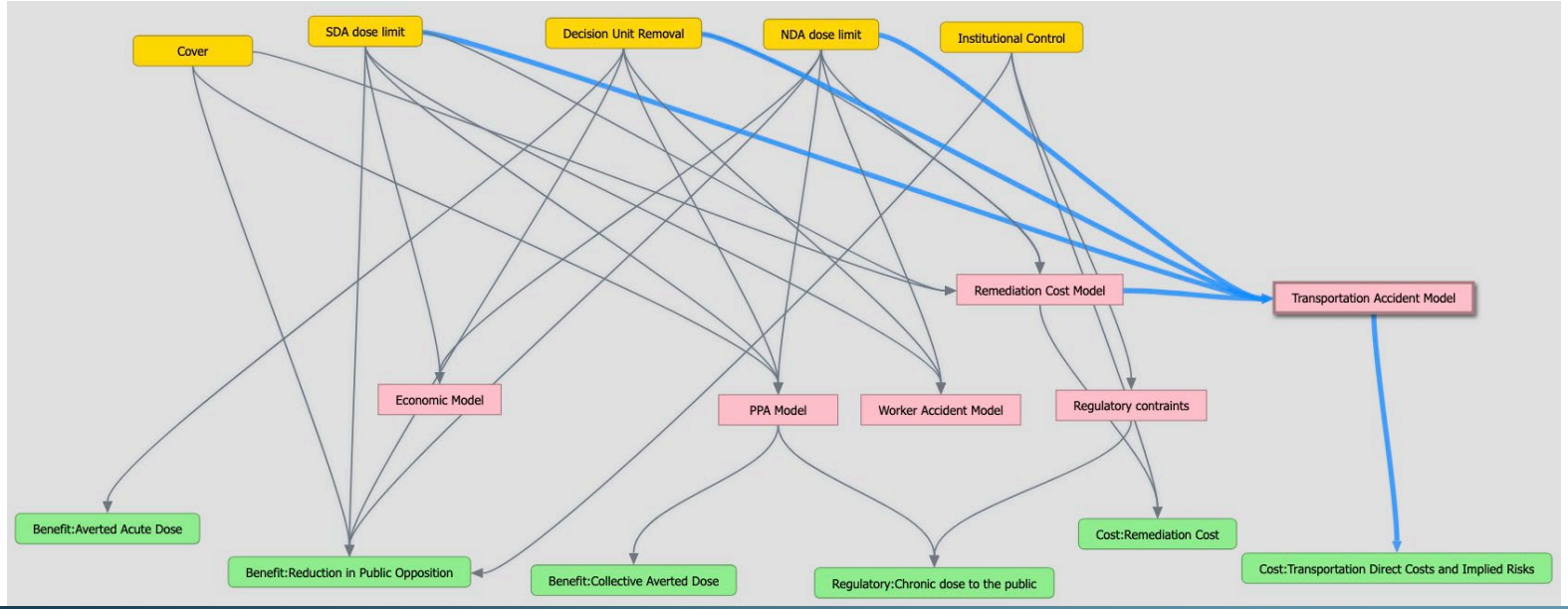
Options are identified that might achieve the Objectives. Defining Options targeted at achieving Objectives potentially often allows for a broader, more comprehensive range of Options.

Management Scenarios are then constructed as collections of various Options with specific decision outcome possibilities in mind.



Influence Diagram

An influence diagram captures the connections and provides the basis for the numerical solutions. The approach is to compare each option (management scenario – orange) by calculating the impact of each option on the objectives (green) – that is, which option best achieves the set of objectives. The values and weights represent the Agencies' objectives, values and preference weights, and the probabilities come from SME knowledge/expert opinion, models, data or other information (pink).



Quick Start
Project Description
1 Context
Decision Sketch
Background
Map
2 Objectives
Brainstorm
Define Objectives
Preferences
3 Options
Define Options
Scenarios
4 Consequences
Consequence Chart
Influence Diagram
Bayesian Network
5 Take Action
Adaptive Management
Decision Charter
Parking Lot

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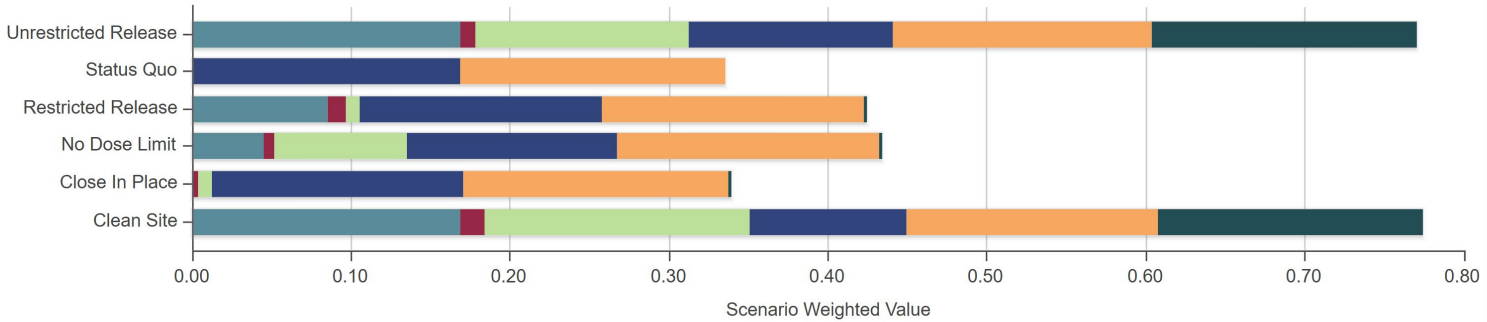
Save | Reload | Charts | Grid View | Sort Chart | Chart Legend | Hide Objectives | Refine Weighting | Use Refined Weighting | Reset Consequences

Consequence Chart



Scenarios Effect on Measures

Averted acute dose – Averted chronic dose – Public opposition – Rem. cost – Trans. cost – Regulatory

The total length of the bars represents the total cost-benefit for each option – the longer the overall bar, the better the option.
Each segment of the bars can be compared to determine which objectives provide the greatest influence on the results.
The weighted value is essentially the sum of values x preference weights x probability across all the objectives.

West Valley Project Status

- Note that the decision model, inputs and results presented herein are *purely illustrative*, demonstrating the basic approach and the connection between ALARA and SDM (or decision analysis) and the LTR that supports this type of optimization.
- Check in next time for the actual final model, results, and conclusions.

Summary

- Values are implicit in making any decision.
- Values are implicit in regulations and compliance thresholds.
- NUREG 1757 suggests using an ALARA cost-benefit analysis.
- In turn, this suggests the need to identify relevant values, translate these values to Objectives and associated Measures to guide / quantify / constrain the ALARA analysis.
- SDM provides a decision science-based approach for building a defensible and transparent ALARA analysis, making as many implicit values explicit as practicable.
  - EDD (engage, deliberate, decide), rather than DAD (decide, announce, defend).
- GiSdT is useful software for implementing SDM.