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USING DECISION ANALYSIS IN EVALUATION AND PRIORITIZATION OF TECHNOLOGIES FOR LONG TERM STEWARDSHIP

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ABSTRACT

The purpose of this paper is to describe a systematic approach to assess and prioritize technology concepts and systems for future research and development (R&D) funding. This paper discusses the analysis and rationale used in developing an evaluation process to assist those engaged in prioritizing technologies. This paper will explain the developed evaluation process, discuss the methodology, and summarize the rationale underlying the process.

I. PURPOSE

The purpose of this project was to develop a "filtering" process to assist those tasked with assessing and prioritizing technologies for future research and development funding. The developed process can be used to create a portfolio of technologies for each of the stages of development identified in the *Technology Decision Process Guidance Manual* published by the Office of Science and Technology (OST).[1] Initially this process was designed for the Department of Energy Long-Term Stewardship roadmap teams, however this paper will address a more generic version of the process and method. This process may be useful for other programs where people are trying to assess and prioritize technologies for future R&D funding.

II. DEVELOPMENT METHOD

Experts in the fields of human factors, decision analysis, and modeling conducted several meetings in order to identify the strongest approach for this prioritization task. Many discussions involved what and how much information the user needed in making the prioritized ratings. In particular, we discussed the type of cost data needed and how much of these data are actually available during a given prioritization process. Based on these initial discussions and additional review of published literature, we decided that the best method for this task was expert estimation. Expert estimation is when a person(s) with a high degree of skill or knowledge in a subject area forms an opinion and draws conclusion from the subject matter. This approach best met our needs because there were experts available and we concluded that, at least for some of the potential concepts being evaluated, there might not be complete or extensive data available. The Nominal Group Technique (NGT)[2] was identified as the most desired approach for this prioritization task. The Nominal Group Technique is designed to overcome certain aspects of unconstrained face-to-face discussion that can interfere with effective group problem solving and decision making. The Nominal Group Technique will be discussed further in Section III. Next, we determined what characteristics of technology concepts and systems were important to consider in this evaluation and prioritization task. The final result is the "Process for Evaluation and Prioritization of Technologies for Long Term Stewardship," which is described in this paper. Other supporting information, such as definitions, detailed instructions, and some limited cost data for existing technologies and functions, are not included here but may be found in the full report.[3]

III. PROCESS OVERVIEW FOR EVALUATION AND PRIORITIZATION OF TECHNOLOGIES FOR LONG TERM STEWARDSHIP

The following flowchart represents the sequence of events used in the evaluation process:

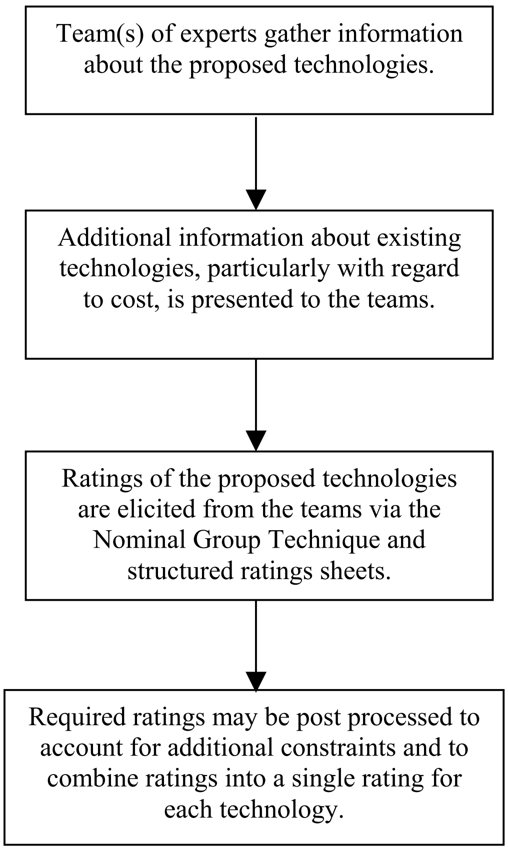

Figure 1. The sequence of events in the evaluation process.

The team(s) of experts start by gathering information about the proposed technologies. Data on current technologies in particular, cost information (if it is available) is provided to the teams. The users then proceed to give rating information about the proposed technologies. The ratings will be made using a set of structured rating sheets (copies of which may be found in the full report).[3] These rating sheets are comparative in nature and use a systematic approach to gather data for prioritizing technologies. Then, by using the Nominal Group Technique, individuals make their own ratings on the proposed technologies. We used the Nominal Group Technique to inhibit the reluctance of team member participation. Particular areas of concern that are addressed and mitigated by using the NGT include group discussion by an opinionated high-status individual, the diversion of time and effort, and getting stuck on a single line of argument for long periods of time. After this procedure, the group convenes and revisits the individual ratings. Individuals then make a second individual rating of the proposed technologies. Using this information, the group will then make a group rating, via consensus or aggregation. The group rating will be elicited from the team members via a facilitated session. Finally, post-processing of the elicited ratings may be necessary for such purposes as incorporating time constraints and site information.

IV. STRUCTURED RATINGS

An important part of this process is obtaining ratings from team members using structured forms. These structured forms or ratings sheets provide two pathways for ratings. These pathways are shown below in Figure 2. The pathway to be followed is determined by: 1) the presence or 2) absence of an existing or a baseline technology.

The two pathways are necessary because of the different information that will be available for use. For example, when there is an existing technology, raters will be able to compare proposed technologies to that specific existing technology, and bring technology-specific cost and risk data into their ratings. When there is no existing technology, raters will have to rely on more "average" or "generic" data to make their ratings. Slightly different wording is used for the ratings questions in each pathway.

Both sets of structured rating sheets follow the same basic pattern. After proposed technologies are identified, ratings are made using the following five steps:

- **<u>Step 1</u> -** Evaluate which stage of technological development a proposed technology is in.

  This serves to insure that proposed technologies would only be rated against other proposed technologies in a similar state of development and placed in their corresponding “bins.” The three designated

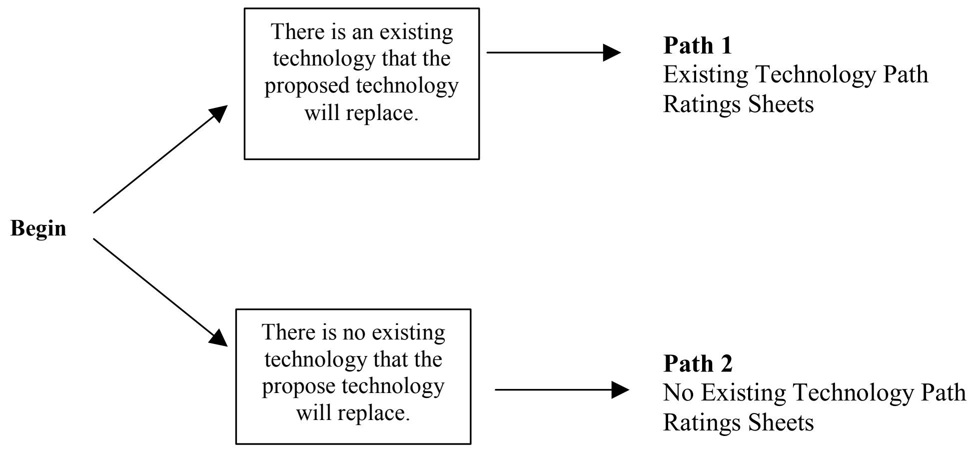

Figure 2. The pathways to two different sets of rating sheets.

bins are labeled research, development, and demonstration.

- **<u>Step 2</u> -** Evaluate the likelihood of technological success.

  The further along a technology is in the development cycle (Step 1) the more likely is the technological success. Additional modifiers were used to account for additional characteristics that contributed to the "likelihood of technological success." These modifiers include the ability to meet the required schedule, the quality of the research and development, operability, and maintainability.

- **<u>Step 3</u>** – Evaluate the likelihood of implementation success.

  This is determined by evaluating the likelihood to cause improved public acceptance, if the technology is compatible with existing technology required for the activity, and the likelihood of successful implementation considering other various characteristics such as stakeholder involvement and public acceptance.

- **<u>Step 4</u> –** Evaluate Costs.

  The difficulty in choosing a component to evaluate cost came in deciding what level of detail to encompass. Our initial cost evaluation section many components (e.g., development costs, implementation costs, operations costs, maintenance costs, disposition costs, labor vs. non-labor, onetime vs. repetitive). However, reviewers' comments and the difficulty of obtaining good cost data for existing technologies have led us to reduce the cost evaluation to a single component, the Cost Benefit of Having the Function Performed, which is essentially an evaluation of return on investment. If more specific cost information is available, it can easily be considered within the process of making this overall cost rating. Figure 3 shows the rating scale for the "Cost Benefit of Having the Function Performed."

A. Cost Benefit of Having the Function Performed.

Proposed Technology

○	○	○	○	○	○	○
Undoubtedly Worse (recoup investment in 200 years)	Conspicuously Worse (recoup investment in 74 years)	Moderately Worse (recoup investment in 27 years)	Alike (recoup investment in 10 years)	Moderately Better (recoup investment in 3.7 years)	Conspicuously Better (recoup investment in 1.4 years)	Undoubtedly Better (recoup investment in 0.5 years)

Figure 3. Rating the cost benefit of having the function performed.

- **Step 5 –** Evaluate Risks.

  To evaluate risk we chose four components: reduction in risk to human health due to radiation, reduction in risk to human health due to other hazards, reduction in risk to environment, reduction in risk as a result of enhancing the sustainability of the LTS Program.

  The first three of these factors are standard considerations. The reduction in risk to human health has been broken out into two components; one covering radiation risks, and the second covering other risks. This not only allows for a separate consideration of radiation issues, but we also use it to double the contribution of reduction in risk to human health. The fourth component, reduction in risk as a result of enhancing the sustainability of the LTS program, focuses more on the organizational issues inherent in LTS.

V. CALCULATING FIGURES OF MERIT

Each rating has a scale between 5 and 7 points. The rating scales used to measure the designated variables or modifiers were adapted from Meister.[5] In order to calculate a quantitative Figure of Merit, each rating on the structured forms had an associated numeric weighting. The numeric weightings assigned to the "stages of technological development" were adapted using the 6-scale stage and gate system designated by the Office of Science and Technology.[1] The scales for evaluating technological success and implementation success are 5-point scales and have parallel wording with the phrases eliciting responses at least one standard deviation apart. The scale for the cost metric is a 7-point rating scale. We felt that raters might have more concrete information on cost and thus could reliably make ratings on a 7-point scale rather than the 5-point scales used for technological success and implementation success.

The labels for the 7 point scales were selected from sets given by Meister[5] that have parallel wording with the phrases being at least one standard deviation apart. The wording is the same as the 5-point scales with extra points on each end. In the case where there is no existing technology, the wording for the scale is anchored by the time needed to recoup investment.

After all the ratings are completed, a cost metric and a risk metric are then calculated by using the Figure of Merit for each proposed technology (See Equations 1 and 2 below). The Figure of Merit used in this process was modified from the original Figure of Merit used by the Environmental Management Office of Science and Technology.[4] The resulting figures are used to assist the user(s) in prioritizing technologies to receive funding for future research and development. The Figures of Merit are dimensionless numbers that can only be used to compare one proposed technology against another. These figures are useful in comparing (prioritizing and ranking) proposed technologies within a bin (i.e. stage of development) to determine the level of funding that an individual proposed technology would receive. The Figures of Merit are not meaningful in themselves, but are used in comparison with other calculated Figures of Merit values within the same "bin."

The Figures of Merit calculations for cost and risk are given below:

[1] Figure of Merit (Cost) = $L(T) \bullet L(I) \bullet M_{Cost}$

[2] Figure of Merit (Risk) = $L(T) \bullet L(I) \bullet B_{Risk}$

Where:

$L(T)$ = likelihood of technological success of the proposed technology.

$L(I)$ = likelihood of implementation success of the proposed technology.

M_{Cost} = cost metric for the proposed technology.

B_{Risk} = risk benefit metric of using the proposed technology.

Once the Figures of Merit are calculated for cost and risk, the results for the proposed technologies can be entered as data points in a graphical representation.

An example of the graphical representation of the figures of merit for proposed technologies is displayed in Figure 4.

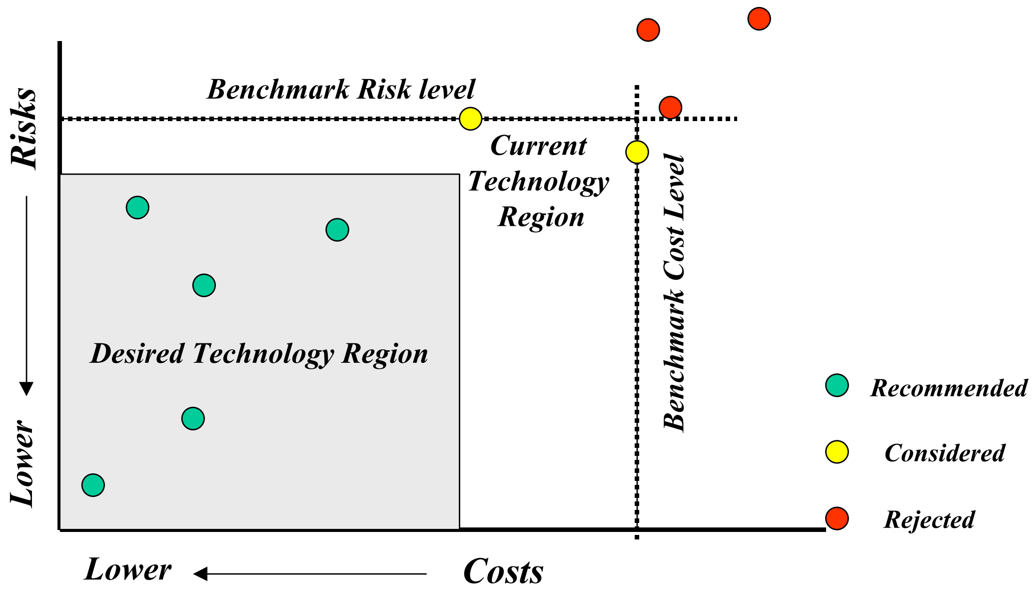

Figure 4. Graph of technologies with cost figure of merit vs. risk figure of merit.

So, from this example we can conclude that there are 5 technologies that fall into the "desired region." These technologies have reduced risk and cost associated with them. Three others are rejected because they are outside of the benchmark range for both cost and risk and two are possible considerations.

VI. PROCESS IMPLEMENTATION

Two versions of the ratings scales were developed to assist the working groups: a computer-based version and a paper-based version. In the computer-based version, the user will only be presented with the relevant ratings. Decisions concerning which rating sheets to use and calculations of figures of merit are made automatically by the computer. The paper-based version will contain all information needed to execute the process but will require facilitators to assist the teams in identifying the appropriate rating sheets and in calculating the resulting Figures of Merit.

VII. DISCUSSION

The purpose of this project was to develop a systematic approach in identifying and prioritizing technology concepts and systems for future R&D funding. We chose an expert estimation approach, specifically the Nominal Group Technique due, to the limited information available to the teams making the prioritization decisions and the availability of knowledgeable experts.

The prioritization of technologies is a 5-step process: 1) Evaluating the stage of technological development, 2) Evaluating the likelihood of technological success, 3) Evaluating the likelihood of implementation success, 4) Calculating costs, and 5) Calculating risks. Comparative structured ratings are done within these five steps and the values obtained are used to calculate the Figures of Merit for both cost and risk.

The approach we used to develop this prioritization process may be useful in similar tasks, because it is more systematic that guessing. Additionally, all team members contribute to the final result, not just the most vocal members.

VIII. ACKNOWLEDGEMENTS

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