TITLE: Prioritization Methodology Using Hazard Analysis Results at Los Alamos National Laboratory

AUTHOR(S): Kent Sasser
Mary Hall
Desmond Stack
Dan Brooks

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Prioritization Methodology Using Hazard Analysis Results at Los Alamos National Laboratory

M. Kent Sasser, Mary Hall, Desmond Stack
Los Alamos National Laboratory
Los Alamos, New Mexico
(505) 667-2613

Daniel G. Brooks
Arizona State University
(602) 497-2624

INTRODUCTION

The principles of decision analysis can be used to develop a risk-based decision process that integrates required Department of Energy (DOE) Safety Analysis Reports (SARS) with risk management policy to provide facility managers with a decision process for systematic and consistent management of risk. This paper describes the application of this process to managing Los Alamos National Laboratory Plutonium Facility risks using the results of a SAR for that facility.

OBJECTIVES AND APPLICATION OF REPORTED WORK

Risk management activities, such as prioritizing risk-reducing projects, often are commissioned for facilities as special tasks supported by special task forces and conducted independently of other on-going risk assessment and risk management activities. Many DOE facilities have completed hazard analyses (HAs) as part of their efforts to upgrade their SARS to meet the new DOE standard that was issued in 1994. Although a complete SAR would contain more resource allocation information than the HA, the HA usually is completed before the SAR.

This paper describes how SAR results, and particularly HA results, can be used directly to support managers’ risk-based prioritization of project funding. This can reduce the time to conduct prioritization modeling, increase the quality of the results, and, perhaps most importantly, integrate the results into the on-going risk management activities of the site.

BACKGROUND

The DOE Standard for the preparation of SARS for nonreactor nuclear facilities (DOE-STD-3009-94) gives the “new standard” guidelines for managing risk at DOE facilities dealing with nuclear materials. The DOE standard defines hazard as “a source of danger” to health, the environment, or operations, “without regard for the likelihood” of occurrence of the accident resulting in the danger. It defines risk as the expression of the probability that an event will occur and the consequence (the hazard) of that event. This paper uses these terms consistent with the DOE definitions. The new standard formally incorporates under “hazard” the DOE concern for worker safety and the environment in addition to on-going protection of the public. This represents “a new emphasis for SARS” within DOE according to the standard.

The initial SAR analytical effort for all facilities is a hazard analysis (HA) that systematically identifies facility hazards and accident potentials through hazard identification and evaluation. This is a qualitative effort that forms the basis for the full SAR, “including specifically addressing defense in depth and protection of workers and the environment.” The HA

- considers the complete spectrum of accidents that may occur;
- analyzes potential consequences to the public, the workers, and the environment;
- estimates likelihoods of occurrence;
- identifies preventive and mitigative features; and
- identifies a selected subset of accidents for formal quantitative analysis.
The HA uses information from sources outside the SAR process, develops an understanding of the hazard sources, and then provides these estimates to management for operational responses to manage the hazards. This process is shown in Fig. 1 for worker safety hazards.

The HA results provide the link between important resources available for assessing facility risks and the operational safety changes that are developed to manage risks at a facility. Because of its logical importance in translating existing risk assessment information into future risk management activities, the HA can play a crucial role in influencing budget decisions and maintaining risk control at DOE facilities.

The accidents identified in the HA process are ranked qualitatively using a “likelihood and consequence ranking matrix;” an example is shown in Fig. 2. This qualitative ranking is the basis for focusing analysis efforts on the most significant risks. The accident analyses use quantitative methods for evaluating the risk and the effectiveness of preventive and mitigating features to control it.

Levels of Hazard Evaluation

The level of information appropriate for hazard evaluation depends on, among other things, the life-cycle stage of a facility. Figure 3 shows how the level of hazard evaluation varies over the life cycle of a facility.

In addition to the life cycle stage of the facility, the level of information is influenced by the type of the process, its size and complexity, and the nature of the operations taking place in the process or facility.

- **Type of process.** This refers to the inherent functions of the process and includes the chemical, physical, mechanical, biological, electrical, computer, and human components of the process. Some techniques are better suited for modeling some processes than others. For example, failure mode and effects analysis (FMEA) is effective in evaluating computer systems, but hazards and operability analyses (HAZOPs) are more useful in analyzing processing systems.

- **Size and complexity.** Hazard evaluation should be conducted at a level compatible with the purpose of the study. The complexity and size of the hazard problem should be matched by the appropriateness of the evaluation technique so that useful insights are produced in a timely manner, consistent with the level of effort and information available.

- **Nature of operations.** The operations may be continuous, batch, fixed in location or mobile, robotic or labor intensive, long-lived or transient.

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**Fig. 1. HA process for worker safety issues.**
Conclusions from risk analysis that identify situations of major concern (combinations 7, 8 and 9)

Combinations that identify situations of concern (combinations 5 and 6)

Fig. 2. Basis for qualitative ranking of risks in the HA process.

Fig. 3. Levels of hazard evaluation used at different stages in a facility’s life cycle.
The charts in Figs. 2 and 3 show that HAS use a large amount of external existing information; they integrate this with facility-specific accident analyses; and they are conducted early in the life of a facility. In addition, they are required by DOE as part of the SAR process. Clearly, HAS represent a valuable source of information that can aid risk-based decision making. In addition to obtaining valuable inputs to the risk management process, the resulting insights can be incorporated into the formal SAR process at an early phase in the facility's lifecycle.

Linking HA Results and Risk-Based Prioritization

Because HAs occur early in the development of SARs, they are frequently available when decisions about possible upgrades or improvements of facilities are being evaluated. In addition, the facility SAR becomes a living document and is updated annually. HA results can be used as input to risk-based prioritization of mitigative features both early in the facility life cycle or later when upgrades are considered. In turn, risk-based prioritization of mitigative features can aid further detailed accident analysis and full probabilistic risk assessment that comes later in the SAR process. This is done by identifying the hazards and potential mitigations that have the best benefit-to-cost characteristics.

Risk-based prioritization serves the SAR process in two ways.

1. It uses HA (or HA) analysis results to produce insights for risk managers that aid them in determining how best to allocate scarce resources to improve the overall safety of their facilities.
2. It provides analyses that are useful in conducting the quantitative analyses later on in the SAR process by focusing analysis on the most cost-effective hazard reduction options.
3. It also can use and integrate results from other parts of the SAR that call for resource allocation.

HAS provide key inputs to the SAR process by identifying hazards; prioritization uses HA results to help focus attention on those activities that most effectively reduce hazards.

The remainder of this paper describes the use of HA results for prioritizing hazard-reducing activities proposed for the TA-55 facility at Los Alamos National Laboratory.

RISK-BASED DECISION MAKING: THE METHODOLOGY

Risk management, or "risk-based" decision making, is not a particular technique or methodology but rather a general description that can be applied to any decision-making procedure that explicitly takes risk into consideration when evaluating activities. Because "risk" can mean different things to different people, it is important for the organization to clearly define what risk means and how it will be taken into account in evaluating decision options. In this paper, we propose to define risk as any threat against achieving an organization’s fundamental objectives. The next section describes the methodology used to formally incorporate HA results into risk-based prioritization of risk-reducing activities for plutonium risk management.

The prioritization methodology used in this application is based on multiattribute utility theory. This is a prescriptive methodology for modeling uncertainty and consequence values when there are multiple objectives to be achieved, multiple stakeholders, and significant uncertainty. The methodology uses probability to quantify uncertainty and uses utility to quantify the value of consequences. The axioms underlying the methodology guarantee that if the axioms hold true, the best way to prioritize activities is based on their expected benefit-to-cost ratio. Several references provide general descriptions of the underlying theory and its development, including Clemen (1992), Keeney and Raiffa (1976), and Raiffa (1964). Multiattribute utility theory has been applied to the evaluation and prioritization of risk-reducing activities in many different contexts and at different levels of detail.

Defining and Identifying Risk

Because risk can mean very different things in different contexts, it is important to make the meaning as specific as possible for each application. The structure for this definition process for a given application begins with the general definition that risk is the possible occurrence of an undesirable outcome. This definition includes the idea of value because the outcome is identified as undesirable; it also includes the idea of uncertainty because the outcome is possible but has not already occurred.
Value and Its Role in Defining Risk. The definition of risk begins not with scenarios but with identification of the resources of value that a facility is trying to protect. This is accomplished by specifying the objectives of the facility; risk is the possibility of an undesirable effect on the achievement of these objectives. When the objectives have been identified, quantitative scales are developed to measure the severity of impact on these objectives. These evaluation measures do two things: (1) they make specific what is meant by the objective statement, thereby clarifying facility objectives, and (2) they make explicit the degree of risk associated with an outcome.

Objectives. Defining objectives is the basis for defining consequences—the first step in identifying hazards. The DOE standard for SARs identifies the common objective for all DOE facilities: accomplishing the mission of the facility while protecting the public, worker safety, and the environment.

The DOE standard is not specific about what values of the public are protected, but it would include at a minimum the public health and safety. DOE "Programmatic Commitment" as described in the SAR standard is a means for achieving the fundamental objectives listed above. Because only fundamental objectives are used in identifying hazards, programmatic commitment is not listed explicitly but is implicitly present as a means to achieving these safety objectives.

Measurement Scales and Value Functions. It is still necessary to define what "undesirable" means for each of the objectives. This requires development of measurement scales and associated value functions. The measurement scales show the units in which impacts on the objectives are measured, and the value functions show what is preferred as an outcome. The DOE standard refers to this issue regarding worker safety as "the fundamental question of how worker safety is most appropriately addressed [measured] in the SAR." (p. 6).

This two-step process reflects both technical and value judgments. The technical judgment is the determination of the appropriate scale for measuring impacts on the objective; for example, the best way to measure impacts on human health. The value judgment is the determination of what is preferred.

The HA process is an aid in developing both measurement scales and value functions. There are often existing databases reflecting regulatory requirements for reporting effects in various operational areas such as worker health, environmental impacts, or regulatory violations that can help in establishing measures. HAs also provide direction for developing value functions by indicating relative risk ranks for various levels of impacts, ranging from very serious (risk rank 1) to almost benign (risk rank 4). This value structure can aid the decision process by identifying the most significant risks.

Uncertainty. Scenarios are the sequences of events that can result in an undesirable impact on the facility’s objectives as measured by the measurement scales and associated value functions (telling how great the impact was and how undesirable it was). The event uncertainties are quantified by probabilities and the sequence of events is represented by event trees.

The HA process provides a structured approach to this activity. Process flow diagrams describe the normal operations of the facility; base maps describe the surrounding context within which the facility operates; policies and procedures describe the work processes at the facility. Using these descriptive documents, a team of persons familiar with the operations can identify the following components of risk scenarios.

- Process hazards such as (a) inventories of hazardous materials, (b) extreme operating conditions such as erosion processes or bad vibrations, and (c) extreme procedures such as overcrowding exits
- Initiating events such as (a) processing upsets resulting from interrupts, (b) management system failures such as inadequate staffing, (c) human errors such as operating errors, and (d) external natural events such as earthquakes
- Intermediate or propagating events such as protection failure, detection failure, power failure, ignitions, and lack of system response
- Incident outcomes such as discharge, fire, detonation, release, exposure, and so on. The outcomes are defined further in terms of the facility objectives and the measurement scales used to capture the severity of
impact. These might include health impacts, violation levels, environmental degradation, community concerns, and so on.

Probabilities are estimated using both frequency data and expert judgment. There are often frequency data for initiating events. These can be used as a base-level frequency estimate for a scenario. The HA team then can estimate the probabilities of various events following the initiating event. These estimates can be made by developing models of the processes involved, doing simulations, performing statistical analyses, or obtaining judgmental assessments from process experts. In each case, the basis for the estimate is made explicit, and the auditability of the assumptions, judgments and data use is maintained.

The result is an estimate of the scenario probabilities and consequences because the sequence of events for which the probability estimates are made defines an outcome. This provides the basis for developing a risk profile describing a risk distribution: probability of occurrences and the consequences associated with these occurrences.

Developing Responses to Identified Risks

The HA process involves identifying problems before they occur; evaluating the risk associated with these problems, including the probability of occurrence and the magnitude of the consequences; ranking these risks; and exploring possible preventive or mitigative actions.

Risk-based prioritization ranks responses to risks based on the effectiveness of the responses rather than ranking risks. However, the process uses the HA ranking because after potential high-risk problems are identified, it is possible to identify responses to reduce these potential risks. Risk reduction can include reducing the frequency, or the consequences—or both—for a given risk scenario.

The process of developing mitigating responses uses the process diagrams developed for the HA, the accident scenarios developed from the process diagrams, and the structured development of responses to the accident scenarios. The outcome of this activity is that risks and the projects explicitly designed to reduce risks have been identified systematically.

Estimating the Value of Risk-Reducing (Mitigative) Activities

The degree to which risks are mitigated by proposed projects requires that the hazard level and likelihood be considered under two different sets of conditions. The first, or "baseline," condition is the estimated risk associated with the occurrence of the scenario if no mitigative action is taken. The second, or "modified," condition is the estimated risk associated with the scenario as if the mitigating activity were fully implemented and in place. The implementation of the mitigating activity can affect the seriousness of the hazard (less severe, less widespread, or both), the likelihood of the impact, or both.

The amount of risk reduced by implementing an activity is defined by the following relation:

\[
\text{Reduced risk} = \text{Baseline risk} - \text{Modified Risk}
\]

The difference in the baseline and modified risks represents the reduction in risk attributable to implementing an activity.

Expressing Benefits in Economic Terms

To give an economic value to the overall risk reduced by an activity, some value must be attached to adverse impacts for each of the objectives. This economic value can be estimated by determining the importance of each of the objectives in economic terms. These economic "weights" for each of the objectives represent decision-makers' willingness to pay to reduce adverse impacts against each objective. Establishing willingness to pay is a routine part of risk management and is often done commercially in determining the value of intangibles.

In practice, the economic weight associated with each objective is determined using a series of tradeoffs in which decision-makers indicate at each step their willingness to pay for certain types of outcomes. This process is similar in concept to bidding activity that determines the values of products in the market. The monetary value of averted risk is
based on these estimates of the decision makers’ willingness to pay for changes in the level of risk impact for all the objectives.

DOE facilities, along with other Federal government agencies, have established willingness-to-pay ranges to prevent a statistical fatality among the public. This range centers at approximately $5M. The willingness to pay to prevent adverse impacts (as measured by the impact scales) can be established using tradeoff comparisons with the $5M value of preventing a fatality.

This tradeoff exercise applied to the HA objectives defining hazards resulted in the economic values for each of the objectives as shown in the Appendix.

Evaluating Activities and Prioritizing Their Implementation

Implementing an activity to reduce risks typically requires expenditure of resources. Prioritizing mitigative activities is based on the economic value of the risk reduction an activity provides and the resources required to support the activity.

Prioritization of activities is usually approached in one of three ways, each of which yields different insights. The first, and easiest, is to consider only the amount of benefit provided by each activity. The activities are implemented according to their total risk reduction, so the activity that reduces risk the most is the first activity funded and so on. This method ignores costs.

A second means of prioritization is to consider the activities against a single resource. In this case, activities can be viewed in terms of their economic benefit and economic costs and compared on a risk-based cost-benefit basis. This view of the activities can aid decision-makers when considering which activities to drop when budgets are decreased or, similarly, the rate of decrease in benefit for each unit decrease in resource availability. The optimization principle in this selection process is to maximize the amount of risk-reduction benefit achieved for each incremental dollar spent.

Because it is common for resources to come from different sources in different years with different limits, it is not possible to just “follow a list until you run out of money” as a strategy for implementing risk-reducing activities. Taking into account the more realistic picture of activity selection leads to a third way of prioritizing the allocation of resources based on risk-reduction value, including resources from multiple sources over multiple years. In this context, decision makers select a portfolio of activities consistent with a multiyear budget so that the total economic benefit of risk-reduction achieved over the activity horizon is maximized rather than maximizing the economic benefit per incremental dollar spent.

RISK-BASED DECISION MAKING: THE APPLICATION TO TA-55

The Los Alamos Nuclear Materials Technology (NMT) Division performs a large amount of nuclear materials research and development activities. NMT is responsible for the Plutonium Facility, which is located at TA-55. The primary work at TA-55 is done in the PF-4 laboratory building. Extensive research and development activities, both defense and nondefense, are conducted within PF-4 by various NMT groups. A number of radionuclides, including $^{238}\text{Pu}$, $^{239}\text{Pu}$, enriched uranium, and other actinides are contained in various process gloveboxes. These radionuclides are in several physical forms (powders, metals, oxides, and aqueous forms) and states. Large inventories are contained within PF-4. The material is contained, in addition to the gloveboxes, in storage containers, vaults, or shipping containers depending on the stage of processing.

An HA was conducted for the PF-4 processes. The HA methodology is an extension of the preliminary and process hazard methods described in AIChE (1992). Specific accident scenarios with estimates of frequency and consequences were developed for each identified hazard associated with process activities. NMT staff aided in developing scenarios for accident description and quantification.
Defining Objectives

The DOE objectives as identified in the SAR standard include protection of the public, the worker, and the environment. Taking these into account along with TA-55 objectives resulted in the following objectives: minimize adverse affects on

- health and safety of workers or the public,
- public concerns and confidence,
- environmental resources,
- Laboratory accomplishment of its programs and mission,
- regulatory compliance, and
- costs associated with response to accidents.

The statement of these objectives was developed from the DOE SAR standard and a series of interviews with Laboratory senior management. After a first round of interviews, further interaction with special technical groups helped provide more detailed descriptions of the categories. Laboratory legal council was consulted on compliance issues; health and safety managers were involved in defining both worker and public health and safety issues.

Measurement Scales and Value Functions

A series of meetings with appropriate Laboratory technical specialists produced a quantitative scale for measuring impacts on each of the objectives. Figure 4 shows the measurement scales. The scales were reviewed by several teams of experts to ensure that they accurately represented the technical information requested in the scoring process. Laboratory management also reviewed the measurement scales. They then participated in a series of formal elicitation sessions in which they responded to tradeoff questions. These sessions produced a value function for each scale in each evaluation category.

Combining Evaluation Measurements

The economic weights, or tradeoff coefficients, for each of the objectives reflect the fact that the hazard prevention objectives are not of equal importance. The Appendix shows the value functions and tradeoff weights for the measurement scales.

In addition to determining the relative weights for the evaluation categories, the assessments produced a rule for combining these weighted measures. In the Laboratory application, a series of tradeoff exercises done with various groups of managers showed that it was valid to use a linear combination of category scores.

Sensitivity analysis showed that changing the tradeoff weights over plausible ranges had only a modest effect on the benefit associated with each activity. Even major changes in the weights (orders of magnitude) had little effect on the overall ranking of activities by total benefit.

Developing Scenarios and Scoring Mitigative Activities

Figure 5 shows the scoring form used to record the HA Team’s assessment of how well an activity would reduce either a hazard or its likelihood of occurring. The form has space for recording the event tree describing the accident scenario from the HA process that was the basis for both accident and the mitigative activity.

Prioritizing Activities

Selecting the set of activities that yields the greatest benefit and still can be funded under the set of resource constraints (by year and source) is an optimization problem. The diagram below shows how mitigative activities identified in the HA process were ranked by benefit-to-cost ratio.

Figure 6 shows the cumulative benefit of implementing activities in order of their priority as a function of their cumulative cost. It is clear from the graph that some activities are well worth implementing, some provide benefit but are expensive and should be redesigned, and some provide little benefit and require substantial resources.
### Consequence Matrix for TA-50-1

<table>
<thead>
<tr>
<th>Adverse Health Effects for ...</th>
<th>Adverse Effects on the Ecology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Public</td>
<td>On-Site Worker</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Severity of Effect</strong></td>
<td><strong>Number</strong></td>
</tr>
<tr>
<td>1. Immediate acute &amp; severe result</td>
<td>1. 100 to 1000</td>
</tr>
<tr>
<td>- ERPG-2 for 10 min</td>
<td></td>
</tr>
<tr>
<td>- &gt; 25 rem</td>
<td></td>
</tr>
<tr>
<td>- fatality or permanent debilating injury</td>
<td></td>
</tr>
<tr>
<td>2. Long-term significant result</td>
<td>2. 10 to 100</td>
</tr>
<tr>
<td>- ERPG-2 1 to 10 min</td>
<td></td>
</tr>
<tr>
<td>- 5 - 25 rem</td>
<td></td>
</tr>
<tr>
<td>- Lost-time and hospitalization</td>
<td></td>
</tr>
<tr>
<td>3. Short-term significant result</td>
<td>3. 3 - 10</td>
</tr>
<tr>
<td>- &lt; ERPG-2</td>
<td></td>
</tr>
<tr>
<td>- 0.1 to 5 rem</td>
<td></td>
</tr>
<tr>
<td>- First-aid only</td>
<td></td>
</tr>
<tr>
<td>4. Minor result</td>
<td>4. few: 1 - 3</td>
</tr>
<tr>
<td>- Background to 0.1 rem</td>
<td></td>
</tr>
<tr>
<td>- no medical treatment</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**Fig. 4(a). Part one of the measurement scales.**

### Adverse impacts on Program Support

<table>
<thead>
<tr>
<th>Severity of Effect</th>
<th>Importance of Program Effected</th>
<th>Severity of Non-compliance</th>
<th>Response Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Severe Impact</td>
<td>1. Very important: Effected programs are large (multi-division) and central to the Lab Mission support &amp; future development</td>
<td>1. Severe Impact: Effected legal charges by the regulatory agency, substantial fines, potential shut-down or criminal or civil proceedings</td>
<td>1. Severe: Costs of clean-up or repair could be as much as $10 million/year for as long as 5 years</td>
</tr>
<tr>
<td>2. Significant Impact</td>
<td>2. Important: Effected programs are at the division level and support Mission-related activity</td>
<td>2. Significant: Effected legal charges by the regulatory agency, substantial fines or court order</td>
<td>2. Significant: Costs of as much as $5 million total</td>
</tr>
<tr>
<td>3. Modest Impact</td>
<td>3. Moderate: Effected programs are at the Group level, are tangential to Lab Mission and are worth as much as $5 million/year</td>
<td>3. Modest: Effected legal charges by the regulatory agency, substantial fines or court order</td>
<td>3. Modest: Costs of as much as $1 million</td>
</tr>
<tr>
<td>4. Minor Impact</td>
<td>4. Unimportant: Effected programs are not important to the mission and worth less than $1 million/year</td>
<td>4. Minor: Effected legal charges by the regulatory agency, substantial fines or court order</td>
<td>4. Minor: Costs of about $100 thousand or less.</td>
</tr>
</tbody>
</table>

---

**Fig. 4(b). Part two of the measurement scales.**
**Scenario Worksheet**

**PHA Risk Scenario Scoring Form**

<table>
<thead>
<tr>
<th>Scenario Name:</th>
<th>Scenario Number:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluator:</td>
<td>Date:</td>
</tr>
</tbody>
</table>

**Scenario Specifics:**

<table>
<thead>
<tr>
<th>Process/flow ID:</th>
<th>Initiating event:</th>
<th>Resulting events:</th>
<th>Consequence:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Impacts on health & safety of workers:**
  - Severity of Impact: __________  __________  __________
  - Number Impacted: __________

- **Impact on health & safety of on-site workers:**
  - Severity of Impact: __________  __________  __________
  - Number Impacted: __________

- **Impact on health & safety of the public:**
  - Severity of Impact: __________  __________  __________
  - Number Impacted: __________

- **Impact on ecological resources:**
  - Severity of Impact: __________  __________  __________
  - Extent of Impact: __________

- **Impact on support of Lab programs:**
  - Severity of Impact: __________  __________  __________
  - Importance of program(s): __________

- **Impact on regulatory compliance:**
  - Severity of Impact: __________  __________  __________
  - Cost of response to impacts: __________

Fig. 5. HA scenario worksheet and scoring form.
Impact on Allocation of Funds

The dashed line in Fig. 6 shows the slope with $1 of benefit achieved for $1 of investment. The graph makes apparent the fact that two projects initially viewed as the keys to risk management—training and plutonium repackaging—were both significant contributors to risk reduction, but their costs were large enough to make them unattractive at that investment level. The result of the analysis was immediate support for the “fixes” that made up the most attractive projects (lockout, glovebox fixes, and surveillance) and to review the design of the training and repackaging programs.

Some graphical results help further investigation of the individual projects under review. The graph in Fig. 7 illustrates the process by showing the benefits of hydrogen monitors in the gloveboxes.

This shows that the primary contribution of the glovebox monitors is (1) reduction in interruption of mission support and (2) reduction in the effect on on-site workers. Therefore, the primary justification for the project is not in terms of a safety issue but as a mission support improvement. Although the workers are already protected by alarms, this project provides earlier detection that avoids more complete shutdowns.

Software Support

The Microsoft database program Access provides several benefits: the database structure facilitates investigation of various project strengths and weaknesses through the query capabilities; the software language provides the ability to do all the necessary benefit computations; finally, the visual basic language supports a user-friendly interface so that projects are easily scored and recorded.
5. LESSONS LEARNED AND CONCLUSIONS

The life cycle chart in Fig. 2 shows that HAs are conducted for almost all DOE facilities fairly early in either their construction or in the development of their SARs. The result is that HA results are often available to managers when decisions must be made regarding the allocation of resources for risk management or facility upgrades. Although more detailed risk assessments can be used to prioritize projects, our work demonstrates that HA results can be a very useful aid in evaluating funding allocations.

There appear to be several benefits from using the HA results and, ideally, the overall SAR recommendations as well.

- The HA team expertise is used to rank risks under current HA procedures but incorporating project evaluation along with the HA allows the team expertise to be used in prioritizing risk-reducing projects as well.
- The evaluation of projects using HA results helps identify areas in which additional information is valuable; this insight influences future investigations of both risks and mitigative activities or projects.
- Linking risk-based prioritization to the overall SAR process helps institutionalize this risk management activity along with the risk assessment activities required to continue supporting the SAR. This provides a much more natural link with operational responses to SAR findings that later become a part of facility risk management policy.
- Using SAR results reduces redundancy of effort, increases the breadth of influence of the analysis, and encourages early attempts at quantifying and storing (database) scenario analysis and information on all recommended activities requiring resource allocation. These logistical improvements make the SAR process a more productive effort in terms of its immediate effects on risk reduction at the facility.
6. REFERENCES


APPENDIX

The value functions and weights for the evaluation of projects at TA-55 are shown on the next two pages.
# Risk Categories & Measures for Plutonium Facility Prioritization

<table>
<thead>
<tr>
<th>ADVERSE HEALTH EFFECTS</th>
<th>ADVERSE EFFECTS ON THE ECOLOGY ($15M)</th>
<th>ADVERSE PUBLIC PERCEPTIONS ($10M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUBLIC ($5.5M)</td>
<td>ON-SITE WORKER ($4.0M)</td>
<td>WORKER ($2.25M)</td>
</tr>
<tr>
<td>SEVERITY OF EFFECT</td>
<td>NUMBER</td>
<td>SEVERITY OF EFFECT</td>
</tr>
<tr>
<td>1.0 Very Serious Impacts</td>
<td>(1,000)</td>
<td>1.0 Severe Impact</td>
</tr>
<tr>
<td></td>
<td>1. 1,000 to 10,000</td>
<td>permanent damage to ecosystem, habitat of threatened/endangered species, national park, archaeologically valued land</td>
</tr>
<tr>
<td>2.0 Serious Impacts</td>
<td>(100)</td>
<td>2. Significant Impact</td>
</tr>
<tr>
<td></td>
<td>2. 100 to 1,000</td>
<td>Long term damage to ecosystem, T&amp;E habitat, park, etc.</td>
</tr>
<tr>
<td>3.0 Short Term or Moderate Impact</td>
<td>(10)</td>
<td>3. Limited Impacts</td>
</tr>
<tr>
<td></td>
<td>3. 10 to 100</td>
<td>Temporary damage to valued ecosystem, etc. (see above)</td>
</tr>
<tr>
<td>4.0 Minor Impact</td>
<td>(1)</td>
<td>4. Minor Impacts</td>
</tr>
<tr>
<td></td>
<td>4. 1 to 10</td>
<td>Short term, minor, self correcting impact to non-scarce, low value resources</td>
</tr>
<tr>
<td>5.0 No Effect</td>
<td>(E-10)</td>
<td>5. No Impact</td>
</tr>
<tr>
<td></td>
<td>5. E-10</td>
<td></td>
</tr>
</tbody>
</table>