LA-12175-MS

The Prioritization of Environment, Safety, and Health Activities

Los Alamos

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

An Affirmative Action/Equal Opportunity Employer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither The Regents of the University of California, the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by The Regents of the University of California, the United States Government, or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of The Regents of the University of California, the United States Government, or any agency thereof.

LA--12175-MS

DE92 000089

The Prioritization of Environment, Safety, and Health Activities

Harry Otway
John M. Puckett
Detlof von Winterfeldt

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

THE PRIORITIZATION OF ENVIRONMENT, SAFETY, AND HEALTH ACTIVITIES

by

Harry Otway,[1] John M. Puckett,[1] and Detlof von Winterfeldt[2]

ABSTRACT

Federal facilities, including the national laboratories, must bring existing operations into compliance with environment, safety, and health (ES&H) regulations while restoring sites of past operations to conform with today's more rigorous standards. The need for ES&H resources is increasing while overall budgets are decreasing, and the resulting staffing and financial constraints often make it impossible to carry out all necessary activities simultaneously. This has stimulated interest in formal methods to prioritize ES&H activities. We describe the development of an approach called MAPP (Multi-Attribute Prioritization Process), which features expert judgment, user values, and intensive user participation in the system design process. We present results of its application to the prioritization of 41 ES&H activities having a total cost of over $25 million. We conclude that the insights gained from user participation in the design process and the formal prioritization results are probably of comparable value.

0. AN INTRODUCTORY NOTE

This report describes the process of developing and implementing a system called MAPP (Multi-Attribute Prioritization Process) to help prioritize activities of the Health, Safety, and Environment (HSE) Division at the Los Alamos National Laboratory (LANL). The division's mission is to support line managers with resources and programs to ensure that risks to workers, the public, and the environment are responsibly managed. Its staffing level is about 550 full-time equivalents and its total annual budget is about $125 million. LANL operations which must be monitored, including those of contractors, employ more than 10,000 people.

Two of the authors (HO and DvW) were the analysts and designers of the MAPP system, while the other author (JMP), as the HSE Division Leader, was its "customer" as well as a participant in its design. Thus we will be presenting both designer and customer perspectives. This is unusual because the literature in this field normally belongs to the designers alone, who are free to write their own version of the success of the application. The body of the report is written primarily from the viewpoint of the system designers, while the final section presents the division leader's perspective.

The next section summarizes the background for the current interest in prioritization, while Section 2 discusses the different approaches available and our choice of one based on multi-attribute utility analysis (MAUA). Section 3 gives an overview of MAUA and the steps in developing a MAUA-based prioritization system. Section 4 describes the MAPP design process and presents the system structure, while Section 5 reviews how projects were scored and reports prioritization results. In Section 6 we discuss this application as background for the conclusions presented in Section 7. The impressions of the system's "customer" are in Section 8.

1. BACKGROUND

Many organizations whose primary function is research and development must dramatically increase resources devoted to environment, safety, and health (ES&H) issues

[1]Health, Safety, and Environment Division, Los Alamos National Laboratory, Los Alamos, NM 87545.

[2]Institute of Safety and Systems Management, University of Southern California, Los Angeles, CA 90089-0021; Collaborator at Los Alamos.

while overall funding is decreasing. At the national laboratories, this reflects an enhanced awareness of the importance of ES&H, but also that federal facilities have only recently begun to be held accountable for compliance with ES&H regulations. Thus a backlog of current activities must be brought into compliance in a dynamic, increasingly strict regulatory climate, and sites of past operations restored to conform with today's more rigorous standards.

Staffing and financial constraints make it difficult to carry out all required activities simultaneously. However, all activities are not equally effective; some provide only marginal ES&H improvements at relatively high cost, while others could even cause a net loss in ES&H quality by diverting scarce resources away from more productive activities. This has encouraged the development of formal methods to prioritize activities so that funds can be allocated more effectively.

2. CHOOSING A PRIORITIZATION APPROACH

We propose several dimensions on which prioritization approaches can be assessed, and use them to discuss several recent prioritization systems as background for our decision to base MAPP on multi-attribute utility analysis (MAUA).

2.1 The source of values and facts

Values come into the design process in deciding which criteria should be used to judge the kind of activity to be prioritized. For example, worker safety would be expected to be one of the criteria relevant to the prioritization of ES&H activities. At one extreme, the system designers could decide what should be important to the prospective users. At the other end of this continuum, the designers could help the users to identify and articulate what is important to them.

Sometimes it is useful to involve other stakeholders in the value elicitation part of system design. When projects affect the local community, their perspective on the prioritization criteria might complement the views of the user organization. Similarly, public interest group participation in setting prioritization criteria could help to identify differences early on so that they could be dealt with before commitments have been made and positions taken.

"Facts" come into the picture in determining how the projects being prioritized score on each of the criteria, for example, how many worker lives will a proposed ES&H activity save? Again there is a dichotomy, which ranges from using data and models to calculate risks to basing estimates on the formal use of expert judgment.

The regulation and management of hazardous activities increasingly rely on formal expert judgment processes where experience is lacking and traditional "good science" is unable to deliver unambiguous "facts" (Otway and von Winterfeldt, in press). An example is the "trans-scientific" (Weinberg, 1972) problem of trying to assess empirically the effects of low-level toxins. Expert judgment has always played a significant, if often unrecognized role in analysis; recent trends are to make it formal, explicit, and documented so it can be identified and reviewed by others. Expert judgment is now accepted as a reasonable substitute for costly and time-consuming data collection efforts and "number crunching" calculations, one which can provide estimates that are often no more uncertain.

2.2 Process issues: Participation and formality

If a system is to include user values, then obviously users must participate in the design process so that their values can be elicited. Participation furthers user buy-in; the system is more likely to be accepted if the user group knows it reflects their values. In addition, users will have a better understanding of how it works and its limitations. User participation in the design of decision support systems for environmental risk management has demonstrated its importance (Otway and Haastrup, 1988) for meeting user needs.

Each value and factual judgment, and its underlying reasoning, must be documented as part of a formal process of system design and use. In sensitive areas such as ES&H, decisions are often controversial and it may be necessary to defend the reasonableness of the system and its results. The system is easier to defend if it is based on a well-documented design process which included a broad range of views. Formality and documentation have also proved important when results have been challenged in lawsuits or reviewed by peer groups, *eg*, the National Academy of Sciences review of the Department of Energy's prioritization of waste-repository sites (Board on Radioactive Waste Management, 1985).

2.3 Theoretical foundations and simplicity

Some prioritization system have a solid theoretical foundation, while others are based on *ad hoc* assumptions of sometimes uneven quality. Cost-benefit analysis and multi-attribute utility analysis are the most common theoretical bases for existing prioritization systems. Each has a respectable theoretical foundation and intellectual history, in contrast to *ad hoc* systems, such as simple rating and weighting or categorization.

Simplicity is vital so that the system is transparent, understandable, and easy to use; especially if it is to be used effectively, defended, and its results communicated to others after its designers have left. Simplicity is sometimes thought to be incompatible with a sound theoretical basis. However, if the designers keep in mind the dual objectives of simplicity and theoretical foundation, they are often able to design into the system theoretically acceptable shortcuts and simplifications. We believe that achieving simplicity depends more upon the designers' awareness of its importance than on the foundations of the system, but that a proven theoretical approach provides the best starting point.

2.4 A review of recent prioritization systems

Edwards, *et al* (1988) developed a MAUA-based system to prioritize R&D activities for the Construction Engineering Research Laboratory of the Army Corps of Engineers. Of approximately 200 research proposals made each year, only half could be funded, so the prioritization task was to help select new projects, decide which existing ones to continue, and to allocate resources among them. Managers were interviewed to learn what the goals of the system should be and to determine the prioritization criteria. Four senior managers assigned weights to the criteria and internal teams scored the projects. This system was developed with a moderate degree of user involvement and considered user values, but not those of external groups. It accommodated expert judgment, had a reasonable theoretical foundation and was quite simple to use; it has now been successfully used for several years.

One of the most ambitious recent prioritization systems was designed by Longo, *et al* (1990) to help the Department of Energy (DOE) headquarters in its annual allocation of some $2 billion among environmental restoration (ER) projects at its installations. Naturally, there is strong competition for funds, and allocation is further complicated by regulatory requirements and contractual agreements. The system is MAUA-based and is coupled with a formal budget optimization system. Users were involved in developing the prioritization criteria and also in the design of the scoring process. There was some external review, but no direct external involvement in these tasks. Criteria weights were elicited from selected DOE managers. An elaborate scoring system was set up to assist laboratory experts to make judgments about the benefits and costs of the proposed ER projects. A complex computer model then integrated the weights, the expert scores, and the cost information into a budget optimization algorithm.

This system incorporated a fair amount of user values, but did not directly include external values. The scoring inputs came primarily from expert judgments using a formal elicitation process. The system is theoretically sound, but quite complex, and has been criticized for its complexity and the limited external involvement (Weapons Complex Monitor, 1991); DOE currently has an effort underway to provide for more public involvement in future versions. It has been used in preliminary form for two budget cycles.

The Priority Planning Grid (PPG, Ritts, 1990) was developed to prioritize health and safety projects and has been used at several DOE facilities, *eg*, Rocky Flats, Oak Ridge National Laboratory, and the Hanford Site. Its goal is to achieve a more reasonable resource allocation among competing ES&H activities.

The system design had minimal user involvement: The prioritization criteria were developed primarily by the system designer and their weights were derived from a literature review and some management interviews. Project scoring is a mix of risk analysis and expert judgment in which the scorers assign a project to one of several categories on each criterion. The overall priority score is then calculated as a weighted average. The advantages of this system are that it is simple and that it accommodates expert judgment. The disadvantages are that it is based on arbitrary values, has no theoretical or process justification, and poor documentation.

Peerenboom, *et al* (1989) developed a system to prioritize coal gasification R&D projects at a DOE installation, and to allocate funds among competing projects. In addition to the usual problem of budget allocation in a resource-constrained environment, this system also had to provide an optimal portfolio of projects, some of which were complementary, while others were not. This MAUA-based system falls between those of Longo, *et al* (1990) and Edwards, *et al* (1988) in theoretical rigor and complexity. Its values were developed in close cooperation with the user, but it had little or no external value inputs. The system relies on expert judgments, but does not use a formal elicitation process. It has a fairly solid theoretical foundation and is quite simple to use. Process, defensibility and user buy-in were good.

Buehring, *et al* (1991) built on the coal gasification experience to develop a prioritization system for DOE's waste management operations. They propose to enhance the theoretical foundation of the system while keeping it simple to use. External involvement in the value part of the system is foreseen as well as a more elaborate and better documented process for system development and use. This system has not yet been implemented.

2.5 The selection of MAUA

When designing a new system, the approach that is best depends on the nature of the application and its organizational context. For the HSE Division application, we wanted a simple system with a defensible theoretical foundation. Further, it should feature user values, have intensive user participation in system design, and employ formal and documented expert judgment. This is compatible with an approach based on MAUA, which in addition to its strong theoretical basis, has a long history of successful use in support of policy decisions. Thus we chose to base the new system (MAPP) on MAUA.

3.0 MULTI-ATTRIBUTE UTILITY ANALYSIS (MAUA)

A basic premise of MAUA is that a complex global decision (such as choosing among different ES&H projects) can be decomposed into a number of smaller (and easier) decisions to be made on each of the problem's underlying attributes or dimensions. The results of the many small decisions are then reassembled to give guidance on the large decision. The attributes are nothing more than the factors that the decision makers believe relevant to the judgment to be made. In this report, these underlying dimensions will be called prioritization criteria.

When considering ES&H project priorities, managers typically have to weigh multiple objectives, including various aspects of health and safety (*eg*, public and workers), environmental issues (*eg*, effects on air, water, biota), and compliance requirements. When resources are limited, these objectives conflict, forcing difficult tradeoffs: *eg*, between compliance and programmatic objectives, worker and public safety, or environmental protection and human life.

MAUA was developed to help decision makers cope with these complexities (*eg*, Keeney and Raiffa, 1976; von Winterfeldt and Edwards, 1986). It provides an explicit process, a logical structure, and proven assessment techniques for making tradeoffs in resource-constrained environments. MAUA extends the classic expected utility theory of von Neumann and Morgenstern (1947) to multiple objective problems, and has been applied to topics as diverse as facility siting (Keeney, 1980; Merkhofer and Keeney, 1987), technology choice (Chinnis, *et al*, 1975; Keeney, *et al*, 1986), social program evaluation (Edwards, 1980), and prioritization activities (Edwards, *et al*, 1988; Buehring, *et al*, 1990; Longo, *et al*, 1990; Buehring, *et al*, 1991).

3.1 An overview of the MAUA development process

The formal principles for developing a MAUA-based prioritization system are fairly straightforward:

1. The prioritization criteria are developed, usually in interviews with the stakeholders (*eg*, system users) in the prioritization, who participate in the design process. The criteria are simply those factors that they consider relevant to judging the kind of activity under consideration.
2. The criteria are structured as a "value tree" (von Winterfeldt and Edwards, 1986) that shows general prioritization concerns at the root and increasingly detailed criteria in its branches and twigs.
3. The lowest-level criteria are defined, either numerically or qualitatively, so the participants agree on criteria meaning and range.
4. The participants assign weights to the criteria that implicitly express the tradeoffs among them.
5. The participants score projects on each of the criteria, usually by using expert judgment to assess where each project falls in the range of each criterion.
6. Overall priority scores are calculated for each project by multiplying its score on each criterion by the corresponding criterion weight and adding the products across criteria. For those who like equations, this can be expressed formally as

$$PS_j = \sum_{i=1}^{n} w_i s_{ij},$$

where
PS_j is the total priority score calculated for project j,
s_{ij} is the score of project j on the ith criterion,
w_i is the weight assigned to criterion i, and
n is the number of criteria.

If the priority score, PS, is to be used to support budget decisions, two additional steps can help find the most cost-effective funding level:

7. The scoring of each project is repeated at several budget levels so a curve of priority score (a benefit measure) vs cost can be constructed. (In practice, this curve can often be estimated by the scorers.)
8. Algorithms are developed to optimize the allocation of funds so that the largest amount of benefit (*ie*, the sum of priorities) is obtained for the portfolio of activities.

4. THE MAPP-HSE DESIGN: PRIORITIZATION CRITERIA AND WEIGHTS

While the formal ideas for developing a MAUA-based system for prioritizing ES&H projects are straightforward, their practical implementation in HSE Division presented some interesting challenges. First, the division operates under strong legal and other pressures to perform ES&H projects, but the budget to carry out the necessary activities is limited and the burden on management and staff had reached the limit of tolerability. Division managers considered it necessary to cut low priority projects and to curtail those that did not produce marginal benefits commensurate with their cost.

Second, the division represents three quite different problem areas: radiation protection, occupational health and safety, and environment. The professionals and managers working within these areas naturally have different perspectives and criteria by which they assess the importance of projects. Third, the division engages in unusually diverse projects, ranging from small, compliance-driven modifications to multi-million dollar environmental clean-up activities. Fourth, there are very little data to quantitatively assess the potential benefits of projects, *eg*, to reduce worker risks or environmental damage. Thus, the prospective prioritization system had to rely substantially on professional judgment rather than data.

These special problems confirmed our earlier decision, based on theoretical considerations, to involve division managers extensively in the construction and implementation of the MAPP system and to rely heavily on their expert judgments. The rest of this section describes the process of constructing the system, and presents the prioritization criteria and their respective weights.

4.1 Small group interviews

We began the MAPP-HSE design by conducting eight small-group interviews with a total of 20 division-level managers, group leaders, and selected senior staff. The two main objectives of the interviews were to learn what users expected of the system, and to determine the criteria they considered relevant for the prioritization of ES&H activities. The interviews lasted about two hours each, and often took on a therapeutic dimension as group leaders told of their frustration in trying to master an increasing work load with limited resources.

Participants generally agreed that the main benefit hoped for from the system was support to "just say no" to unimportant or marginal projects. A secondary benefit would be a more rational distribution of funds among projects that are part of the division's base program.

Several fundamental issues were raised regarding the role of compliance in establishing priorities and the political nature of many priority decisions. It was generally agreed that the system should function so that reasonable people, not influenced solely by compliance concerns nor overly sensitive to political factors, should be comfortable with its outcomes. Thus the system should be normative in nature, giving guidance as to how priorities should be allocated in a reasonable world, rather than being descriptive and merely reflecting how priorities currently are established.

Most of the effort in these interviews was spent on identifying and structuring the prioritization criteria. This followed the standard process for eliciting value trees (von Winterfeldt and Edwards, 1986; Keeney and von Winterfeldt, 1987). Sample questions asked were: Why is a project important? How would you characterize a frivolous project that should not be funded? What would be your main criteria for prioritizing? How would you define these criteria? These questions generated a long list of criteria that were integrated, edited, and structured into the first-draft value tree shown in Figure 1.

This rough value tree was sent to the interviewees for comment, and their input was incorporated in a revised tree for presentation to a meeting of the division management team.

4.2 First management team meeting.

A one-day retreat of the HSE Division management (*ie*, the twenty people participating in the MAPP design process) was held at a local hotel. The first agenda item was to discuss and further refine the revised value tree. Discussions were supported by on-line computer overhead displays so changes could be made in real time.

The next step was to obtain preliminary criteria weights by asking the participants to divide a total of 100 points among the individual criteria to indicate their relative importance. Since the criteria had not yet been formally defined, they were told to respond based on their personal definitions of them. The results of this weighting were discussed and the managers agreed that they seemed to reflect their intuition about the relative importance of the criteria.

Then the participants were organized in working groups, and each group given the task of drafting scales and markers to define some of the criteria. Scales and markers should provide unambiguous indices of how well or how poorly a project could possibly perform on a criterion. For example, the criterion "short-term injuries to workers" might be measured by the scale, "number of serious injuries during the next year." The low marker would be zero injuries, while the high marker would represent the most important injury-saving project the managers could realistically imagine, *eg*, one preventing ten injuries per year.

The managers were told that it is not always possible to construct quantitative markers, so the criteria could also be defined qualitatively. For example, to define compliance, the high marker might be "Risk of serious violation of a law or regulation with possible personal criminal liability."

After draft scales and markers had been prepared, they were discussed in conjunction with the value tree, resulting in yet another version of the tree. The most notable change was that the criterion "Public Fears and Concerns" was made more general to reflect the importance of communication with workers and the public.

After agreeing on the new tree structure, the managers were asked to weight the criteria again. This time they were told that their weights should reflect the difference in importance they perceived between the low and high marker of each criterion. Despite the new instructions and the more precise criteria definitions, results were similar to the first weighting.

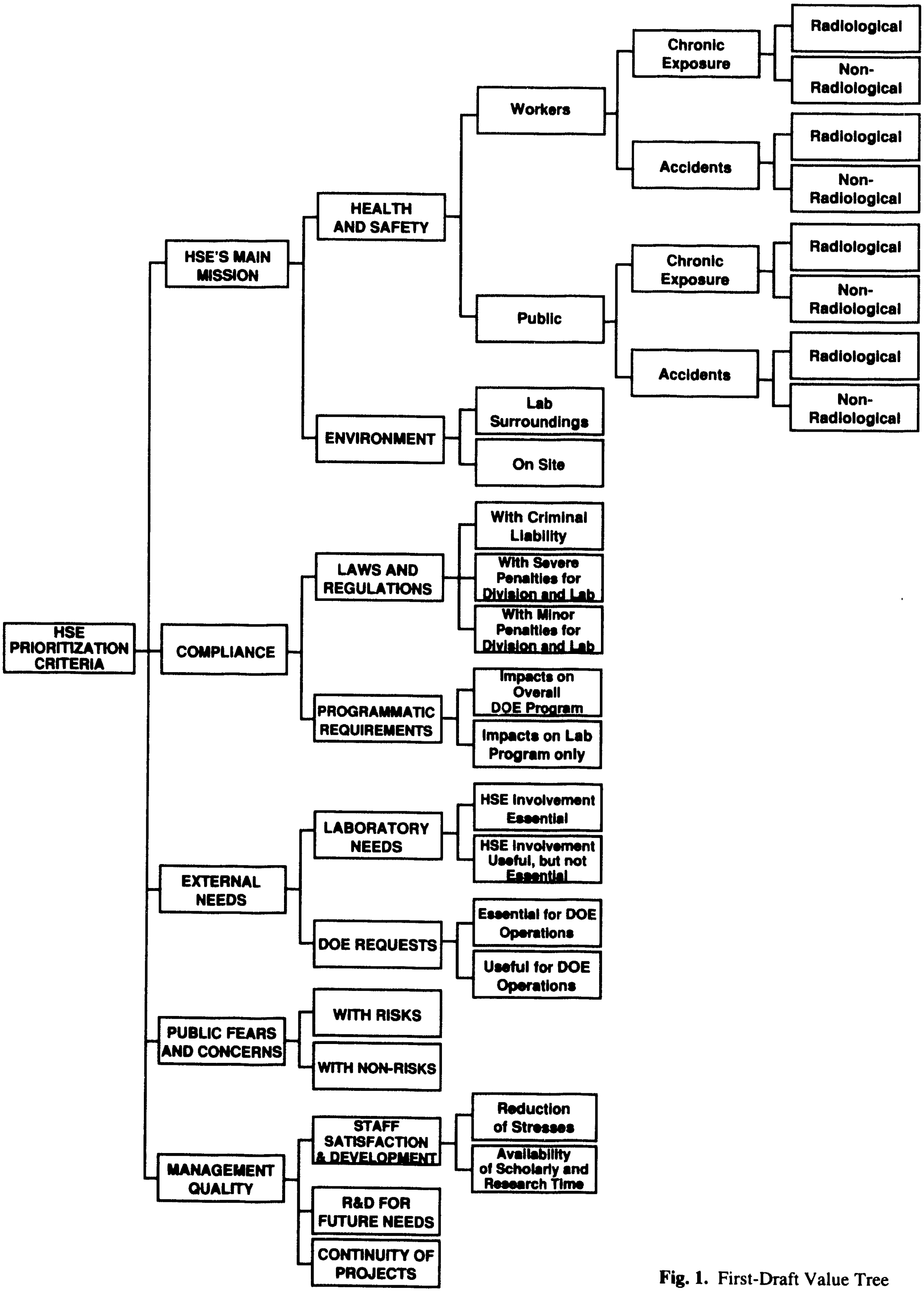


Fig. 1. First-Draft Value Tree

4.3 Second management team meeting

The second management retreat lasted about six hours and was convened at University House, a secluded Laboratory facility used for small meetings.

Prior to the meeting we had again revised the value tree to establish a better balance among the main criteria, and edited the draft markers prepared by the participants to ensure that they were consistent and unambiguous. We also expanded the marker definitions by adding a middle marker, generally half way between the upper and lower markers, a useful reference point when scoring projects on the criteria. In the first and second round weightings, the criterion "Protection of Workers, Public and the Environment" received about 50% of the total weight of the value tree. This, coupled with the fact that ES&H is the main mission of the division, led us to divide it into four sub-criteria. Other changes were minor. The final value tree for the HSE application of MAPP is shown in Figure 2.

The revised value tree and markers were presented and discussed at the beginning of the meeting. The tree was accepted with some minor wording changes, while several modifications were made to the markers. Concern was expressed that managers might not be able to make the judgments required to score projects on the scales defined by the markers, primarily because the markers were more quantitative and precise than the corresponding knowledge of project benefits. After a lengthy discussion, it was decided that each scorer could choose between using the quantitative or the qualitative marker examples. (In later project scoring, most people used the quantitative markers). The final markers are shown in Tables 1 through 7.

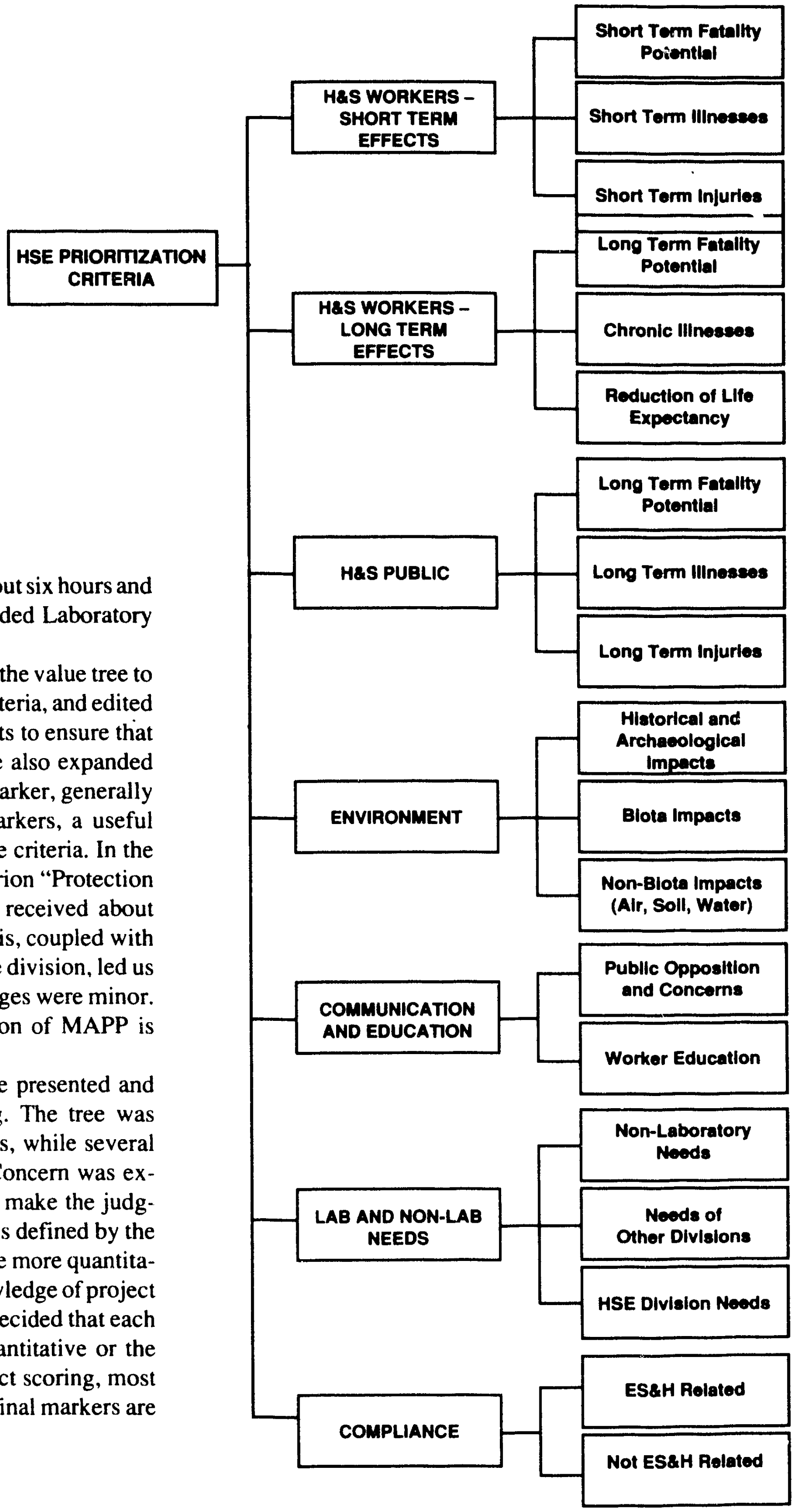


Fig. 2. Final Value Tree

Table 1. Markers for the Criteria Related to the Health and Safety of Workers in the Short Term

Note: The upper marker is described as an impact that would occur if the project of activity (P&A) is not carried out.

UPPER MARKER (w/o P&A)	MIDDLE MARKER	LOWER MARKER (w/ P&A)
100	50	0
	HEALTH AND SAFETY-WORKERS-SHORT TERM	
	1. H&S-WORKERS-SHORT TERM-FATALITIES	
Significant short term fatality potential, e.g., a **.20 chance of a worker dying next year** from electrocution or other acute hazards	Some short term fatality potential, e.g., a **.10 chance of a worker dying next year** from electrocution or other acute hazards	**No short term fatality potential**
	2. H&S-WORKERS-SHORT TERM-ILLNESS	
Significant potential for short term illnesses, e.g., about **2 serious illnesses per year** leading to at least 200 lost workdays or **20 non serious illness per year** leading to the same number of lost workdays	Some potential for short term illnesses, e.g., about **1 serious illness per year** leading to at least 100 lost workdays or **20 non serious illnesses per year** leading to the same number of lost workdays	**No short term illnesses**
	3. H&S-WORKERS-SHORT TERM-INJURIES	
Significant potential for short term injuries, e.g., about **2 serious injuries per year**, including severe burns, broken limbs, etc.	Some potential for short term injuries, e.g., about **1 serious injury per year**, including severe burns, broken limbs, etc.	**No short term injuries**
-------- 0		

Table 2. Markers for the Criteria Related to the Health and Safety of Workers in the Long Term

Note: The upper marker is described as an impact that would occur if the project of activity (P&A) is not carried out.

UPPER MARKER (w/o P&A)	MIDDLE MARKER	LOWER MARKER (w/ P&A)
100	50	0
	HEALTH AND SAFETY-WORKERS-LONG TERM	
	4. H&S-WORKERS-LONG TERM-FATALITY POTENTIAL	
Significant potential for fatalities in the long term, e.g., about **2 fatalities per ten years** from from various job hazards	Some long term fatality potential, e.g., **1 fatality per ten years** from various job hazards	**No long term fatality potential**
	5. H&S-WORKERS-LONG TERM-CHRONIC ILLNESS	
Significant potential for chronic illnesses, e.g., **10 chronic illnesses per year** such as non-fatal cancers	Some potential for chronic illnesses, e.g., **5 chronic illness per year**, such as non-fatal cancers	**No chronic illnesses**
	6. H&S-WORKERS-LONG TERM-LIFE EXPECTANCY	
Significant losses of life expectancy, e.g., **100 years for the LANL worker**, population or about 1 year for each worker of an exposed population of 100 workers or about **4 days per LANL worker**	Some loss of life expectancy, e.g., **50 years for the LANL worker population** or about 1/2 year for each worker of an exposed population of **100 workers or about 2 days per LANL woker**	**No loss of life expectancy**

Table 3. Markers for the Criteria Related to the Health and Safety of the Public in the Long Term

Note: The upper marker is described as an impact that would occur if the project of activity (P&A) is not carried out.

UPPER MARKER (w/o P&A) 100	MIDDLE MARKER 50	LOWER MARKER (w/ P&A) 0
	HEALTH AND SAFETY-PUBLIC-LONG TERM	
	7. H&S-PUBLIC-LONG TERM-FATALITY POTENTIAL	
Small, but credible fatality risk for the residents of Los Alamos, e.g., **10^{-6} per person per year**	Small fatality risk for the residents of Los Alamos, e.g., **1/2 x 10^{-6} per person per year**	**No public fatality risk**
	8. H&S-PUBLIC-LONG TERM-ILLNESS POTENTIAL	
Small, but credible risk of illness to the residents of Los Alamos, e.g., **10^{-5} per person per year**	Small risk of illness to the residents of Los Alamos, e.g., **1/2 x 10^{-5} per person per year**	**No risk of public illnesses**
	9. H&S-PUBLIC-LONG TERM-INJURIES	
Some injury risk for the residents of Los Alamos, e.g., **1 serious injury per year** due to a LANL operation	Small injury risk for the residents of Los Alamos, e.g., **1 serious injury every 2 years** due to LANL operations	**No risk of public injuries**

Table 4. Markers for Criteria Related to the Environment

Note: The upper marker is described as an impact that would occur if the project of activity (P&A) is not carried out.

UPPER MARKER (w/o P&A) 100	MIDDLE MARKER 50	LOWER MARKER (w/ P&A) 0
	ENVIRONMENT	
	10. ENVIRONMENT-HISTORICAL AND ARCHAEOLOGICAL	
Significant archaeological or historical impacts, e.g., destruction of **one historical site of significance** as defined in the National Register of Historic Places	Some archaeological or historical impact, e.g., destruction of **one historical site of minor significance** as defined in the National Register of Historic Places	**No archaeological or historical impacts**
	11. ENVIRONMENT-BIOTA IMPACTS	
Significant impact on a biologically sensitive area, e.g., **destruction of one acre of wetland** or of an area occupied by threatened or endangered species	Some impact on a biologically sensitive area, e.g., **destruction of 1/2 acre of wetland** or of an area occupied by threatened and endangered species	**No impact on biota**
	12. ENVIRONMENT-A BIOTIC (WATER, AIR, SOIL)	
Significant impact on air, water or soil, e.g., from **chemicals threatening the contamination of an aquifer** or from a significant air pollution source	Some impact on air, water or soil, e.g., from **chemicals entering the soil** or from a source of air pollution	**No impacts on air, water or soil**

Table 5. Markers for Criteria Related to Communication and Education

Note: The upper marker is described as an impact that would occur if the project of activity (P&A) is not carried out.

UPPER MARKER (w/o P&A)	MIDDLE MARKER	LOWER MARKER (w/ P&A)
100	50	0
	COMMUNICATION AND EDUCATION	
	13. COMMUNICATION AND EDUCATION-PUBLIC CONCERNS	
Active public opposition to lab activities, public intervention at the political level, mistrust of information provided, persistent fears	**Some public opposition** to lab activities, some media interest and coverage, information provided not fully satisfactory, some fears	**No public concerns**, or existing concerns are addressed in a way that satisfies all parties
	14. COMMUNICATION AND EDUCATION-INTERNAL TO LANL	
Potential to jeopardize worker health and safety by **not providing useful information**, missed opportunity for important worker education	**Only partial information** is provided that could benefit worker health and safety	**Useful information** is provided that benefits workers health and safety

Table 6. Markers for the Criteria Related to Laboratory and Non-Laboratory Needs

Note: The upper marker is described as an impact that would occur if the project of activity (P&A) is not carried out.

UPPER MARKER (w/o P&A)	MIDDLE MARKER	LOWER MARKER (w/ P&A)
100	50	0
	COMMUNICATION AND EDUCATION	
	15. LABORATORY AND NON-LABORATORY NEEDS-NON LAB	
Very high priority of an external agency, agency need cannot be met without HSE staff	**Medium priority of an external agency**, HSE staff involvement beneficial, but not essential	**Low priority of an external agency**, need can be met without HSE staff involvement
	16. LABORATORY AND NON-LABORATORY NEEDS-OTHER DIVISIONS	
Very important need of a LANL division and need cannot be met without HSE staff	**Medium important need of a LANL division**, HSE staff involvement beneficial, but not essential	**Low priority need of a LANL division**
	17. LABORATORY AND NON-LABORATORY NEEDS-HSE DIVISION	
Disruption of ongoing HSE project or activity that is important to HSE. Information that is needed for longer term activities of HSE is not collected	**Some negative impact ongoing HSE project** or activity. Only partial information useful for longer term activities is collected	**No negative impacts** on ongoing or future HSE activities or projects

Table 7. Markers for Criteria Related to Compliance With Laws, Regulations and DOE Orders

Note: The upper marker is described as an impact that would occur if the project of activity (P&A) is not carried out.

UPPER MARKER (W/O P&A)	MIDDLE MARKER	LOWER MARKER (w/ P&A)
100	50	0
	COMPLIANCE WITH LAWS, REGULATIONS AND DOE ORDERS	
	18. COMPLIANCE	
Violation of strict compliance requirements of a regulation, law or order; possible personal criminal liability, likely severe financial or other consequences to LANL, possible project shut down	**Possible violation of some aspect of a regulation, law or order**, no personal criminal liability, but possible repercussions like delays of LANL or HSE projects	**No compliance risk**

We then introduced a more precise weighting procedure called "swing weighting." Respondents are asked to judge the importance of a "swing" in each criterion from its low to its high marker (see von Winterfeldt and Edwards, 1986), *ie*, to assume that a project is described by the low marker of each criterion, and then to indicate which of the criteria would be most important to change to the high marker first, second, third, and so on. The lowest ranked criterion is then assigned an arbitrary weight of ten, and all other criteria assigned weights relative to this ten-point criterion. Thus, assigning a criterion a weight of 50 means that the swing from its low to the high marker is five times more important than the swing from the low to high marker of the lowest ranked criterion. The weights are normalized to sum to 100%.

In implementing this procedure we first asked for swing weights for the sub-criteria within each main criterion, and then for the set of main criteria. In the latter case, respondents were again to assume that all sub-criteria were at their low markers and that they could change all of the markers within one main criterion to their highest level. Which one would they change first, second, and so on? The rating and normalization task was the same.

The results were quite different than the first two rounds of weighting. ES&H concerns got a much larger share of the total weight (72% vs 54%), with the weights for worker health and safety going up dramatically, while the weight for environmental impacts went down. Since the worker health and safety criteria markers are more important than the environmental markers, this is an expected result of using the swing weighting procedure.

4.4 Final elicitation of weights

The final criterion weights were elicited in thirty-minute individual interviews with the managers, using the same procedure. This format was chosen to give them a chance to ask questions, to allow the interviewer to make consistency checks, and to ensure that every respondent understood the task. The results of this weighting, shown in Table 3, were similar to those of the third round. **It is important to note that the criteria weights shown in Table 8 have meaning only in conjunction with the scales and markers (Tables 1 to 7) that define the criteria.**

During the system development process it had become apparent that there were significant value differences between HSE Division managers in the traditional health and safety (H&S) disciplines and those working in environmental management (EM). The character of the work is very different for these two disciplinary areas. For example, H&S activities focus on human beings and the negative outcomes are injuries, illnesses, and in the extreme death, while the environmental work is compliance oriented. Failure to comply with the contractual terms of many of the environmental activities can carry civil and criminal penalties.

A differential analysis of the criteria weights elicited from H&S managers and their EM counterparts showed that the weights were roughly similar except for the compliance criterion, which the H&S managers gave a weight of 14%, compared to 26% for the EM managers. This striking difference suggested a certain duality within HSE Division, but the small sizes of the two subgroups did not allow detailed statistical analysis. We will return to this organizational duality, because it surfaced again later when we began scoring projects.

Table 8. Average Weights for Members of the HSE Division and the ES&H Council

	ALL n=37	HSE n=18	COUNCIL n=19	ANOVA PROBABILITY	SIGNIFICANCE * <.05 ** <.01
H&S WORKERS-SHORT TERM	**0.253**	**0.262**	**0.244**	*0.642*	
Fatalities	0.171	0.161	0.178	*0.858*	
Illnesses	0.036	0.046	0.027	*0.019*	*
Injuries	0.046	0.053	0.039	*0.408*	
H&S WORKERS-LONG TERM	**0.192**	**0.188**	**0.195**	*0.990*	
Fatalities	0.099	0.079	0.118	*0.097*	
Chronic Illnesses	0.060	0.078	0.043	*0.633*	
Life Expectancy	0.033	0.032	0.034	*0.795*	
H&S PUBLIC-LONG TERM	**0.138**	**0.090**	**0.183**	*0.003*	* *
Fatalities	0.066	0.038	0.092	*0.007*	* *
Illnesses	0.029	0.020	0.037	*0.092*	
Injuries	0.043	0.032	0.054	*0.098*	
ENVIRONMENT	**0.127**	**0.127**	**0.125**	*0.643*	
Historical and Archaeolog.	0.019	0.016	0.022	*0.346*	
Biota	0.037	0.037	0.037	*0.546*	
Non-Biota	0.070	0.074	0.066	*0.534*	
COMM. AND EDUCATION	**0.080**	**0.079**	**0.081**	*0.368*	
Public Concerns	0.035	0.036	0.033	*0.462*	
Internal Education	0.045	0.046	0.045	*0.457*	
LAB AND NON-LAB NEEDS	**0.074**	**0.081**	**0.068**	*0.427*	
Non-Lab Needs	0.030	0.032	0.029	*0.296*	
Other Division Needs	0.025	0.026	0.025	*0.852*	
HSE Needs	0.019	0.024	0.014	*0.081*	
COMPLIANCE	**0.137**	**0.173**	**0.104**	*0.002*	* *
ESH related	0.100	0.129	0.073	*0.003*	* *
Not ESH related	0.037	0.044	0.031	*0.400*	

Important Note: These criteria weights have meaning only in conjunction with the scales and markers (Tables 1 to 7) that define them.

4.5 ES&H Council weight elicitation

As a "reality check," criteria weights were also elicited from the ES&H Council, a group of senior Laboratory managers who recommend ES&H policies to the Laboratory director and oversee their implementation. Council members filled out swing weighting questionnaires for the criteria in the HSE Division value tree.

The ES&H Council weights compared very well (Table 8) with those of HSE Division. One difference was that the Council weights for public health and safety were higher. This can be interpreted as senior policy makers being more sensitive to any public health effects, no matter how minor. Alternatively, Council members may have been less attentive to the markers defining this criterion, relating more to its label than to the relatively low consequences of the marker swing.

The other significant difference was in the weight given to the compliance criterion, where the Council average was 10% compared to the HSE Division average of 17%. This difference is in part an artefact of the extremely high weights of the division's EM managers bringing up the division average weight. Obviously, the division EM managers feel pressures to avoid the severe penalties that could result from a compliance violation, however this difference could also be reflecting the Council members' view of the likelihood of these sanctions actually being imposed in practice.

5. SCORING HSE DIVISION PROJECTS AND ACTIVITIES

In this section we describe the procedures used to assign priority scores to projects, and then discuss scoring results and the resolution of several policy issues that emerged during this process.

5.1 The scoring procedure

Each project to be scored is presented to a scoring panel by a person familiar with it. The panel evaluates its impact on each of the lowest level criteria in the value tree, assigning scores between zero and 100 on each criterion.

For example, a project that would provide no health and safety benefits for workers in the short term would receive a zero score on that criterion because this corresponds to the low marker. If the project was expected to reduce the fatality risk of one worker by 20% in the next year, it would be given the high marker score of 100. Equivalencies can be used if the expected impacts are slightly different than those described by the markers, for example, if a project would reduce ten workers' fatality risk next year by 1% each, it would receive the middle marker score of 50, because this is approximately equivalent to reducing the fatality risk of one worker by 10%.

A sample project scoring sheet for the Thermoluminescent Dosimetry (TLD) program is shown in Figure 3.

5.2 TRIAL SCORING

The prioritization system was tested with four trial scoring panels, each of which scored five projects. The scoring meetings lasted about two hours each and involved between five and eight participants: a facilitator, who led the scoring; a project specialist, who provided technical information on the project being scored; the group leader responsible for the project; and the scorers, usually other group leaders representing different ES&H disciplines. Often the group leader responsible for the project filled the project specialist role.

Trial scoring led to several improvements and clarifications in the scoring process. For example, it was not clear if we should score project benefits (*eg*, reductions in health and safety risks or environmental impacts) or the risks and negative impacts if the project was not carried out. Most scorers felt more comfortable with the latter approach, especially for activities already in place for a long time and whose elimination might create risks.

Differences in style between project specialists affected the credit they claimed for the projects they were presenting. For example, one group leader insisted on large benefits for "his" projects, even though other participants on the scoring panel thought them unrealistic. Another group leader was cautious and had to be encouraged to take credit where due. While other members of the scoring panel could counteract these biases by challenging the specialists' judgments, we thought it would be useful to expand the scoring process to include a built-in mechanism to correct for them.

5.3 A three-stage scoring process

Based on the trial scoring experience, we designed a three-stage scoring process. The first stage consisted of a Preliminary Round, very much like the trial scoring round. This was to be followed by a Reconciliation Round, in which the results of a number of preliminary round scoring sessions would be presented to a meeting of all group leaders so comparisons could be made across projects, in terms of both overall priority score and single criteria scores. Any unreconciled issues from the second round would be passed on to the third stage, an Appeals Round, in which final judgments would be made by the division leader and his three deputies. We tried the reconciliation process with the 20 projects from trial scoring and found it easy to achieve consensus.

We held a total of 12 preliminary scoring sessions in which 41 projects were scored. (This includes the trial scorings, because that part of the process had not been changed.) Assignments to the scoring panels were rotated, so all group leaders had a chance to participate.

All 41 preliminary and trial round scores were reviewed in a second, three-hour reconciliation meeting of the group leaders. Unfortunately, several group leaders were required to participate in a mandatory training course that had been called at short notice. They were represented by their deputies or, in some cases, by section leaders from their groups. Therefore some people had their first exposure to the scoring process as members of a scoring reconciliation panel. The not surprizing result was that it was more difficult to achieve consensus.

There was significant discussion of many projects and some priority scores were changed. An important part of this process was to examine how the Preliminary Round project scores compared with each other and if they seemed to be intuitively right. For example, the Green Sheet review activity (ES&H reviews of Engineering Division plans) score was compared with those of ventilation review and engineering surveys because they are similar activities with comparable benefits. (The Green Sheet review score was increased to bring it into line with the other activities.) At the conclusion of the Reconciliation Round, there were only a few issues left unresolved for presentation at the Appeals Round.

HSE DIVISION
PRIORITIZATION SYSTEM
SCORING SHEET

Title of Project TLD Dosimetry Date | 3 | 8 | 91 |

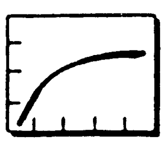
VALUE	WEIGHT (W)	SCORE (S)	SUBTOTAL (WxS)
EH&S Workers-Short Term			
1. Fatalities	0.161	0	—
2. Illnesses	0.046	10	0.46
3. Injuries	0.053	10	0.53
H&S Workers-Long Term			
4. Fatalities	0.079	50	4.0
5. Chronic Illnesses	0.078	50	3.9
6. Life Expectancy Red.	0.032	50	1.6
H&S Public-Long Term			
7. Fatalities	0.038	5	0.17
8. Illnesses	0.020	5	0.10
9. Injuries	0.032	5	0.16
Environment			
10. Historical/Archaeological	0.016	0	—
11. Biota	0.037	0	—
12. Non-Biota	0.074	0	—
Communication/Education			
13. Public	0.036	50	1.8
14. In-House	0.046	100	4.6
Lab and Non-Lab Needs			
15. Non-Lab Needs	0.032	0	—
16. Other Divisions	0.026	75	1.9
17. HSE Division Needs	0.024	80	1.9
Compliance			
18. ES&H Related	0.173	100	17.3

Total Priority Score (PS) | 38 |

Cost of Project 670 K

Cost/Benefit Index (PS/K$) | 73 |

Cost/Benefit Relationship B



C

optimum @ 50% cost

Fig. 3. Project Scoring Sheet

The Appeals Round lasted about two hours and involved the division leader and representatives of his three deputies. For projects where the Reconciliation Round had been unable to reach consensus, its majority opinion and the dissenting minority view were reported to the appeals panel, which tended to support the majority. The exceptions were hazardous material packaging, where they further reduced the benefit estimates of the majority view, in contrast to the minority which felt they should be increased. A similar adjustment was made to the meteorology scores. In the case of hood surveys, the Appeals Committee took a middle road between minority and majority, although it tended more towards the majority. Table 9 shows final results of the scoring process.

Table 9. Prioritization Scores for ES&H Projects

PROJECT TITLE	FINAL SCORE	COST (in $1,000)	SCORE/COST *1000
Emergency Response	87	$1,800	48
Medical Emergency Room	77	$600	128
Workplace Monitoring (Chemicals)	76	$600	127
OSH Training	75	$500	150
Exposure Control Monitoring	75	$2,000	38
Employee Assistance Program	64	$485	132
Respirator Training	62	$400	155
HSE Safety Program	55	$500	110
5000.3A Reporting	54	$650	83
Ventilation Review	52	$200	260
Health Promotion	52	$230	226
HEPA Program	51	$650	78
Radiological Stack Monitoring (EPA)	49	$2,000	25
ES&H Questionnaire Review	48	$400	120
Hazmat Packaging	48	$800	60
Small Job Tickets Review	45	$500	90
Engineering Support	45	$250	180
Hood Surveys	44	$120	367
Waste Minimization	42	$150	280
Salvage Monitoring	42	$200	210
Mixed Waste Analysis Laboratory	40	$500	80
Mixed Waste Permits	39	$125	312
TA-21 Characterization	38	$1,000	38
TL Dosimetry	38	$670	57
Waste Water Survey	38	$515	74
Green Sheet Reviews	38	$820	46
Radiological Stack Monitoring – as is	37	$300	123
Meteorology	37	$500	74
Epidemiological Study of Worker Cancer	36	$100	360
Directorate Teams	36	$1,500	24
ES&H Policy and Documents Review	35	$580	60
Contractor Evaluation	33	$123	268
Waste Stream Data Base	29	$100	290
State Oversight Support	28	$3,000	9
Low Radioactive Disposal Pit	28	$100	280
TA-1 Characterization	27	$500	54
Epidemiological Community Study	26	$35	743
Techn. Support for Solid Waste Management	25	$400	63
DOE Documents and Regulations Review	21	$800	26
Community Involvement	18	$200	90
DOE Requests	17	$300	57

5.4 Discussion of project scoring results

Priority scores ranged over a factor of five, showing that the system was able to differentiate among projects. The new emergency response program was the highest scoring activity with a score of 87, followed by the medical emergency room at 77, primarily because of its high potential for saving employee lives. Several occupational health and safety projects and monitoring activities (*eg*, for chemicals or radiation exposure in the workplace) also scored highly.

Environmental projects (*eg*, characterization of environmental restoration sites, waste minimization) tended to score In the middle ground, *ie*, between 30 and 50 points. The personal TLD monitoring program, which scored 38 points, is interesting because it has a non-linear relationship between funding level and priority score. Dosimeter badges are authorized by the employees' supervisors. The number of badges has continued to increase although the vast majority show no monthly radiation exposure. It was estimated that the number of employees in this program could be decreased by about 50% without much reduction in priority score, although the impact on operations could be significant.

Many paperwork activities that include reviews, development of databases, reporting mechanisms, etc, fall below a priority score of 40, mostly because they do not provide tangible ES&H benefits. However, they usually do get credit for compliance and external needs, which have lower criteria weights than do the ES&H-related criteria.

While projects scoring above 30 were generally thought to be worthwhile, those below 30 might be questioned on the basis of absolute priority score, that is when viewed independently of their cost. One low-scoring project is Laboratory support for the State of New Mexico's oversight of Laboratory ES&H activities (score 28, cost $3 million), to be carried out in accordance with an agreement signed by the DOE, the Laboratory, and the State. This score suggests that the division might want to consider if the cost of this activity could be reduced without changing its priority score appreciably.

The contrast between two activities with very low priority scores is interesting. A proposed community epidemiology study received a score of 26, yet it would cost only $100,000. Given its low cost, and the importance of the knowledge to be gained, this seems to be a commendable activity. On the other hand, responding to DOE requests, most of which are for information or the collection of data, had a lower benefit (17) and a higher cost ($300,000 per year). The cost could be reduced if these requests were responded to differentially, depending on their individual benefits.

5.5 Policy issues related to scoring

Several policy issues emerged during the scoring process and were resolved as part of the Appeals Round. The first was how to count the benefits of activities that are primarily information-seeking in nature, such as characterizing a site or developing a database. It was decided that informational projects should be scored by considering their complete life-cycle; for example, in environmental restoration, from characterization through cleanup. The priority credit for the entire project would be prorated among the various phases depending on how long they were expected to last; if an environmental restoration project is expected to last 20 years, four of which are to be spent on characterization, and if the project is estimated to save one life in the future, then the characterization phase would get credit for saving 4/20 of one life.

A policy judgment was also made on how to score activities that could be delayed without immediate effects, but where deferred negative consequences were to be expected. For example, a delay in building a new radioactive waste disposal pit would force the Laboratory to store these materials above ground. It was agreed that credit could be given to the pit for the benefit equivalent to avoiding one year of above-ground radioactive waste storage.

There was also some concern about the ability of the system to prioritize projects of very different sizes. Trial scoring results seemed to show a level dependence: "Big ticket" items had lower cost-effectiveness scores (priority score divided by cost) than those in the $300,000 to $500,000 range, while very low-cost activities (under $100,000) had the highest cost-effectiveness scores. After this finding, we tried to define projects (for purposes of scoring) so that they would fall in the hundreds-of-thousands cost range, avoiding both very large and very small projects; however, this was not always feasible, so a number of them were scored anyway.

After these scores had been discussed at length, reconciled, and appealed, we came to feel that our initial concern about level dependence was not an artifact of the system, but instead a rather accurate reflection of the nature of the projects themselves. Although large projects tend to be popular, they are often not as cost effective as less dramatic, but more easily managed, midsized activities. On the other hand, very small projects, such as the community epidemiology study, are small because they are pilots for new activities that are being proposed precisely because large initial benefits seem readily achievable.

A more difficult problem is how to cost projects that are implemented by more than one Laboratory division. For example, an HSE Division ventilation review may save lives by discovering ventilation inadequacies; however the lives are not really "saved" until the Engineering Division has made the required improvements. What is the relevant cost to consider in an HSE Division budget decision? Respirator training provides a different example of this conceptual problem. The HSE Division cost of this established activity is well known, but should the cost of trainees' lost work time (borne by their divisions) to attend training sessions be charged to the activity? The costing problem was never satisfactorily resolved; therefore the cost effectiveness indices in Table 9 are based on HSE Division costs and should be used cautiously.

6. DISCUSSION

In this section we discuss some observations from the HSE Division application of MAPP and comment on the implications of this experience for future work.

6.1 Normative vs descriptive modeling

Fairly late in the process, at the meeting to reconcile trial scorings, one group leader complained that the system did not reflect political realities and thus was not helpful for decision making. Was it correct and useful for MAPP to have been conceived as a normative system rather than a descriptive one?

This stimulated a lengthy discussion about the reasons for developing the system. Agreement was finally reached that it was precisely to help justify resistance to unreasonable pressures, therefore it should reflect how reasonable people would arrive at priorities based upon their own values. Although this issue was resolved, it does continue to emerge occasionally when people momentarily forget that the system was intended to help them place regulatory and political pressures in perspective.

6.2 Direct vs indirect funds

Some HSE Division projects, such as environmental restoration and waste management, are funded directly, with funds earmarked for specific uses. Others, such as occupational health and safety, radiation protection, and environmental surveillance and permitting, are financed internally by indirect funds generated from a burden imposed on the salary and fringe benefits of direct programs. Thus the direct-indirect dichotomy also represents a division of topics and professions.

Some managers whose work is supported mainly by direct funding argued that their projects should not be prioritized and compared to indirect activities because they are already bound by contractual obligations and are not subject to the same budget constraints. It was finally decided that it would be interesting to compare directly and indirectly funded projects, and so the system was tested on both types.

The scoring results seemed intuitively more satisfying to group leaders in occupational health and safety and radiation protection, probably because priority scores for their projects were generally higher than those of environmental activities, which usually score lower on the health and safety criteria that make the largest contributions to MAPP-HSE priorities. Environmental activities are mostly compliance driven and, as discussed earlier, the division's average weights for this criterion were much lower than those of its managers in the environmental area. The average division weights may seem to be a reasonable reflection of how social priorities should be set when environmental quality must be traded off against human life; however, environmental managers are not asked this philosophical question, rather they are expected to comply with the relevant environmental laws and regulations.

Since priorities for directly funded environmental projects are set by their sponsors using an approach similar to MAPP (*eg*, Longo, *et al*, 1990), it does not seem particularly useful to compare them to indirectly funded projects.

6.3 The project scoring procedure

Each scoring panel took about 45 minutes to score its first project, partly because members had to keep referring back to the marker definitions. The time required kept getting shorter, and was typically between five and ten minutes by the fourth or fifth project. Scoring was done on one criterion at a time, the group agreeing on a score before going on to the next criterion. Group consensus was remarkably easy to achieve; disagreements were rare, and most discussions were constructive attempts to accommodate the different disciplinary perspectives represented on the panel.

In retrospect, the three-level scoring procedure was not ideal. The three deputy division leaders participated fully in the design of the system, however their involvement in the scoring process was foreseen only in the appeals round. As it turned out, the reconciliation meetings resolved most differences, so the appeals panel was only convened once, some months after system design had been completed (and at a time when all three deputies were unavailable). Their limited involvement in the scoring process may have reduced their commitment to the system.

For future applications, we propose a two-level scoring process in which division-level managers are responsible for proposing projects to be scored in the preliminary round, and are also involved in the second level, which combines the reconciliation and appeals rounds. In addition, members of the preliminary scoring panel would be permanent, composed of those group leaders who are the best scorers, *ie*, who participate fully in the scoring sessions and make useful intellectual contributions. This extra responsibility should be recognized in some suitable way.

6.4 The overload-participation paradox

One goal of a prioritization system is to reduce workload by helping to allocate resources better. Paradoxically, the overload that creates the need for a prioritization system can also make it difficult for managers to find time to participate in its design. Participation was excellent at the outset, but gradually weakened over the six-month design period, although still remaining at acceptable levels.

Our impression is that workload actually increased during this time, partly due to new regulatory requirements. We also feel that managers' interest in the system decreased somewhat as they realized that it would not help them much in the short-term, reactive mode in which they are forced to operate. A measure of managers' time horizons could be seen when scheduling meetings: Typically their calendars were overbooked for the present week, the next week was half filled, but the week after next was wide open. Yet, when the week after next came around, it too was overbooked. Another indication of short-term pressures was that many of the managers wore pagers to the retreats.

7. CONCLUSIONS

The obvious product of MAPP is a list of projects with their corresponding priority scores, such as those shown in Table 9. These scores are useful in their own right, and the disaggregated, criterion-by-criterion scores can also give insights into how activities could be improved. However, it is important not to become obsessed by the numbers at the risk of forgetting that a prioritization system is simply a tool to support decisions.

A prioritization system can give better decision support if its users have a thorough understanding of its underlying assumptions, how it was designed, how it was meant to be used, and what its limitations are. Participation in the design of the system provides this in-depth knowledge as a by-product, and also helps to instill a sense of system ownership in its future users.

The team-building aspect of working together to decide what values should be important to the organization in setting its priorities is also beneficial. This process can stimulate new perspectives on the work, and improve internal communications by providing a structure and a shared vocabulary to facilitate potentially controversial discussions.

In the HSE Division application, the process of building the value tree and obtaining weights was highly iterative, and involved each of the 20 managers in about 20 hours of design meetings. We went through seven drafts of the value tree and elicited weights four times. In addition, each manager participated in 10 to 20 hours of scoring sessions. After the value tree and weights were in final form, the HSE managers rarely questioned their validity. We observed several informal discussions between managers in which the vocabulary was obviously derived from the shared experience of the system design process.

It is still not clear how MAPP will be used in HSE Division, although its integration into the yearly budget exercise is being explored by division budget staff. In the meantime, some group leaders have begun to use it informally to help set their own priorities, such as for midyear budget reviews, or in responding differentially to requests for support. However, the insights and understanding that the participants gained from the MAPP design process may be as important as the formal results of using the system.

We are now in the final stages of helping the Laboratory's Engineering Division apply the MAPP approach to the prioritization of their projects. This application is more complex than the HSE one; the range of criteria (which include ES&H issues) is broader, and project size varies over four orders of magnitude. The Engineering Division application uses the two-stage scoring procedure proposed in section 6.4.

We are also assessing the feasibility of using the MAPP approach to help prioritize Laboratory taskings and to structure Laboratory comments on draft regulations and orders.

8. THE DIVISION LEADER'S PERSPECTIVE

In order to appreciate the process described in this report, it is important to understand the atmosphere under which HSE Division managers were working. There is a finite budget available to do the required work, direction comes from both outside and inside the Laboratory and, as a consequence, the work is highly reactive. New orders are issued that require rapid implementation, there are unusual occurrences which must be handled immediately, and our core program must still be carried out while being continually modified to reflect evolving regulatory requirements. The need to prioritize had become very critical within HSE Division.

This need led to the decision to embark on the prioritization process. Each group had been doing its own prioritization; the idea of developing a common yardstick to allow comparisons to be made across groups was new, and the approach was innovative, but we knew that we needed something that would apply to all of our work. As Division Leader, I had some concerns as we began the process, mainly about the support I would have from HSE Division employees and managers, and also from senior Laboratory management.

The process as described in the report went very well. We were able to reach consensus rapidly on the criteria and weights. However, as we began to prioritize projects, interest on the part of some division managers began to attenuate. One issue that arose was that the system was comparing all ES&H projects, *ie*, across different disciplines. We felt that the relative importance of the various criteria was fairly reflected in the averaged weights we had assigned them; however, for the managers responsible for environmental projects, which have a large regulatory compliance component, the real-world personal, criminal, and civil liabilities to which they could be subject tended to dominate health and safety concerns. This reflected the fact, mentioned in Section 4.4, that their weighting of the compliance criterion was much higher then that of the other Division managers.

It would have been easy to create two parallel systems by simply using the criteria weights given by the environmental managers as the basis for a separate prioritization system for environmental activities. However, that would have defeated our divisional objective of having a system that would facilitate trade-offs between groups having different functions. Although we felt that the system described in this report truly evaluated ES&H activities based upon our values, no one is willing to take the risk of going to jail.

The value differences between the health and safety disciplines and the environmental management discipline, which were apparent in the system development process, are now being formally recognized. At this writing, the HSE Division is being reorganized along these lines into a Health and Safety (HS) Division and a separate Environmental Management (EM) Division. The prioritization system is still relevant to the needs of the new HS Division, and even benefits from having a well-articulated environmental branch, thanks to the participation of the EM managers in its design. The reverse applies to the relevance of the system to the needs of the new EM Division.

As we move forward with using the prioritization system, it is important that the division leader take the lead, providing direction for its use and continual re-evaluation of its utility. Division managers and employees are constantly faced with the "squeaky wheel" phenomenon and will always be tempted to react to pressure rather than relying on a prioritization process, unless they know that the process is supported by the division leader and that it will be used to defend managers who have used it rationally to avoid working on highly visible, but less effective projects. Obviously, the division leader must also have buy-in from senior management.

As we evaluate our needs to support the Laboratory's ES&H efforts, it seems clear that we must develop a project management system to control what work is undertaken. Prioritization can be done most effectively in conjunction with such a system. I also believe that there should be a contingency fund to allow for the "squeaky wheel" projects that will always surface and, at present, must sometimes be funded from the core program allocation, requiring frequent budget re-forecasting. We should be able to establish core program projects based on the prioritization system with the knowledge that some provision has been made for the *ad hoc* requirements that will certainly emerge.

Finally, there should be sequels to this report where we can evaluate the utility of this MAPP application in our ever-changing world of external requirements and, hence, changing external priorities. From a division leader's perspective, that will be the true test of the prioritization system.

ACKNOWLEDGMENTS

We are grateful to the HSE Division management team for the time, effort, and good ideas that they contributed to this work, and to Al Tiedman for his support.

REFERENCES

Board of Radioactive Waste Management (1985), Letter report to the director of the DOE Office of Radioactive Waste Management, National Academy of Science, Washington, April.

Buehring, W, Whitfield, R and T Walsco (1991), Alternatives for a DOE waste managment operations prioritization system (WMOPS). Discussion Paper, Argonne National Laboratory.

Chinnis J, Kelly C, Minckler, R and M O'Connor (1975), Single channel ground to airborne radio systems (SINGCARS) evaluation model, Technical Report DT/TR 75-2, Decisions and Designs, McLean, VA.

Edwards, W, von Winterfeldt, D and D Moody (1988), Simplicity in decision analysis: An example and a discussion. In D Bell, H Raiffa and A Tversky (eds), *Decision Analysis: Descriptive, Normative and Prescriptive Aspects*, New York, Cambridge University Press, 443–464.

Edwards, W (1980), Reflections on and criticism of a highly political multiattribute utility analysis. In L Cobb and R Thrall (eds), *Mathematical Frontiers of Behavioral and Policy Sciences*, Boulder, Westview Press, 157–168.

Keeney, R and H Raiffa (1976), *Decisons with Multiple Objectives: Preferences and Value Tradeoffs*, New York, Wiley.

Keeney, R, Lathrop, J and A Sicherman (1986), An analysis of Baltimore Gas and Oil Company's technology choice, *Operations Research* **34**, 18-39.

Keeney, R and D von Winterfeldt (1987), Operational procedures to evaluate decisions with multiple objectives, Research Report RP-2141-10, Electric Power Research Institute, Palo Alto.

Keeney, R (1980), *Siting Energy Facilities*, New York, Academic Press.

Longo, T, Whitfield, R, Cotton, T and M Merkhofer (1990), DOE's formal priority system for funding environmental cleanup, *Federal Facilities Environmental Journal* **1**, 219–231.

Merkhofer, M and R Keeney (1987), A multiattribute utility analysis of alternative sites for the disposal of nuclear waste, *Risk Analysis* **5**, 173–194.

von Neumann, J and O Morgenstern (1947), *Theory of Games and Economic Behavior*, Princeton, Princeton University Press.

Otway, H and P Haastrup (1988), Designing risk management support systems, *Annals of Operations Research* **16**, 439–446.

Otway, H and D von Winterfeldt (in press), Expert judgment in risk analysis and management: Process, context, and pitfalls, *Risk Analysis*.

Peerenboom, J, Buehring, W and T Joseph (1989), Selecting a portfolio of environmental programs for a synthetic fuels facility, *Operations Research* **37**, 689–699.

Ritts, J (1990), DOE's Hanford Site Priority Planning Grid application of the risk ranking technique, Tenera, L P, November 1.

Weapons Complex Monitor (1991), DOE cleanup priority scheme weighs health risk almost 3x enviro risk, May 8, 3–5.

Weinberg, A (1972), Science and trans-science, *Minerva* **X**, 209–222.

von Winterfeldt, D and W Edwards (1986), *Decision analysis and behavioral research*, Cambridge University Press, Cambridge.

END

DATE FILMED

11 / 06 / 91