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USE OF PROBABILISTIC METHODS FOR ANALYSIS OF COST AND DURATION UNCERTAINTIES IN A DECISION ANALYSIS FRAMEWORK

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1. Abstract

Probabilistic forecasting techniques have been used in many risk assessment and performance assessment applications on radioactive waste disposal projects such as Yucca Mountain and the Waste Isolation Pilot Plant (WIPP). Probabilistic techniques such as Monte Carlo and Latin Hypercube sampling methods[i] are routinely used to treat uncertainties in physical parameters important in simulating radionuclide transport in a coupled geohydrologic system and assessing the ability of that system to comply with regulatory release limits. However, the use of probabilistic techniques in the treatment of uncertainties in the cost and duration of programmatic alternatives on risk and performance assessment projects is less common. Where significant uncertainties exist and where programmatic decisions must be made despite existing uncertainties, probabilistic techniques may yield important insights into decision options, especially when used in a decision analysis framework and when properly balanced with deterministic analyses[ii]. For relatively simple evaluations, these types of probabilistic evaluations can be made using personal computer-based software[iii].

An example application of probabilistic forecasting is described here. Sandia proposed a method for analysis of options for interim storage of special nuclear material at a Department of Energy site. Several different facility options were proposed, some off-site and some on-site, involving various levels of institutional control. Off-site options had significant uncertainties in the time required to obtain permits and all options had uncertainties in the actual storage time before final disposition options might be implemented. Estimated storage time ranged from a minimum of 15 to a maximum of 50 years. Additional capital investments might be required for some facility options at the longer storage durations. Techniques had to allow incorporation of potentially nonlinear decision-maker preferences with regard to total costs. The method is as follows:

1. Define probability distributions for capital, operating, and decontamination and decommissioning costs for each facility option. The time to implement a new facility option can also be defined as a probability distribution.

2. Calculate probabilistic forecasts of life cycle costs (see Figure 1 for an example) for each option based on 15-, 25- and 50-year storage durations. Assign probabilities to each storage duration. Calculate the expected cost for an alternative (C_A) as follows, treating the life cycle costs and storage duration as chance nodes on a decision tree:

$$E[C_A] = \Sigma P_i E[C_{Ai}]$$

where E denotes expected value, P_i is the probability of the storage duration taking i years, (i=15, 25, 50), and $E[C_{Ai}]$ is the expected cost of alternative A if the duration is i years.

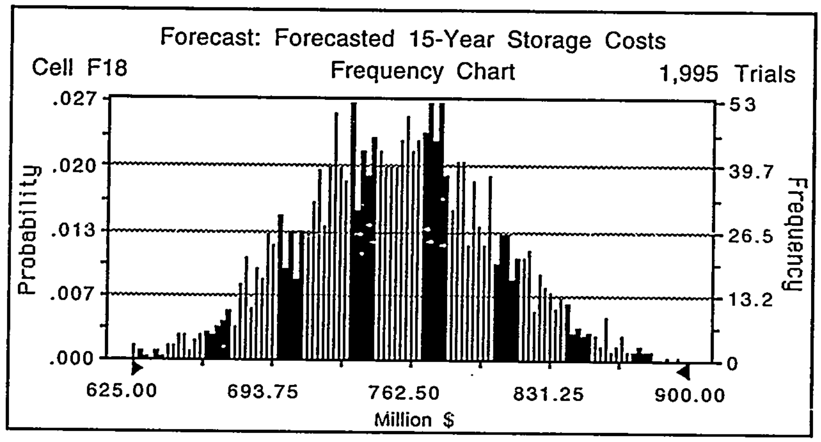

Figure 1. Example forecast of life cycle costs.

3. Apply utility functions[iv] to forecasted costs to reflect decision-maker preferences on cost, such as a lower value or utility for alternatives with somewhat higher expected costs but lower uncertainty in costs (i.e., smaller variance).

4. Compare alternatives on the basis of cost and cost utility, examining the full forecasted distribution for life cycle costs as well as the expected value.

5. Evaluate the key contributors to a cost forecast (see Figure 2 for an example), examining any cost components dominating the forecast, and develop recommendations.

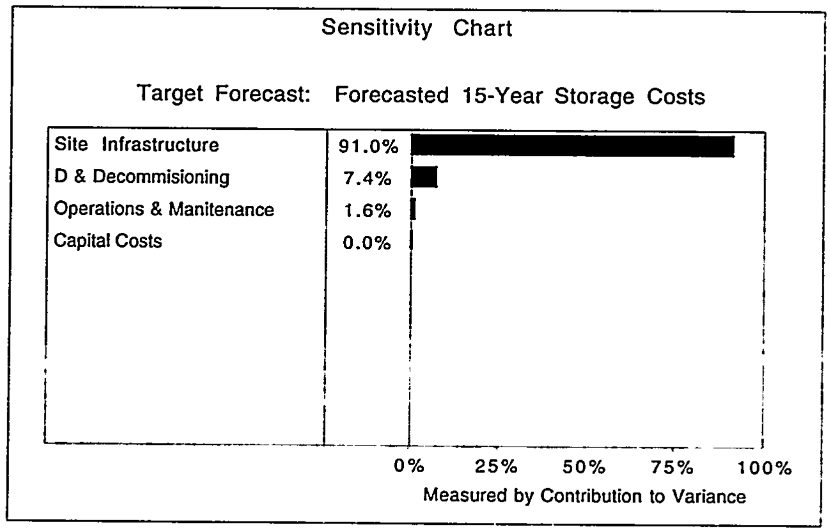

Figure 2. Example sensitivity analysis to determine major contributors to forecasted life cycle costs. Input variables ranked in terms of greatest contribution to total variance.

This method can be used to explicitly incorporate the uncertainty in key cost and duration components of life cycle costs for interim storage options. In addition, properly balanced with deterministic evaluations, probabilistic techniques have application to many other planning problems in which uncertainty in cost and duration are potential important decision factors. Modifications of the method can also be incorporated into a broader decision framework, such as multi-attribute utility analysis, as an adjunct to risk or performance assessments, or to extend risk-based prioritization analyses such as the WIPP Systems Prioritization Method[v, vi].

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[ii] Prindle, N.H., D.M. Boak, R.F. Weiner, W. Beyeler, S. Hora, M.G. Marietta, J.C. Helton, D.Rudeen, H. Jow, and M. Tierney. 1995. *The Second Iteration of the Systems Prioritization Method: A Systems Prioritization and Decision-Aiding Tool for the Waste Isolation Pilot Plant. Volume III: Analysis for Final Programmatic Recommendations.* SAND95-2017/3. Albuquerque, NM: Sandia National Laboratories.

[iii] Decisioneering. 1993. *Crystal Ball: Forecasting and Risk Analysis for Spreadsheet Users.* 3rd Edition. Denver, CO: Decisioneering, Inc. (Telephone: 303-292-2291).

[iv] Keeney, R.L., and H. Raiffa. 1993. *Decisions with Multiple Objectives: Preferences and Value Tradeoffs.* New York, NY: Cambridge University Press.

[v] Prindle, N.H., F.T. Mendenhall, D.M. Boak, W. Beyeler, D. Rudeen, R.C. Lincoln, K. Trauth, D.R. Anderson, M. Marietta, and J. Helton. 1995. *The Second Iteration of the Systems Prioritization Method: A Systems Prioritization and Decision-Aiding Tool for the Waste Isolation Pilot Plant. Volume 1: Synopsis of Method and Results.* SAND95-2017/1. Albuquerque, NM: Sandia National Laboratories.

[vi] Prindle, N.H., F.T. Mendenhall, W. Beyeler, K. Trauth, S. Hora, D. Rudeen, and D.M. Boak. 1995. *The Second Iteration of the Systems Prioritization Method: A Systems Prioritization and Decision-Aiding Tool for the Waste Isolation Pilot Plant. Volume II: Summary of Technical Input and Model Implementation.* SAND95-2017/2. Albuquerque, NM: Sandia National Laboratories.

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