DISPOSAL TECHNOLOGY ALTERNATIVE ASSESSMENT USING MULTIATTRIBUTE UTILITY ESTIMATION

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ABSTRACT

Facing a general objection on the part of the public to continuation of shallow land burial, states and compacts that are developing new low-level radioactive waste (LLW) disposal facilities must choose from an array of alternative designs for disposal of LLW. To select the most appropriate disposal methodology to be used at their facility, the states and compacts have often turned to multi-attribute utility estimation. This approach provides a rigorous and very traceable methodology for selecting among a number of alternatives and it often provides insights into relative strengths and weaknesses of the different candidates. It offers the opportunity for public participation in selecting both the issues by which the disposal alternatives can be evaluated and the relative importance of those issues.

This paper reviews the progress in the use of the multi-attribute utility estimation method in selecting among the wide range of alternatives to shallow land burial for disposal of LLW. It demonstrates how the method has been used to rank order a wide spectrum of disposal technologies and how the agencies that must make the selection have often used this approach to generate advisory input to their selection rather than as a rigorous method of automatically choosing the technology to be used.

INTRODUCTION

Multi-attribute utility analysis can make comparisons between alternative disposal technologies based on a spectrum of concerns that include technical, social, economic, and political considerations. It is a semi-quantitative decision analysis methodology that takes into account both the technical merit of a particular alternative and the relative importance of factors used to make the technical judgment. While the methodology results in a distinctive score for each of the alternatives being evaluated, it is often more useful in providing insights as to the important characteristics of the alternatives. Those insights can then be used by the appropriate authorities to make the final selection.

The use of the multi-attribute utility estimation method for disposal technology evaluation is portrayed in Fig. 1. It begins with the selection of a number of issues that bear on the desirability of the candidate disposal technologies. The list of issues should address all major concerns and there should be a minimal overlap among the issues. Sometimes the broadly-stated issues are divided into subissues, often called factors.

Once the issues and factors are defined, they are often used by two independent groups, as illustrated in the figure. The first group, usually comprised of persons with a wide range of interests, assigns importance weights to all the issues and their component factors. The second group, consisting primarily of technical experts, rates the performance of each candidate disposal alternative according to each factor. Scores are calculated for each issue by taking the product of each factor importance weight and the corresponding performance rating and summing over all factors for a particular issue. The issue scores, in turn, are weighted by issue importance weights and the weighted issue scores are summed to obtain a final score for each disposal technology. Usually the disposal technologies are then rank ordered according to their scores.

A number of additional sophisticated analyses can be performed in the context of multi-attribute utility estimation analysis. For example, analyses can be conducted to answer the question, "What if a different weight was assigned to a particular issue?" Points at which changes in issue weights will change the rank order of the technologies can be determined. In general, these more sophisticated analyses investigate the sensitivity of the overall rank order to the choices to the weights and ratings that have been assigned. However, this kind of analysis has not generally been done in the selection of disposal technologies to date.

The multi-attribute utility estimation approach is a linear approach. It does not allow for the use of threshold values or pass/fail types of criteria. The kind of difficulty that this can create was observed in its use as part of the Texas LLW siting process. One factor used in the initial siting process was the availability (for purchase) of land. Since this was only one of a large number of factors, the total score for any site was quite insensitive to the availability of land. However, when a number of recommended sites were chosen, it was determined that there would be great difficulty in obtaining land at some of the sites rated highest. In fact, that difficulty could be insurmountable. In retrospect, it appears there that all sites for which the land was not available should have been eliminated before the application of the multi-attribute utility estimation approach.

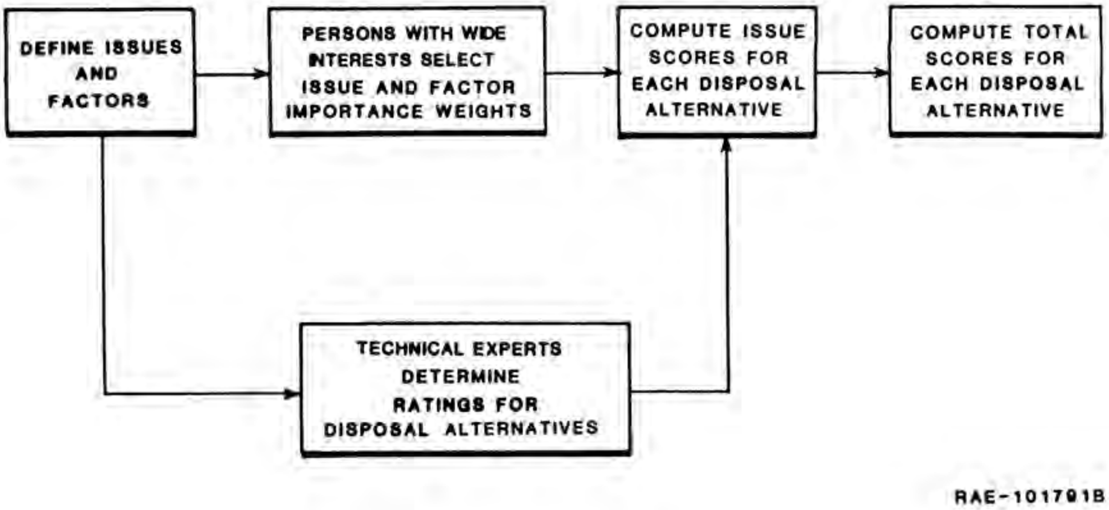

Fig. 1. Steps in the Multiattribute Utility Estimation Process for Selection of a Disposal Alternative.

APPLICATION OF MULTI-ATTRIBUTE UTILITY ESTIMATION TO CHOOSING DISPOSAL TECHNOLOGIES

Multi-attribute utility estimation has been used in at least three instances to choose disposal technologies. It has been applied by the Texas Low-Level Radioactive Waste Disposal Authority, by the Midwest Compact, and by the Southeast Compact. The following sections describe those three applications and illustrate lessons learned from their use.

Application In Texas

The multi-attribute utility estimation procedure was used in Texas to evaluate 11 disposal technologies including: shallow land disposal, improved shallow land disposal, above-ground vaults, below-ground vaults, above-ground modular concrete canisters, above/below-ground modular concrete canisters, below-ground modular concrete canisters, earth-mounded concrete bunkers, mined cavities, and lined and unlined augered holes (1).

These technologies were evaluated against 11 issues; 31 factors or subissues were defined for the 11 issues. Issues weights and factor weights were assigned by a citizens group formed to advise the Texas Authority. The disposal technologies were rated by a group of technical experts, including members of the Authority and their contractors.

Figure 2 shows the final scores that were provided for the 11 disposal techniques. The average score is indicated by a triangle, and the range of scores, based on a range of issue and factor weights and technical ratings, is indicated by the vertical bars. It can be seen that improved shallow land disposal and shallow land disposal scored highest using this method. However, because the legislative directive was used to consider alternatives that contained enhancements to shallow land disposal, basically the Texas Authority chose to evaluate below-ground modular concrete canisters, above-ground vaults, and above/below-ground modular concrete canisters. The modular concrete canister designs were supplemented by below-ground vaults for odd-shaped and over-sized waste packages.

For the application of multi-attribute utility estimation in Texas, the issue weights were not constrained to sum to a particular number. Therefore the members of the citizens advisory committee that assigned the weights tended to assign high weights to all issues they identified.

The Midwest Interstate Compact

The Midwest Interstate Compact performed a preliminary ranking of near-surface disposal technologies to gain insight into the relative advantages and disadvantages of these technologies. Initially, a multi-attribute utility estimation approach was used. Each of the disposal technologies was rated according to a number of issues, based on the assumption that there would be a unity rating for shallow land burial for each issue. Therefore, some of the alternative disposal technologies had ratings higher than one and others had ratings lower than one, depending on the technology and the issue being rated. The Compact Commissioners were polled to determine the weights to assign to the different issues. They were required to assign weights that would sum to a number of 100. More than 50 percent of the

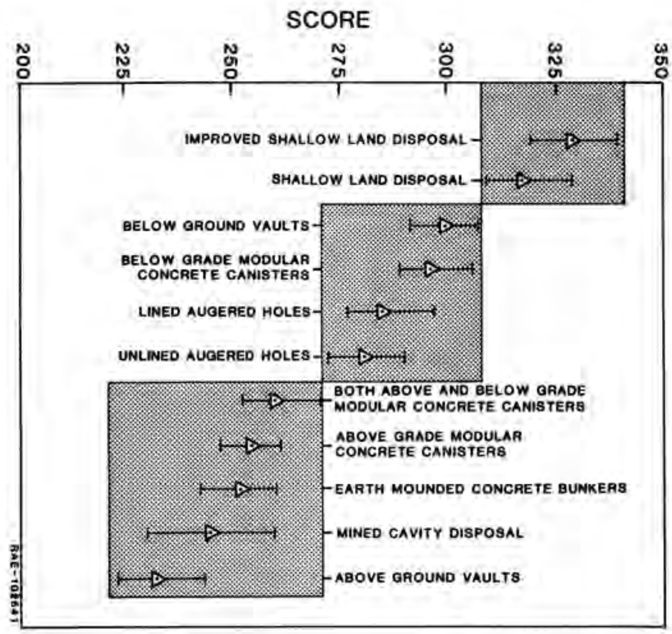

Fig. 2. Rankings of Disposal Designs by the State of Texas.

total weight was assigned to issues related to environmental protection (2).

Based on the insights gained from using the multi-attribute utility estimation process, the Commissioners chose to recommend four disposal technologies for development within the Midwest Compact. There were:

- Modular concrete canister disposal, below ground
- Modular concrete canister disposal, above ground
- Below-ground vaults
- Above-ground vaults

Note that one of the four technologies recommended by the Commissioners (e.g., modular concrete canister disposal, above ground) was not one of the technologies that was originally evaluated. However, it was felt that sufficient insight was gained in the evaluation that this technology could be recommended.

Southeast Compact

Six disposal alternatives were evaluated in a preliminary assessment for the Southeast Compact (3). They were: shallow land burial, concrete canister disposal, mined cavities, above-ground vaults, below-ground vaults, and augered holes. These technologies were evaluated using multi-attribute utility estimation against nine issues. A Delphi workshop was conducted for designated representatives of the Southeast Compact Commission to discuss the issues and assign weights for each issue. Weights were constrained to total 100. The ratings of the six disposal technologies against the nine issues were provided by a contractor to the Compact. A range of numbers from one to five was assigned for each issue for each disposal technology, with one being considered to be the highest rating. Following this procedure, shallow land burial received the best rating, followed by concrete canister disposal. Above-ground vaults received the poorest rating. The host state, North Carolina, has reserved the right to choose the disposal technology.

DISPOSAL TECHNOLOGY PROFILE EXERCISE

In conjunction with the DOE's LLW Management Disposal Technology seminar on alternative disposal concepts in Boston (June 28, to July 1, 1987) an exercise was performed to demonstrate the use of multi-attribute utility estimation in selecting a disposal technology for an LLW facility. The main purpose of the exercise was to introduce the methodology to the attendees and provide feedback for the disposal technology seminar, rather than to select a specific technology. Seminar attendees were given a list of five factors or attributes that bear on the desirability of the candidate disposal technologies. They were: protection of public health and safety, worker safety, radiation safety to intruders, long-term stability, and economics and cost. The attendees were asked to determine the relative importance of these five issues. Then they were asked to rate five candidate disposal technologies for each issue. The candidate disposal technologies were: shallow land burial, above-ground vaults, below-ground vaults, earth-mounded concrete bunkers, and modular concrete canisters. Since the issue weights and rating the disposal technology ratings were done by the same people, there is a lack of

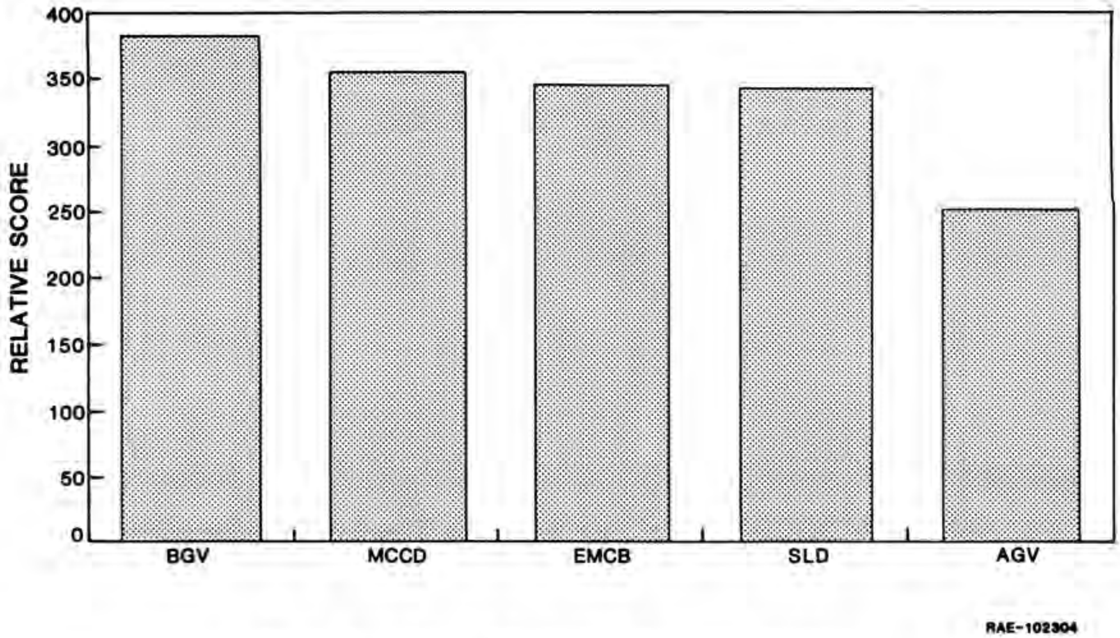

Fig. 3. Final Disposal Technology from DOE Seminar.

independence in this exercise. However, the results are informative.

In the initial evaluation of disposal technologies (before the lectures on disposal alternatives), below-ground vaults are rated the highest and modular concrete canisters are second highest. Essentially equal scores were given earth-mounded concrete bunkers and shallow land disposal. Above-ground vaults were rated lowest. These ratings were essentially independent of the extent of the participants technical background.

At the conclusion of the lectures and discussions of disposal alternatives, the same group of participants was asked to repeat the multi-attribute utility estimation analysis of the same set of disposal technologies. The results are shown in Fig. 3. The relative order ot the different disposal technologies are essentially the same as the exercise conducted before the start of the lectures. However, there appeared to be a stronger preference for below-ground vaults, especially by attendees affiliated with states, compacts or federal agencies. The distinction between above-ground vaults (rated least favorable in both exercises) and the disposal technology rated second lowest (shallow land disposal) increased between the first exercise and the second exercise. During the second exercise, essentially equal scores were assigned to modular concrete canisters, earth-mounded concrete bunkers, and shallow land disposal. The impact of several days of presentations on alternative disposal technologies came through clearly in the final exercise; the relative ratings of the five technologies were very similar to those that would be supported by information given during the lecture series.

As noted above, the purpose of these two exercises were to illustrate the use of the methodology and to determine whether the discussions over several days had any impact on the thinking of the attendees.

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