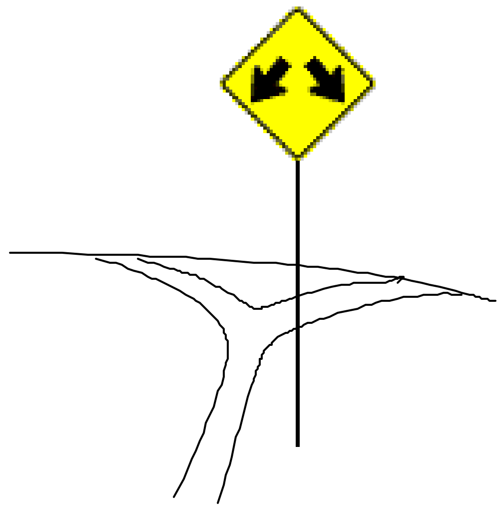
WSRC-IM-2002-00002

GUIDEBOOK TO DECISION-MAKING METHODS



Developed for the Department of Energy

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December 2001

PREFACE

In the Affair of so much Importance to you, wherein you ask my Advice, I cannot for want of sufficient Premises, advise you *what* to determine, but if you please I will tell *you how*. When those difficult Cases occur, they are difficult, chiefly because while we have them under Consideration, all the Reasons pro and *con* are not present to the Mind at the same time; but sometimes one Set present themselves, and at other times another, the first being out of Sight. Hence the various Purposes or Inclinations that alternately prevail, and the Uncertainty that perplexes us.

To get over this, my Way is, to divide half a Sheet of Paper by a Line into two Columns; writing over the one *Pro*, and over the other *Con*. Then during three or four Days Consideration, I put down under the different Heads short Hints of the different Motives, that at different Times occur to me, *for* or *against* the Measure. When I have thus got them all together in one View, I endeavor to estimate their respective Weights; and where I find two, one on each side, that seem equal, I strike them both out. If I find a Reason pro equal to some two Reasons *con,* I strike out the three. If I judge some two Reasons *con,* equal to some three Reasons pro, I strike out the five; and thus proceeding I find at length where the Balance lies; and if after a Day or two of farther consideration, nothing new that is of Importance occurs on either side, I come to a Determination accordingly. And, tho' the Weight of Reasons cannot be taken with the Precision of Algebraic Quantities, yet, when each is thus considered, separately and comparatively, and the whole lies before me, I think I can judge better, and am less liable to make a rash Step; and in fact I have found great Advantage from this kind of Equation, in what may be called *Moral* or *Prudential Algebra*.
1

— B. Franklin, London, September 19, 1772[1]

This guidebook introduces both a process and a selection of proven methods for disciplined decision-making so that the results are clearer, more transparent, and easier for reviewers to understand and accept. It was written to implement Recommendation 14 of the Integrated Nuclear Materials Management (INMM) Plan and set a standard for a consistent decision process. From this guidebook decision-maker(s) and their support staffs will learn:

- the benefits of using a disciplined decision-making approach
- prerequisites to the decision-making process
- how to choose among several decision-making methods
- how to apply the method chosen

This guidebook also presents examples of the decision-making methods in action and recommends sources of additional information on decision-making methods

This guidebook was compiled with input from a team experienced in the decision-making process from the Savannah River Site, Sandia National Laboratories, Idaho National Engineering and Environmental Laboratory, and the U.S. Department of Energy.

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[1] Appendix C-Further Reading 1,Forman and Selly

CONTENTS

1.0 Purpose

Decision-makers have to choose between alternative actions every day. Often the alternatives and supporting information presented is inadequate to support or explain the recommended action. **The goal of the *Guidebook to Decision-Making Methods* is to help decision-makers and the decision support staff choose and document the best alternative in a clear and transparent fashion.** This guidebook will help all parties concerned know what questions to ask and when to ask them.

1.1 What is a disciplined decision-making process?

Good decisions can best be reached when everyone involved uses a clearly defined and acknowledged decision-making process. A clear and transparent decision process depends on asking and answering enough questions to ensure that the final report will clearly answer the questions of reviewers and stakeholders. This guidebook provides:

- An eight step decision-making process (Section 2)
- Descriptions of specific decision methods (Section 3)
- Examples of the specific decision methods in action (Appendix A)
- Written aids, suggestions, and questions to help implement the decision-making process (Appendix B), and
- Supporting references for further reading (Appendix C).

1.2 Why use a disciplined decision-making process?

For most familiar everyday problems, decisions based on intuition can produce acceptable results because they involve few objectives and only one or two decision-makers. In the DOE environment, problems are more complex. Most decisions involve multiple objectives, several decision-makers, and are subject to external review. A disciplined and transparent decision-making process employing credible evaluation methods will provide:

- Structure to approach complex problems
- Rationale for decisions
- Consistency in the decision making process
- Objectivity
- Documented assumptions, criteria, and values used to make decisions. and
- Decisions that are repeatable, reviewable, revisable, and easy to understand

Using such a disciplined approach can help avoid misunderstandings that lead to questions about the validity of the analyses and ultimately slow progress. Its use will set a baseline for continuous improvement in decision making in the DOE nuclear materials complex.

1.3 When should a formal decision-making method be used?

The decision-making methods described in this guidebook are readily applicable to a wide range of decisions, from ones as simple as picking a restaurant for a special meal to those that are complicated by interdepartmental government interfaces. Use of this decision-making process and supporting methods is recommended any time decisions:

- Require many reviews at different management levels
- Involve more than one program
- Require congressional line item approval
- Affect new or redirected funding
- Require approval for new facilities or upgrades to existing facilities
- Have alternatives with high technical risk
- Have alternatives that appear equally viable
- Require a decision to revise or discontinue work on a program
- Have impact mainly in the future
- Involve multiple or competing drivers, or
- Define data needed to support future decisions

In short this guide should be followed any time a clear, transparent, and understandable decision is desired.

2.0 Decision-Making Process

First priority in making a decision is to establish who are the decision-maker(s) and stakeholders in the decision - the audience for the decision. Identifying the decision-maker(s) early in the process cuts down on disagreement about problem definition, requirements, goals, and criteria.

Although the decision-maker(s) seldom will be involved in the day-to-day work of making evaluations, feedback from the decision-maker(s) is vital at four steps in the process:

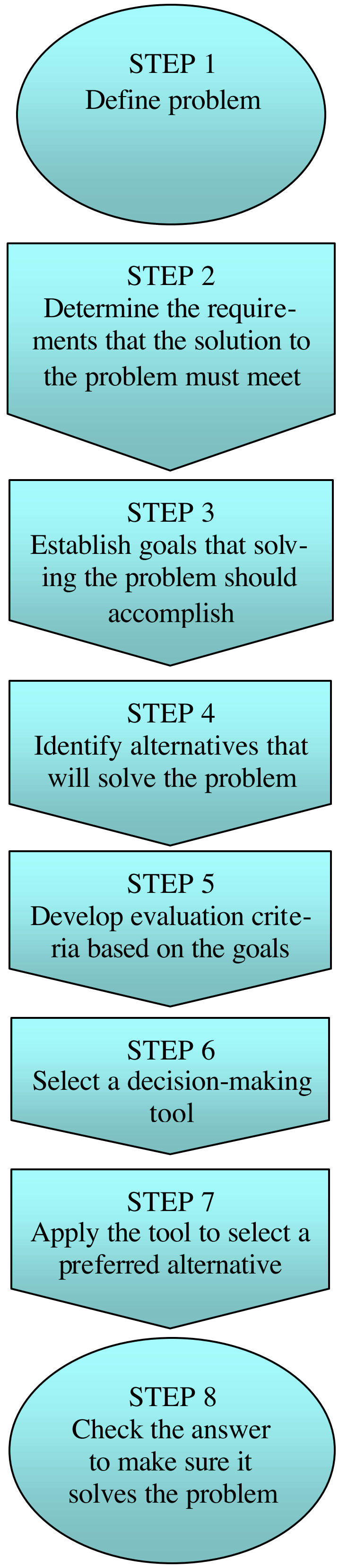
1. Problem definition [step 1]
2. Requirements identification [step 2]
3. Goal establishment [step 3]
4. Evaluation criteria development [step 5]

When appropriate, stakeholders should also be consulted. By acquiring their input during the early steps of the decision process, stakeholders can provide useful feedback before a decision is made.

Figure 1 shows the steps in the decision-making process. The process flows from top to bottom, but may return to a previous step from any point in the process when new information is discovered.

It is the decision team's job to make sure that all steps of the process are adequately performed. **Usually the decision support staff should include the help of skilled and experienced analysts/facilitators to assist with all stages of the decision process.** Expert facilitation can help assure that all the steps are properly performed and documented. Their experience and expertise will help provide transparency to the decision making process and help avoid misunderstandings that often lead to questions about the validity of the analyses which ultimately slow progress.

Figure 1 General Decision–Making Process



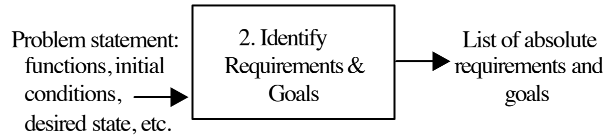
2.1 Step 1, Define the Problem

Problem definition is the crucial first step in making a good decision. This process must, as a minimum, identify root causes, limiting assumptions, system and organizational boundaries and interfaces, and any stakeholder issues. **The goal is to express the issue in a clear, one-sentence *problem statement* that describes both the initial conditions and the desired conditions.** It is essential that the decision-maker(s) and support staff concur on a ***written*** problem statement to ensure that they all agree on what problem is going to be solved before proceeding to the next steps.

The key to developing an adequate problem statement is to ask enough questions about the problem to ensure that the final report will clearly answer the questions of reviewers and stakeholders (see Figure 2 below). When stakeholders are involved, it may be appropriate to have them review the problem statement with its initial and desired state to provide an external check before requirements and goals are defined.

Some questions which may be helpful to the process are suggested Appendix B. For more information, the reader can consult texts on problem definition available from the business press.[2]

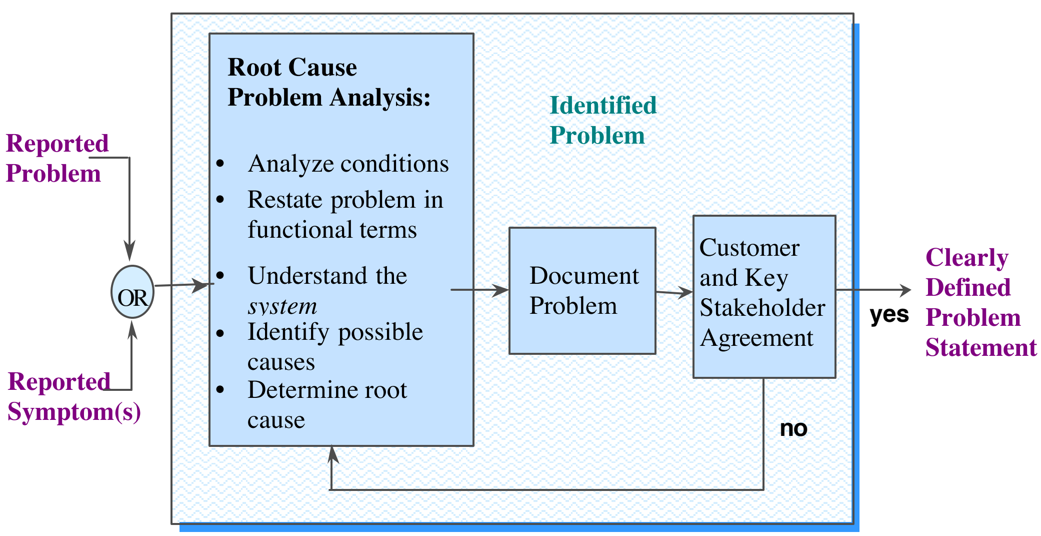
2.2 Step 2, Determine Requirements



Requirements are conditions that any acceptable solution to the problem *must* meet. Requirements spell out what the solution to the problem *must* do. For example, a requirement might be that a process must ("shall" in the vernacular of writing requirements) produce at least ten units per day. Any alternatives that produced only nine units per day would be discarded. Requirements that don't discriminate between alternatives need not be used at this time.

With the decision-maker's concurrence, experts in operations, maintenance, environment, safety, health and other technical disciplines typically provide the requirements that a viable alternative must meet. Aids for identifying requirements appear in Appendix B. For more information, the reader can consult texts on requirements management available from the business press.[3]

Figure 2. Problem Definition:
Ask enough questions to be able to answer questions from others.



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[2] Appendix C-Further Reading 2, Folger and LeBlanc and 3, Gause
[3] Appendix C-Further Reading 4, Hammond, Keeney and Raffia, and 5, Hooks and Farry

2.3 Step 3, Establish Goals

Goals are broad statements of intent and desirable programmatic values. Examples might be: reduce worker radiological exposure, lower costs, lower public risk, etc. Goals go beyond the minimum essential *must have's* (i.e. requirements) to *wants* and *desires*. Goals should be stated positively (i.e. what something *should do,* not what it *shouldn't do*). Because goals are useful in identifying superior alternatives (i.e., define in more detail the desired state of the problem), they are developed prior to alternative identification.

Sometimes goals may conflict, but this is neither unusual, nor cause for concern. During goal definition, it is not necessary to eliminate conflict among goals nor to define the relative importance of the goals. The process of establishing goals may suggest new or revised requirements or requirements that should be converted to goals. In any case, understanding the requirements and goals is important to defining alternatives. Aids for identifying goals appear in Appendix B.

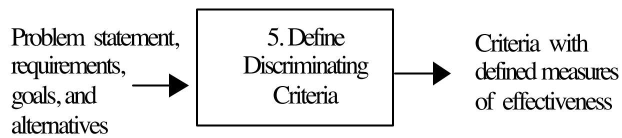
2.4 Step 4, Identify Alternatives

Alternatives offer different approaches for changing the initial condition into the desired condition. The decision team evaluates the requirements and goals and suggests alternatives that will meet the requirements and satisfy as many goals as possible. Generally, the alternatives vary in their ability to meet the requirements and goals. Those alternatives that do not meet the requirements must be screened out from further consideration. If an alternative does not meet the requirements, three actions are available:

1. The alternative is discarded
2. The requirement is changed or eliminated
3. The requirement is restated as a goal

The description of each alternative must clearly show how it solves the defined problem and how it differs from the other alternatives. A written description and a diagram of the specific functions performed to solve the problem will prove useful. Aids for identifying alternatives appear in Appendix B.

2.5 Step 5, Define Criteria



Usually no one alternative will be the best for all goals, requiring alternatives to be compared with each other. The best alternative will be the one that most nearly achieves the goals. Decision criteria which will discriminate among alternatives must be based on the goals. It is necessary to define discriminating criteria as objective measures of the goals to measure how well each alternative achieves the project goals.

Each criterion should measure something important, and not depend on another criterion. Criteria must discriminate among alternatives in a meaningful way (e.g., if the color of all alternatives is the same or the user is indifferent to the color selection, then color should not be a criterion)[4].

Criteria should be:

- Able to discriminate among the alternatives
- Complete – include all goals
- Operational – meaningful to the decision maker's understanding of the implications of the alternatives
- Non-redundant – avoid double counting
- Few in number – to keep the problem dimensions manageable

Using a few real discriminators will result in a more understandable decision analysis product. However, every goal must generate at least one

[4] A summary of INMM goals and criteria appears in Appendix B.

criterion. If a goal does not suggest a criterion, it should be abandoned.

Several methods can be used to facilitate criteria selection.

Brainstorming: Team brainstorming may be used to develop goals and associated criteria. (Brainstorming is discussed in Appendix B.)

Round Robin: Team members are individually asked for their goals and the criteria associated with them. The initial elicitation of ideas should be done non-judgmentally – all ideas are recorded before criticism of any is allowed.

When members of the goal-setting group differ widely in rank or position, it can be useful to employ the military method in which the lowest ranking member is asked first to avoid being influenced by the opinions of the higher-ranking members.

Reverse Direction Method: Team members consider available alternatives, identify differences among them, and develop criteria that reflect these differences.

Previously Defined Criteria: End users, stakeholders, or the decision-maker(s) may provide criteria.

Input from the decision-maker(s) is essential to the development of useful criteria. Moreover, the decision-maker's approval is crucial before the criteria are used to evaluate the alternatives. Additional aids for defining criteria appear in Appendix B.

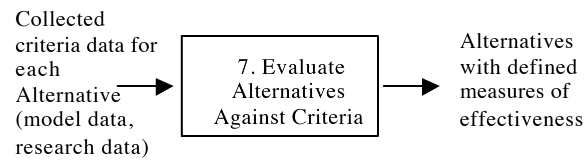
2.6 Step 6, Select a Decision-Making Tool

Section 3.0 introduces and describes these widely employed tools:

- Pros and Cons Analysis
- Kepner-Tregoe Decision Analysis (K-T)
- Analytic Hierarchy Process (AHP)
- Multi-Attribute Utility Theory Analysis (MAUT)
- Cost Benefit Analysis (CBA)
- Custom Tailored Tools

Some of these methods can be complicated and difficult to apply. The method selection needs to be based on the complexity of the problem and the experience of the team. Generally, the simpler the method, the better. More complex analyses can be added later if needed. Appendix A provides step-by-step examples of these methods.

2.7 Step 7, Evaluate Alternatives against Criteria



Alternatives can be evaluated with quantitative methods, qualitative methods, or any combination. Criteria can be weighted and used to rank the alternatives. Both sensitivity and uncertainty analyses can be used to improve the quality of the selection process. Experienced analysts can provide the necessary thorough understanding of the mechanics of the chosen decision-making methodology. The step-by-step examples in Appendix A suggest some methods for performing these evaluations. Additional aids for evaluating alternatives appear in Appendix B.

2.8 Step 8, Validate Solution(s) against Problem Statement

After the evaluation process has selected a preferred alternative, the solution should be checked to ensure that it truly solves the problem identified. Compare the original problem statement to the goals and requirements. A final solution should fulfill the desired state, meet requirements, and best achieve the goals within the values of the decision makers. Once the preferred alternative has been validated, the decision-making support staff can present it as a recommendation to the decision-maker(s). A final report to the decision-maker(s) must be written documenting the decision process, assumptions, methods, and conclusions recommending the final solution. Appendix B provides suggestions for the final report outline.

3.0 Decision Making Methods

Decision Analysis techniques are rational processes/systematic procedures for applying critical thinking to information, data, and experience in order to make a balanced decision when the choice between alternatives is unclear. They provide organized ways of applying critical thinking skills developed around accumulating answers to questions about the problem. Steps include clarifying purpose, evaluating alternatives, assessing risks and benefits, and making a decision. These steps usually involve *scoring* criteria and alternatives. This scoring (a systematic method for handling and communicating information) provides a common language and approach that removes decision making from the realm of personal preference or idiosyncratic behavior (see Appendix B for scoring and weighting options).

The evaluation methods introduced here are highly recommended. They are adaptable to many situations, as determined by the complexity of the problem, needs of the customer, experience of the decision team/analysts/facilitators, and the time and resources available. No one decision-making method is appropriate for all decisions. The examples provided in Appendix A are intended to facilitate understanding and use of these methods.

3.1 Pros and Cons Analysis

Pros and Cons Analysis is a qualitative comparison method in which good things (pros) and bad things (cons) are identified about each alternative. Lists of the pros and cons, based on the input of subject matter experts, are compared one to another for each alternative. (See B. Franklin's description on page ii and the example in Appendix A.) The alternative with the strongest pros and weakest cons is preferred. The decision documentation should include an exposition, which justifies why the preferred alternative's pros are more important and its cons are less consequential than those of the other alternatives.

Pros and Cons Analysis is suitable for simple decisions with few alternatives (2 to 4) and few discriminating criteria (1 to 5) of approximately equal value. It requires no mathematical skill and can be implemented rapidly.

3.2 Kepner-Tregoe (K-T) Decision Analysis

K-T is a quantitative comparison method in which a team of experts numerically score criteria and alternatives based on individual judgements/assessments. The size of the team needed tends to be inversely proportional to the quality of the data available – the more intangible and qualitative the data, the greater the number of people that should be involved.

In K-T parlance each evaluation criterion is first scored based on its relative importance to the other criteria (1 = least; 10 = most). These scores become the *criteria weights* (see K-T example in Appendix A). "Once the WANT objectives *(goals)* [have] been identified, each one [is] weighted according to its relative importance. The *most* important objective [is] identified and given a weight of 10. All other objectives [are] then weighted in comparison with the first, from 10 (equally important) down to a possible 1 (not very important). When the time comes to evaluate the alternatives, we do so by assessing them *relative to each other* against all WANT objectives – one at a time."[5]

The alternatives are scored individually against each of the goal criteria based on their relative performance. "We give a score of 10 to the alternative that comes *closest* to meeting the objective, and score the other alternatives *relative to it*. It is not an ideal that we seek through this comparative evaluation. What we seek is an answer to the question: 'Of these (real and attainable) alternatives, which best fulfills the objective?'"[6]

A total score is determined for each alternative by multiplying its score for each criterion by the criterion weights (relative weighting factor for each criterion) and then summing across all criteria. The preferred alternative will have the highest total score.

[5] Appendix C-Further Reading 6, Kepner and Tregoe, P.92
[6] Ibid, p.95

K-T Decision Analysis is suitable for moderately complex decisions involving a few criteria. The method requires only basic arithmetic. Its main disadvantage is that it may not be clear how much better a score of "10" is than a score of "8", for example. Moreover, total alternative scores may be close together, making a clear choice difficult.[7]

3.3 Analytic Hierarchy Process (AHP)

AHP is a quantitative comparison method used to select a preferred alternative by using pair-wise comparisons of the alternatives based on their relative performance against the criteria. The basis of this technique is that humans are more capable of making relative judgements than absolute judgements. "The Analytic Hierarchy Process is a systematic procedure for representing the elements of any problem, hierarchically. It organizes the basic rationality by breaking down a problem into its smaller and smaller constituent parts and then guides decision makers through a series of pairwise comparison judgements (which are documented and can be reexamined) to express the relative strength or intensity of impact of the elements in the hierarchy. These judgements are then translated to numbers (ratio scale estimates). The AHP includes procedures and principles used to synthesize the many judgements to derive priorities among criteria and subsequently for alternative solutions."[8]

Alternatives and criteria are scored using a pair-wise comparison method and mathematics (see AHP example in Appendix A). The pair-wise comparisons are made using a nine-point scale:

1 = Equal importance or preference
3 = Moderate importance or preference of one over another
5 = Strong or essential importance or preference
7 = Very strong or demonstrated importance or preference
9 = Extreme importance or preference

Matrices are developed wherein each criterion/alternative is compared against the others. If Criterion A is strongly more important compared to Criterion B (i.e. a value of "5"), then Criterion B has a value of 1/5 compared to Criterion A. Thus, for each comparative score given, the reciprocal is awarded to the opposite relationship. The "priority vector" (i.e. the normalized weight) is calculated for each criterion using the geometric mean[9] of each row in the matrix divided by the sum of the geometric means of all the criteria (see example in Appendix A). This process is then repeated for the alternatives comparing them one to another to determine their relative value/importance for each criterion (i.e. determine the normalized alternative score). The calculations are easily set up in a spreadsheet, and commercial software packages are available.

HINT: The order of comparison can help simplify this process. Try to identify and begin with the most important criterion and work through the criteria to the least important. When comparing alternatives try to identify and begin with the one with the greatest benefits for each associated criterion.

To identify the preferred alternative multiply each normalized alternative score by the corresponding normalized criterion weight, and sum the results for all of an alternatives criteria. The preferred alternative will have the highest total score.

AHP, like the other methods, can rank alternatives according to quantitative or qualitative (subjective) data. Qualitative/subjective criteria are based on the evaluation team's feelings or perceptions about how an alternative ranks. The criteria weights and alternative comparisons are combined in the decision synthesis to give the relative value (ratio/score) for each alternative for the prescribed decision context. A sensitivity analysis can be performed to determine how the alternative selection would change with different criteria weights. The

[7] Appendix C-Further Reading 6, Kepner and Tregoe
[8] Appendix C-Further Reading 7, Saaty and Kearns, p.19

[9] The geometric mean is the nth root of the product of n scores. Thus, the geometric mean of the scores: 1, 2, 3, and 10 is the fourth root of (1 x 2 x 3 x 10), which is the fourth root of 60. $(60)^{1/4} = 2.78$. The geometric mean is less affected by extreme values than is the arithmetic mean. It is useful as a measure of central tendency for some positively skewed distributions.

whole process can be repeated and revised, until everyone is satisfied that all the important features needed to solve the problem, or select the preferred alternative, have been covered.

AHP is a useful technique when there are multiple criteria since most people cannot deal with more than seven decision considerations at a time.[10] AHP is suitable for decisions with both quantitative and qualitative criteria. It puts them in the same decision context by relying on relative comparisons instead of attempting to define absolutes. It facilitates discussion of the importance of criteria and the ability of each alternative to meet the criteria. Its greatest strength is the analytical hierarchy that provides a structured model of the problem, mimicking the way people generally approach complex situations by allowing relative judgements in lieu of absolute judgements. Another strength is its systematic use of the geometric mean to define functional utilities based on simple comparisons and to provide consistent, meaningful results. The size of AHP matrices make this method somewhat less flexible than either K-T or MAUT when newly discovered alternatives or criteria need to be considered. Commercially available software, however, can reduce this burden and facilitate the whole process. Although software is not required for implementation, it can be helpful especially if a large number of alternatives (>8), or criteria (>5) must be considered.[11]

3.4 Multi-Attribute Utility Theory (MAUT)

MAUT is a quantitative comparison method used to combine dissimilar measures of costs, risks, and benefits, along with individual and stakeholder preferences, into high-level, aggregated preferences. The foundation of MAUT is the use of utility functions. Utility functions transform diverse criteria to one common, dimensionless scale (0 to 1) known as the multi-attribute "utility". Once utility functions are created an alternative's raw data (objective) or the analyst's beliefs (subjective) can be converted to utility scores. As with the other methods, the criteria are weighted according to importance. To identify the preferred alternative, multiply each normalized alternative's utility score results for all of an alternative's criteria. The preferred alternative will have the highest total score.

Utility functions (and MAUT) are typically used, when quantitative information is known about each alternative, which can result in firmer estimates of the alternative performance. Utility graphs are created based on the data for each criterion. Every decision criterion has a utility function created for it. The utility functions transform an alternative's raw score (i.e. dimensioned – feet, pounds, gallons per minute, dollars, etc.) to a dimensionless utility score, between 0 and 1. The utility scores are weighted by multiplying the utility score by the weight of the decision criterion, which reflects the decision-making support staff's and decision-maker's values, and totaled for each alternative. The total scores indicate the ranking for the alternatives.

The MAUT evaluation method is suitable for complex decisions with multiple criteria and many alternatives. Additional alternatives can be readily added to a MAUT analysis, provided they have data available to determine the utility from the utility graphs. Once the utility functions have been developed, any number of alternatives can be scored against them.

The **Simple Multi Attribute Rating Technique (SMART)** can be a useful variant of the MAUT method. This method utilizes *simple* utility relationships. Data normalization to define the MAUT/SMART utility functions can be performed using any convenient scale. Five, seven, and ten point scales are the most commonly used. In a classical MAUT the full range of the scoring scale would be used even when there was no real difference between alternatives scores. The SMART methodology allows for use of less of the scale range if the data does not discriminate adequately so that, for example, alternatives which are not significantly different for a particular criterion can be scored equally. This is particularly important when confidence in the differences in data is low. In these cases, less of the range is used to ensure that low confidence data differences do not present unwarranted large discriminations between the alternatives. When actual numerical data are

[10] Appendix C-Further Reading 8, Miller, p.81-97

[11] Appendix C-Further Reading 9 and 10, Saaty

unavailable, subjective reasoning, opinions, and/or consensus scoring can be substituted and documented in the final report instead. Research has demonstrated that simplified MAUT decision analysis methods are robust and replicate decisions made from more complex MAUT analysis with a high degree of confidence.[12]

3.5 Cost-Benefit Analysis

Cost-Benefit Analysis (see example in Appendix A) is "a systematic quantitative method of assessing the desirability of government projects or policies when it is important to take a long view of future effects and a broad view of possible side-effects."[13] CBA is a good approach when the primary basis for making decisions is the monetary cost vs. monetary benefit of the alternatives. General guidance for conducting cost-benefit and cost-effectiveness analyses is provided in the U.S. Office of Management and Budget, OMB Circular No. A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*.[14] The discount rates for this methodology are updated annually by the OMB.

The standard criterion for deciding whether a government program can be justified on economic principles is net present value -- the discounted monetized value of expected net benefits (i.e., benefits minus costs). Net present value is computed by assigning monetary values to benefits and costs, discounting future benefits and costs using an appropriate discount rate, and subtracting the sum total of discounted costs from the sum total of discounted benefits. Discounting benefits and costs transforms gains and losses occurring in different time periods to a common unit of measurement. Programs with positive net present value increase social resources and are generally preferred. Programs with negative net present value should generally be avoided. When " benefits" and "costs" can be quantified in dollar terms (as, for example avoided cost) over several years, these benefits can be subtracted from the costs (or dollar outlays) and the present value of the benefit calculated. "Both intangible and tangible benefits and costs should be recognized. The relevant cost concept is broader than the private-sector production and compliance cost or government cash expenditures. Costs should reflect opportunity cost of any resources used, measured by the return to those resources in their most productive application elsewhere."[15] The alternative returning the largest discounted benefit is preferred.

In Pros and Cons analysis cost is regarded intuitively along with the other advantages and disadvantages ("high cost" is a con; "low cost" is a pro). The other techniques provide numerical ranking of alternatives based on either intangible (i.e. unable to be quantified in dollar terms) or tangible (quantifiable in dollar terms) benefits.[16]

3.6 Custom Tailored Tools

Customized tools may be needed to help understand complex behavior within a system. Very complex methods can be used to give straightforward results. Because custom-tailored tools are not off-the-shelf, they can require significant time and resources for development. If a decision cannot be made using the tools described previously, or the decision must be made many times employing the same kinds of considerations, the decision-making support staff should consider employing specialists with experience in computer modeling and decision analysis to develop a custom-tailored tool.

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[12] Appendix C-Further Reading 11, Edwards and Barron, 12, Goodwin and Wright, 4, Hammond, Keeney, and Raiffa

[13] Appendix C-Further Reading 13, U.S. Office of Management and Budget, p. 15

[14] Ibid

[15] Appendix C-Further Reading 13, U.S. Office of Management and Budget

[16] Appendix C-Further Reading 14, Broadman, Greenberg, Vining, and Weimer; 15, Canada, Sullivan, and White; 16, Electric Power Research Institute; 17, Snell; and 13, U.S. Office of Management and Budget.

4.0 Summary

The goal of this Guidebook to Decision-Making Methods is to help decision-makers and their decision support staffs choose and document the best alternative in a clear and transparent fashion. The decision-making methods described in this guidebook are readily applicable to a wide range of decisions, from ones as simple as picking a restaurant for a special meal to those that are complicated by interdepartmental government interfaces. Expert facilitation can help assure that all the steps are properly performed documented. Feedback from the decision-maker(s) is vital to the process.

The key to developing an adequate problem statement is to ask enough questions about the problem to ensure that the final report will clearly answer the questions of reviewers and stakeholders. Requirements spell out what the solution to the problem must do. Goals are useful in identifying superior alternatives. The decision team evaluates the requirements and goals and suggests alternatives that will meet the requirements and satisfy as many goals as possible. The best alternative will be the one that most nearly achieves the goals. Criteria must be developed to discriminate among alternatives in a meaningful way. The decision-maker's approval is crucial before the criteria are used to evaluate the alternatives.

Alternatives can be evaluated with quantitative methods, qualitative methods, or any combination. **The evaluation methods introduced here are highly recommended**. They are adaptable to many situations, as determined by the complexity of the problem, needs of the customer, experience of the decision team / analysts / facilitators, and the time and resources available. The decision-making method selection needs to be based on the complexity of the problem and the experience of the team. A final solution should fulfill the desired state, meet requirements, and best achieve the goals within the values of the decision makers.

Once the preferred alternative has been validated, the decision-making support staff can pre sent it as a recommendation to the decision-maker(s). A final report to the decision-maker(s) must be written documenting the decision process, assumptions, methods, and conclusions recommending the final solution.

Appendix A – Decision-Making Tools at Work

Step 1 Problem: Pick a replacement vehicle for the motor pool fleet

(The definition of the problem dictates the requirements. As the vehicle is for a motor pool, the requirements will differ from those for a family car, for example.)

Step 2 Requirements:

1. Vehicle shall be made in U. S. A.
2. Vehicle shall seat at least four adults, but no more than six adults
3. Vehicle shall cost no more than $28,000
4. Vehicle shall be new and the current model year

(Other requirements may be appropriate, but the above four will suffice for this example.)

Step 3 Goals:

- Maximize passenger comfort
- Maximize passenger safety
- Maximize fuel-efficiency
- Maximize reliability
- Minimize investment cost

Step 4 Alternatives:

There are many alternatives but the requirements eliminate the consideration of a number of them:

Requirement 1 eliminates the products not manufactured in the USA
Requirement 2 eliminates vans, buses, and sports cars
Requirement 3 eliminates high-end luxury cars
Requirement 4 eliminates used vehicles

Despite the limitations imposed by the requirements, many alternatives remain. This example will evaluate four, current, U. S. models against the goals:

For this simple problem the following quantitative data are available. This is how the four models stack up:

Arrow
Seats two adults in the front seat and three in the back seat

Rear seat leg and shoulder room	86 inches
Number of safety stars	14
Fuel consumption	21 mpg
Reliability	80
Cost	$26,000

Baton

Seats three adults in the front seat and three in the back seat

Rear seat leg and shoulder room	88 inches
Number of safety stars	17
Fuel consumption	19 mpg
Reliability	70
Cost	$21,000

Carefree
Seats two adults in the front seat and three in the back seat

Rear seat leg and shoulder room	80 inches
Number of safety stars	15
Fuel consumption	22 mpg
Reliability	65
Cost	$17,000

Dash
Seats three adults in the front seat and three in the back seat

Rear seat leg and shoulder room	89 inches
Number of safety stars	19
Fuel consumption	21 mpg
Reliability	85
Cost	$24,000

Step 5 Criteria:

"Maximize comfort"	will be based on the combined rear seat leg and shoulder room. (Note: front seat passenger leg and shoulder room was found to be too nearly the same to discriminate among the alternatives.)
"Maximize safety"	will be based on the total number of stars awarded by the National Highway Traffic Safety Administration for head-on and side impact.
"Maximize fuel efficiency"	will be based on the EPA fuel consumption for city driving.
"Maximize reliability"	will be based on the reliability rating given each vehicle by a consumer product testing company.
"Minimize Cost"	will be based on the purchase price.

Step 6 Decision-Making Tool Selection:

To demonstrate the application of the decision-making tools described in this Guidebook this problem will be solved using each method. In a typical decision situation tool selection would depend on the mutual experience of the decision team, any expert facilitator, and the complexity of the problem. Data, either quantitative or qualitative, would be gathered and tabulated for evaluation against the defined criteria.

Step 7 Apply the Selected Method

PROS AND CONS ANALYSIS

Lists of the pros and cons, based on the input of subject matter experts, are compared one to another for each alternative.

Table 1. Example of Pros And Cons Analysis

Arrow		*Baton*	
Pro	Con	Pro	Con
Good fuel efficiency	Highest cost	Next to most room	Worst fuel efficiency
Next to best reliability	Fewest safety stars		

Carefree		*Dash*	
Pro	Con	Pro	Con
Lowest cost	Next to fewest safety stars	Most safety stars	
Best fuel efficiency	Least room	Best reliability	
	Worst reliability	Good fuel efficiency	
		Most room	
		Best reliability	

Step 8 Validate Solution:

Safety and reliability are the most important criteria. Dash is best in these areas. Dash scores pros in the other criteria, as well. Dash has five advantages and no disadvantages, so Dash is the preferred alternative. Dash meets all the requirements and solves the problem.

Step 7 Apply the Selected Method

KEPNER-TREGOE DECISION ANALYSIS

In this example a team consensus approach based on the decision-making support staff's and decision-maker's values was used to obtain both the criteria weight and the alternative score relative to each criterion. The team was polled and the average score for each element, rounded to the nearest integer, obtained. The Total Score is the product of the Criteria Weight and the Alternative Score summed for the alternative.

Table 2. Example of Kepner-Tregoe Decision Analysis

Criteria/ Want objectives	Criteria Weight	*Arrow*	Alter-native Score	Total Score
Comfort	5	86 in. rear seat leg and shoulder room, seats 5	6	30
Safety	10	14 stars	5	50
Fuel efficiency	7	21 mpg	9	63
Reliability	9	80	9	81
Cost	10	$26,000	5	50
		Total		**274**
		Baton		
Comfort	5	88 in. rear seat leg and shoulder room, seats 6	9	45
Safety	10	17 stars	8	80
Fuel efficiency	7	19 mpg	8	56
Reliability	9	70	7	63
Cost	10	$21,000	8	80
		Total		**324**
		Carefree		
Comfort	5	80 in. rear seat leg and shoulder room, seats 5	4	20
Safety	10	15 stars	6	60
Fuel efficiency	7	22 mpg	10	70
Reliability	9	65	5	45
Cost	10	$17,000	10	100
		Total		**295**
		Dash		
Comfort	5	89 in rear seat leg and shoulder room, seats 6	10	50
Safety	10	19 stars	10	100
Fuel efficiency	7	21 mpg	9	63
Reliability	9	85	10	90
Cost	10	$24,000	6	60
		Total		**363**

Step 8 Validate Solution:

The totals of the weighted scores show that the Dash most nearly meets the wants/goals (or put another way, has the most "benefits"). Dash meets all the requirements and solves the problem.

Step 7 Apply the Selected Method

ANALYTICAL HIERARCHY PROCESS

In this example a team consensus approach based on the decision-making support staff's and decision-maker's values was used to obtain the relative pair-wise comparisons for each criterion. The team was polled and the average score for each comparison, rounded to the nearest integer, obtained. For example the team consensus was that Safety as compared to Comfort deserved a 7 - very strong or demonstrated importance or preference.

HINT: The team first ranked the criteria in order of importance – Safety, Cost, Reliability, Fuel efficiency, and Comfort and then compared them one to another (Table 3) to determine their relative importance (score). The basis for this ranking must be included in the final report. The ranking order presented here is not a requirement. Ranking order can vary depending on many factors.

Table 3. Example of Pair-Wise Comparison of CRITERIA

Safety- Comfort	7	Cost- Comfort	6	Reliability- Comfort	6	Fuel efficiency- Comfort	4
Safety- Fuel efficiency	4	Cost- Fuel efficiency	2	Reliability- Fuel efficiency	2		
Safety- Reliability	3	Cost- Reliability	1				
Safety- Cost	2						

The remaining, or reciprocal, comparisons of the criteria are determined by inspection for incorporation in the calculation of the normalized criteria weights in Table 4.

Table 4. Example of Calculating Priority Vector or Normalized Criteria Weights

	Comfort	Safety	Fuel Efficiency	Reliability	Cost	Geometric Mean	Normalized Weight
Comfort	1	1/7	1/4	1/6	1/6	0.251	0.038
Safety	7	1	4	3	2	2.787	0.426
Fuel efficiency	4	1/4	1	1/2	1/2	0.758	0.116
Reliability	6	1/3	2	1	1	1.320	0.202
Cost	6	1/2	2	1	1	1.431	0.219
						SUM= 6.546	

The geometric mean is less affected by extreme values than is the arithmetic mean. It is the nth root of the product of n scores. Thus, the geometric mean of the scores: 1, 2, 3, and 10 is the fourth root of (1 x 2 x 3 x 10), which is the fourth root of 60. $(60)^{1/4} = 2.78$. It is useful as a measure of central tendency for some positively skewed distributions. The normalized criterion weight is its geometric mean divided by the sum of the geometric means of all the criteria. The geometric mean and normalized weights can be computed using spreadsheet software as shown in Figure 1.

Next the team performed pair-wise comparisons of the alternatives with regard to each criterion. For example the team consensus was that Dash as compared to Baton with respect to comfort deserved a 1 - equal importance or preference. The 1 inch difference in the comfort measurement between Dash and Baton was deemed to have no real impact while the difference in the comfort measurements between Dash and Arrow and between Dash and Carefree coupled with seating capacities were deemed to have a greater impact.

Figure 1. Example of Spreadsheet Set-up for AHP Matrices

	A	B	C	D	E	F	G	H
1		Comfort	Safety	Fuel efficiency	Reliability	Cost	Geometric Mean	Normalized Weight
2	Comfort	1	=1/7	=1 /4	=1/6	=1/6	=GEOMEAN(B2:F2)	=+G2/$G$7
3	Safety	7	1	4	3	2	=GEOMEAN(B3:F3)	=+G3/$G$7
4	Fuel efficiency	4	=1 /4	1	=1/2	=1/2	=GEOMEAN(B4:F4)	=+G4/$G$7
5	Reliability	6	=1/3	2	1	1	=GEOMEAN(B5:F5)	=+G5/$G$7
6	Cost	6	=1/2	2	1	1	=GEOMEAN(B6:F6)	=+G6/$G$7
7							=SUM(G2:G6)	

Table 5. Example of Pair-Wise Comparison of ALTERNATIVES With Respect to COMFORT

Dash - Baton	1	Baton - Arrow	2	Arrow - Carefree	3
Dash - Arrow	4	Baton - Carefree	3		
Dash - Carefree	5				

The remaining, or reciprocal, comparisons of the alternatives are determined by inspection for incorporation in the calculation of the normalized alternative scores in Table 6. Each alternative was compared in Tables 7 - 14 to determine its normalized score for each criterion.

Table 6. Example of Calculating Priority Vector or Normalized Alternative Score With Respect to COMFORT

	Arrow	Baton	Carefree	Dash	Geometric Mean	Normalized Score
Arrow	1	1/2	3	1/4	0.78254229	0.160040343
Baton	2	1	3	1	1.56508458	0.320080687
Carefree	1/3	1/2	1	1/5	0.427287006	0.087385896
Dash	4	1	5	1	2.114742527	0.432493074

Table 7. Example of Pair-Wise Comparison of ALTERNATIVES With Respect to SAFETY

Dash - Baton	2	Baton - Arrow	2	Carefree - Arrow	1
Dash - Arrow	5	Baton - Carefree	3		
Dash - Carefree	4				

Table 8. Example of Calculating Priority Vector or Normalized Alternative Score With Respect to SAFETY

	Arrow	Baton	Carefree	Dash	Geometric Mean	Normalized Score
Arrow	1	1/2	1	1/5	0.562341325	0.114052057
Baton	2	1	3	1/2	1.316074013	0.266921425
Carefree	1	1/3	1	1/4	0.537284965	0.108970215
Dash	5	2	4	1	2.514866859	0.510056303

Table 9. Example of Pair-Wise Comparison of ALTERNATIVES With Respect to FUEL EFFICIENCY

Carefree - Baton	3	Dash - Arrow	1	Arrow - Baton	2
Carefree - Arrow	1	Dash - Baton	2		
Carefree - Dash	1				

Table 10. Example of Calculating Priority Vector or Normalized Alternative Score With Respect to FUEL EFFICIENCY

	Arrow	Baton	Carefree	Dash	Geometric Mean	Normalized Score
Arrow	1	2	1	1	1.189207115	0.277263153
Baton	1/2	1	1/2	1/2	0.594603558	0.138631576
Carefree	1	3	1	1	1.316074013	0.306842118
Dash	1	2	1	1	1.189207115	0.277263153

Table 11. Example of Pair-Wise Comparison of ALTERNATIVES With Respect to RELIABILITY

Dash - Baton	4	Arrow - Baton	3	Baton - Carefree	2
Dash - Arrow	2	Arrow - Carefree	4		
Dash - Carefree	6				

Table 12. Example of Calculating Priority Vector or Normalized Alternative Score With Respect to RELIABILITY

	Arrow	Baton	Carefree	Dash	Geometric Mean	Normalized Score
Arrow	1	3	4	1/2	1.56508458	0.300049178
Baton	1/3	1	2	1/4	0.638943088	0.122494561
Carefree	1/4	1/2	1	1/6	0.379917843	0.072835704
Dash	2	4	6	1	2.632148026	0.504620557

Table 13. Example of Pair-Wise Comparison of ALTERNATIVES With Respect to COST

Carefree - Baton	3	Baton - Dash	3	Dash - Arrow	2
Carefree - Dash	4	Baton - Arrow	4		
Carefree - Arrow	5				

Table 14. Example of Calculating Priority Vector or Normalized Alternative Score With Respect to COST

	Arrow	Baton	Carefree	Dash	Geometric Mean	Normalized Score
Arrow	1	1/4	1/5	1/2	0.397635364	0.075972332
Baton	4	1	1/3	3	1.414213562	0.270200068
Carefree	5	3	1	4	2.783157684	0.531750942
Dash	2	1/3	1/4	1	0.638943088	0.122076658

To identify the preferred alternative multiply each normalized alternative score by the corresponding normalized criterion weight, and sum the results for all of an alternatives criteria. The preferred alternative will have the highest total score.

Table 15. Example of AHP Decision Analysis

Criteria/ Want objectives	Normalized Criteria Weight	*Arrow*	Normalized Alternative Score	Total Score
Comfort	0.038	86 in. rear seat leg and shoulder room, seats 5	0.160040343	0.0061
Safety	0.426	14 stars	0.114052057	0.0486
Fuel efficiency	0.116	21 mpg	0.277263153	0.0322
Reliability	0.202	80	0.300049178	0.0606
Cost	0.219	$26,000	0.075972332	0.0166
		Total		**0.1641**
		Baton		
Comfort	0.038	88 in. rear seat leg and shoulder room, seats 6	0.320080687	0.0122
Safety	0.426	17 stars	0.266921425	0.1137
Fuel efficiency	0.116	19 mpg	0.138631576	0.0161
Reliability	0.202	70	0.122494561	0.0427
Cost	0.219	$21,000	0.270200068	0.0592
		Total		**0.2259**
		Carefree		
Comfort	0.038	80 in. rear seat leg and shoulder room, seats 5	0.087385896	0.0033
Safety	0.426	15 stars	0.108970215	0.0464
Fuel efficiency	0.116	22 mpg	0.306842118	0.0356
Reliability	0.202	65	0.072835704	0.0147
Cost	0.219	$17,000	0.531750942	0.1165
		Total		**0.2165**
		Dash		
Comfort	0.038	89 in rear seat leg and shoulder room, seats 6	0.432493074	0.0164
Safety	0.426	19 stars	0.510056303	0.2173
Fuel efficiency	0.116	21 mpg	0.277263153	0.0322
Reliability	0.202	85	0.504620557	0.1019
Cost	0.219	$24,000	0.122076658	0.0267
		Total		**0.3945**

Step 8 Validate Solution:

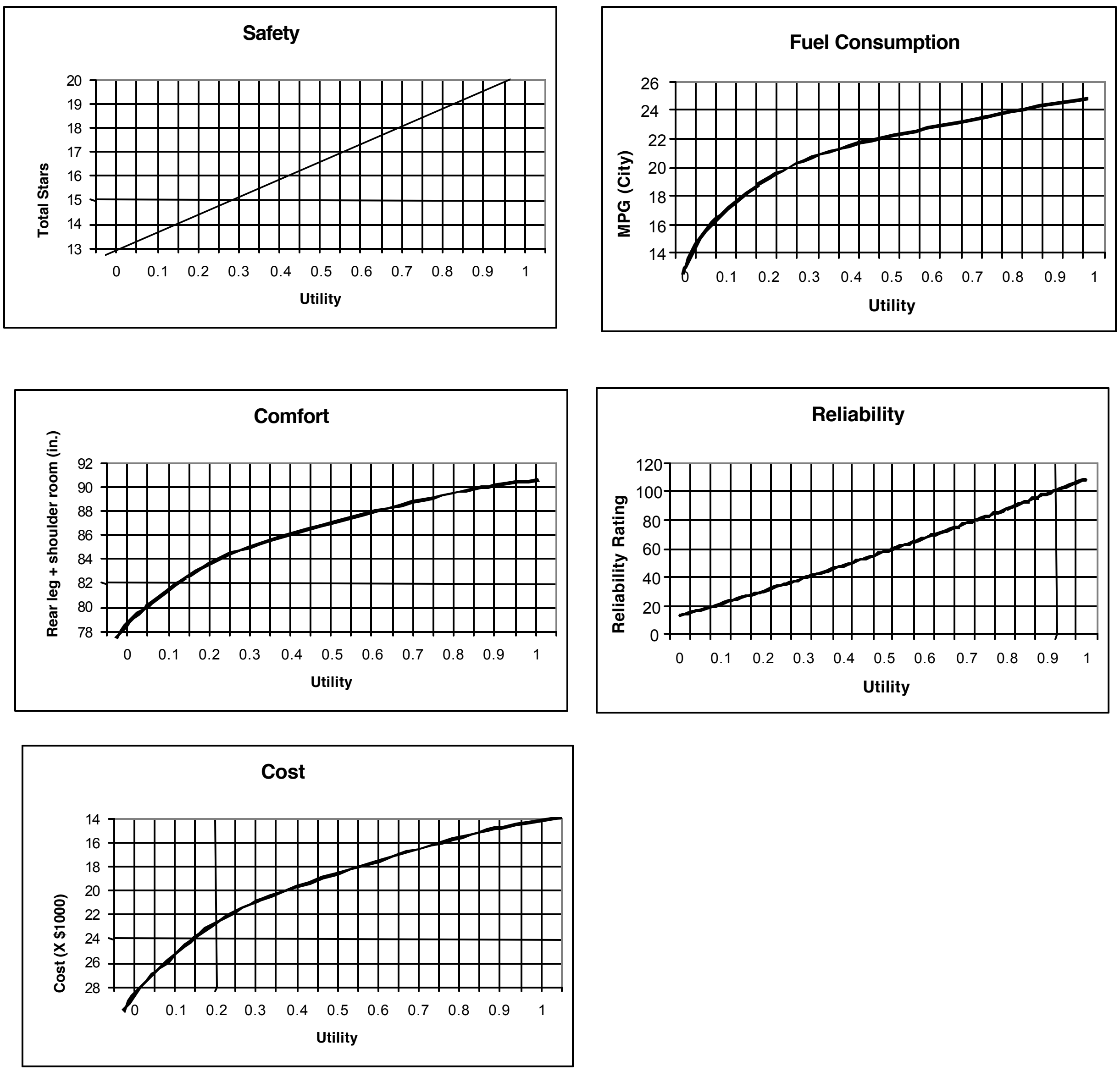
The totals of the weighted scores show that the Dash most nearly meets the wants/goals (or put another way, has the most “benefits”). Dash meets all the requirements and solves the problem.

Step 7 Apply the Selected Method

MULTI-ATTRIBUTE UTILITY THEORY ANALYSIS

The team generated utility functions from evaluation studies of many comparable vehicles (see Figure 2). Note that the cost utility curve gives a value of 0 for all vehicles costing more than $28,000 which was one of the requirements.

Figure 2. Examples of Utility Functions



In this example a team consensus approach based on the decision-making support staff's and decision-maker's values was used to obtain the criteria weights which were then normalized to a 0 –1 range. The team was polled and the average score for each element, rounded to the nearest integer, obtained and that value divided by the *largest score*. The Total Score is the product of the Criteria Weight and the Alternative Utility summed for the alternative.

Table 16. Example of MAUT Decision Analysis

Criteria/ Want objectives	Criteria Weight	*Arrow*	Alter-native Utility*	Weighted Utility Score‡
Comfort	.5	86 in. rear seat leg and shoulder room, seats 5	0.375	0.1875
Safety	1	14 stars	0.150	0.15
Fuel efficiency	.7	21 mpg	0.300	0.21
Reliability	.9	80	0.700	0.63
Cost	1	$26,000	0.075	0.075
		Total		**1.2525**
		Baton		
Comfort	.5	88 in. rear seat leg and shoulder room, seats 6	0.600	0.3
Safety	1	17 stars	0.550	0.55
Fuel efficiency	.7	19 mpg	0.175	0.1225
Reliability	.9	70	0.600	0.54
Cost	1	$21,000	0.275	0.275
		Total		**1.7875**
		Carefree		
Comfort	.5	80 in. rear seat leg and shoulder room, seats 5	0.050	0.025
Safety	1	15 stars	0.275	0.275
Fuel efficiency	.7	22 mpg	0.400	0.28
Reliability	.9	65	0.550	0.495
Cost	1	$17,000	0.650	0.65
		Total		**1.725**
		Dash		
Comfort	.5	89 in rear seat leg and shoulder room, seats 6	0.700	0.35
Safety	1	19 stars	0.825	0.825
Fuel efficiency	.7	21 mpg	0.300	0.21
Reliability	.9	85	0.750	0.675
Cost	1	$24,000	0.150	0.15
		Total		**2.21**

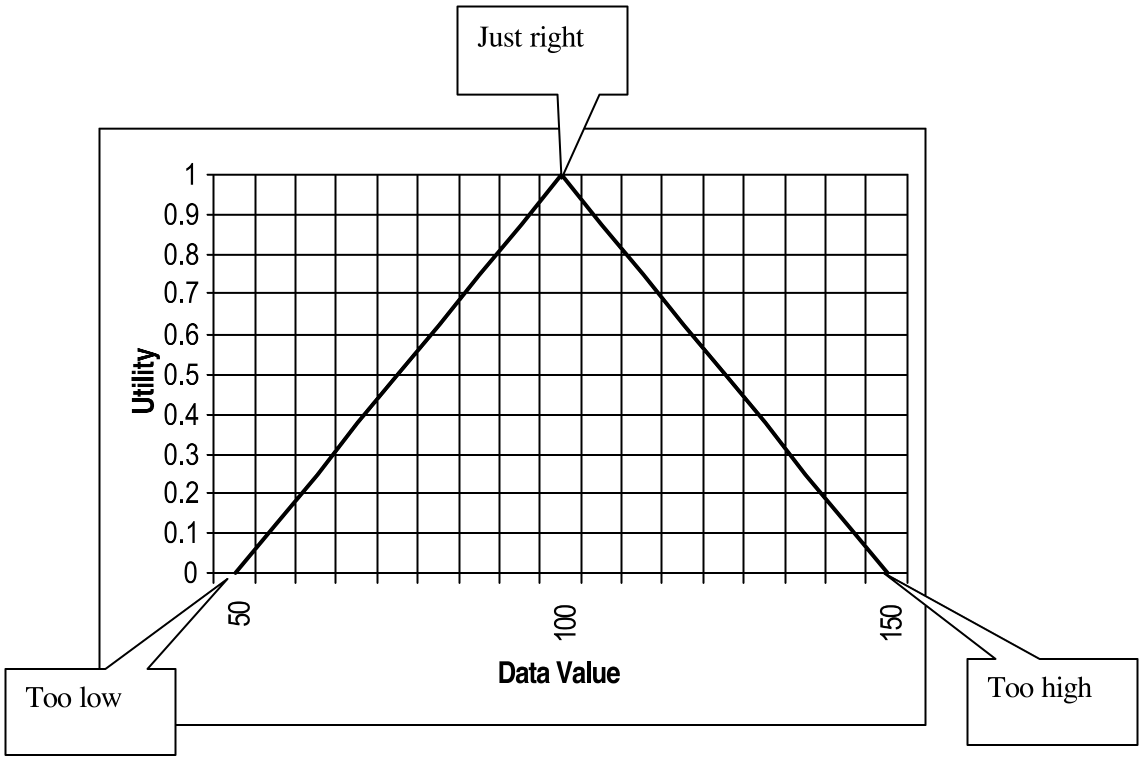
*Extracted from the utility graphs
‡Utility Score X Criterion Weight

Step 8 Validate Solution:

The totals of the weighted scores show that the Dash most nearly meets the wants/goals (or put another way, has the most "benefits"). Dash meets all the requirements and solves the problem.

MAUT can also accommodate utility functions that have an optimum utility. One example of this could be a projectile targeting system. If, for example, the required range were 100 meters, systems that yielded results over or under that range would have lowered utility values compared to systems that yielded results nearer 100 meters. An example of just such a utility curve is shown in Figure 3.

Figure 3. Example of Utility Function Having Optimum Utility



Step 7 Apply the Selected Method

SIMPLE MULTI ATTRIBUTE RATING TECHNIQUE (SMART)

As in the previous examples a team consensus approach based on the decision-making support staff's and decision-maker's values was used to obtain the criteria weights which were then normalized to a 0 –1 range. The team was polled and the average score for each element, rounded to the nearest integer, obtained. In this example (shown in Table 17) the team consensus value is divided by the *sum* of the scores to obtain the Normalized Weight Factor for each criterion (goal). Table 18 repeats the raw data and criteria previously established.

Table 17. Example Goal Weights

Goal Number	Goal Name	Goal Weight Factor	Normalized Weight Factor
1	Maximize Passenger Comfort	1	0.034
2	Maximize Passenger Safety	10	0.345
3	Maximize Fuel-efficiency	3	0.103
4	Maximize Reliability	5	0.172
5	Minimize Investment Cost	10	0.345

Table 18. Data used in normalized scoring

		Alternatives			
Criteria	Criteria Description	Arrow	Baton	Carefree	Dash
Combined rear seat room	Based on the combined rear seat leg and shoulder room. (Note: front seat passsenger leg and shoulder room was found not to discriminate.)	86 inches of leg and shoulder room, Seats 5	88 inches of leg and shoulder room, Seats 6	80 inches of leg and shoulder room, Seats 5	89 inches of leg and shoulder room, Seats 6
Number of safety stars	Based on the total number of stars awarded by the National Highway Traffic Safety Administration for head-on and side impact.	14 stars	17 stars	15 stars	19 stars
City fuel economy rate	Based on the EPA fuel consumption for city driving.	21 mpg	19 mpg	22 mpg	21 mpg
Consumer Reports reliability rating	Based on the reliability rating given by the consumer product testing company.	80	70	65	85
Purchase cost	Based on the purchase price.	$26K	$21K	$17K	$24K

The team established rules of thumb for each criterion representing their utility functions and then proceeded to score each alternative rounding to integer values as appropriate. A 1-5 performance *score* scale is used where a "1" score always means worst performance (0) and a "5" score always means best performance (1). The team scored Dash and Baton the same for combined rear seat room based on the fact that a 1" difference was insignificant. Since the SMART methodology allows for use of less of the scale range if the data does not discriminate adequately, they also scored Baton's fuel economy as a 2 because a lower rating wouldn't discriminate adequately. The normalized scores in Table 19 are converted to utility values between 0 and 1 (1= 0, 2= .25, 3= .5, 4= .75, 5= 1.0) as shown in Figure 4. (Remember that the foundation of MAUT is the use of utility functions to transform an alternative's raw score to a dimensionless utility score between 0 and 1.) A weighted criterion score (not shown) is obtained by multiplying the utility values by the Normalized Weight Factors from Table 17. The weighted criterion scores are summed into the overall final utility scores shown at the tops of the columns in Figure 4.

Figure 4 displays the main tradeoffs across the criteria using a Consumer Reports format that is easy for decision makers and others to understand. This presentation format provides a different visual perspective of the same/similar information as compared with previous examples.

Table 19. Normalized Scores

Criteria	Scoring Explanation	Alternatives: Arrow	Baton	Carefree	Dash	Scoring rule of thumb
Combined rear seat room	5 for large space and 1 for small space	4	5	2	5	3" per point
Number of safety stars	5 for big number of stars, 1 for low number of stars	1	4	2	5	1 star per point
City fuel economy rate	5 for high mpg, 1 for low mpg	4	2	5	4	1mpg per point
Consumer Reports reliability rating	5 for high reliability rating, 1 for low reliability rating	4	2	1	5	5 rating points per point
Purchase cost	5 for low purchase cost, 1 for high purchase cost	1	3	5	2	$2-$3K per point

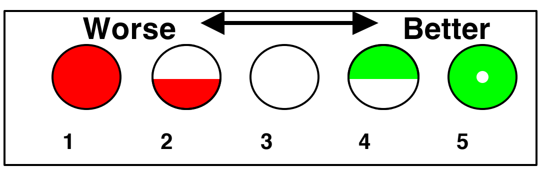
Figure 4. Final Evaluation Result, Dash has highest score.

Problem: Pick a replacement vehicle for the motor pool.

Scoring Method: 1 to 5 Scale

Alternatives

Criteria	Arrow Overall Score: 23.2%	Baton Overall Score: 53.4%	Carefree Overall Score: 54.3%	Dash Overall Score: 71.5%
Combined rear seat room	4.0 = 0.75	5.0 = 1.0	2.0 = 0.25	5.0 = 1.0
Number of safety stars	1.0 = 0	4.0 = 0.75	2.0 = 0.25	5.0 = 1.0
City fuel economy rate	4.0 = 0.75	2.0 = 0.25	5.0 = 1.0	4.0 = 0.75
Consumer Reports reliability rating	4.0 = 0.75	2.0 = 0.25	1.0 = 0	5.0 = 1.0
Purchase cost	1.0 = 0	3.0 = 0.5	5.0 = 1.0	2.0 = 0.25



Step 8 Validate Solution:

The shaded alternative in Figure 4, Dash, has the highest overall utility score and most nearly meets the wants/goals (or put another way, has the most "benefits"). Dash meets all the requirements and solves the problem.

Step 7 Apply the Selected Method

COST-BENEFIT ANALYSIS

The object of a CBA is to calculate the Net Present Value of an alternative. OMB Circular No. A-94 provides the following example of a Net Present Value calculation.[17]

QUANTIFIED BENEFIT-COST EXAMPLE

Assume a 10-year program which will commit the Government to the stream of real (or constant-dollar) expenditures appearing in column (2) of Table 20 and which will result in a series of real benefits appearing in column (3). The discount factor for a 7 percent discount rate is shown in column (4). The present value cost for each of the 10 years is calculated by multiplying column (2) by column (4); the present value benefit for each of the 10 years is calculated by multiplying column (3) by column (4). The present values of costs and benefits are presented in columns (5) and (6) respectively.

Table 20. Example of CBA Calculation

Year since Initiation, Renewal, or Expansion (1)	Expected yearly cost (2)	Expected yearly benefit (3)	Discount factors for 7% (4)	Present value of costs Col. 2 x Col. 4 (5)	Present value of benefits Col. 3 x Col. 4 (6)
1	$10.00	$ 0.00	0.9346	$ 9.35	$0.00
2	20.00	0.00	0.8734	17.47	0.00
3	30.00	5.00	0.8163	24.49	4.08
4	30.00	10.00	0.7629	22.89	7.63
5	20.00	30.00	0.7130	14.26	21.39
6	10.00	40.00	0.6663	6.66	26.65
7	5.00	40.00	0.6227	3.11	24.91
8	5.00	40.00	0.5820	2.91	23.28
9	5.00	40.00	0.5439	2.72	21.76
10	5.00	25.00	0.5083	2.54	12.71
Total				$106.40	$142.41

NOTE: The discount factor is calculated as 1/(1 + i)t where i is the interest rate (.07) and t is the year (OMB Circular A-94 specifies a 7% discount rate).

The sum of column (5) is the total present value of costs and the sum of column (6) is the total present value of benefits. Net present value is $36.01, the difference between the sum of discounted benefits and the sum of discounted costs.

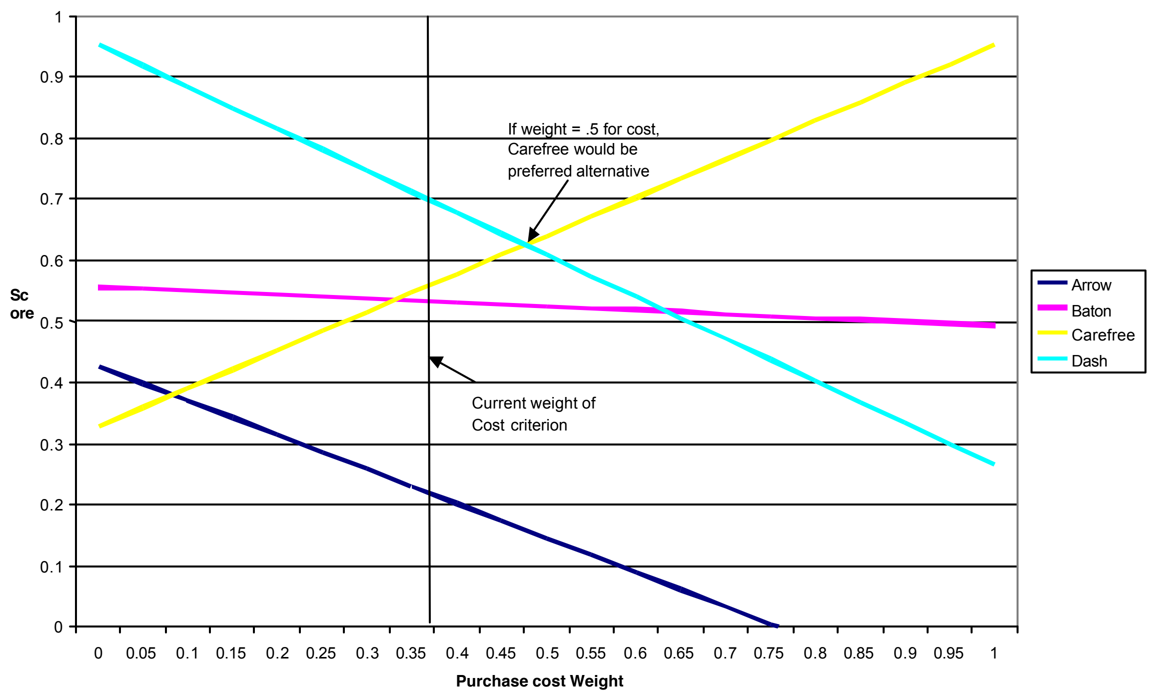
Step 8 Validate Solution:

Only alternatives meeting all requirements should be considered. This calculation would be performed for each alternative and the alternative with the largest Net Present Value would be preferred.

[17] Appendix C-Further Reading 13, U.S. Office of Management and Budget, p.18

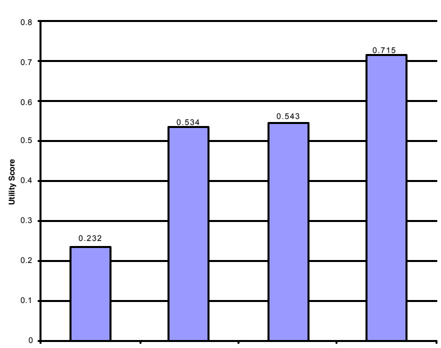
The examples in Appendix A demonstrate that data resulting from any of these methodologies can be generated and presented in a variety of formats ranging from hand reduction techniques to sophisticated computer driven software packages. As discussed in section 1.8 of Appendix B sensitivity analyses can be useful to the decision makers by allowing them to evaluate their values (Criteria/Goal Weights) to make sure they select the alternative that best meets their values (honesty check). For example Figure 5 shows how an increase in the purchase cost criterion Goal Weight Factor from the SMART example could change the outcome. Increasing the cost Normalized Weight Factor from the current value of 34.5% to 50% would result in Carefree having the highest overall utility score.

Figure 5. Purchase Cost Sensitivity Analysis

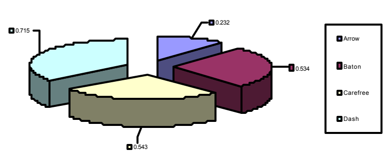


Three sample formats for presenting the Overall Score data from Figure 4, Final Evaluation Result, are presented below – a Bar Chart, a Pie Chart, and a Polar Chart. There are numerous additional ways in which the data from these examples can be presented. The decision team should pick the method that best displays their results and conclusions.

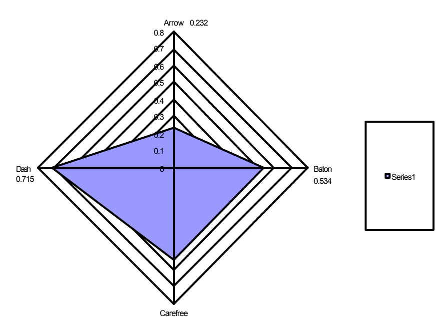
Bar Chart



Pie Chart



Polar Chart



Appendix B – Decision Process Aids

1.0 Introduction

This appendix provides helps, additional information, and potential forms or products to be developed during each of the process steps defined in Section 2 of this Guidebook.

Usually the decision making support staff should engage the help of, skilled and experienced analysts/facilitators to assist with all stages of the decision process. Expert facilitation can help assure that all the steps are properly performed and documented. Their experience and expertise will help provide transparency to the decision making process and help avoid misunderstandings that often lead to questions about the validity of the analyses which ultimately slow progress. Table B-8 (page 39) provides some Decision Support Personnel Contacts at several DOE sites.

1.1 Brainstorming

Brainstorming is the chief tool used by the decision support team to identify, analyze, and develop the problem and potential alternative solutions. Brainstorming is a technique for using the subconscious to generate ideas. Brainstorming tools like lateral thinking, affinity diagrams, and interrelationship digraphs can be used to aid the process. Creative, divergent thinking is essential in this step. No ideas are critiqued until later in the process and all ideas are recorded. Once brainstorming has concluded, ideas can be accepted, refined, and combined with other ideas or cast aside as is appropriate.

1.2 Aid to Defining a Problem

The following suggestions/questions may be useful in defining the scope and resource needs for a given problem.

1. Initial Problem Statement:
    - Initial Undesired State
    - Desired State
2. List problem symptoms/triggers.
3. Scope of Evaluation – how big is the system? Who is impacted by this problem/issue?
4. How much time and funding is available to perform the evaluation?
5. Who will be the project lead for the decision analysis?
6. Who are the personnel (what functional areas are involved) needed for the evaluation?
7. Who will provide the decision process and facilitation support?
8. How will the decision team interact?
9. Who are the reviewers, decision-maker(s), and stake holders?
10. Is external review (e.g. DNFSB, etc.) anticipated.
11. Has the decision stalled out in the past?
12. What is the level of complexity?
    - Simple, only a few parameters tell the whole story
    - Complicated, many parameters and data that are not known by one person
    - Complex interactions and quantitative data needed to support decision
    - Need an expert system developed to help make repetitive consistent decisions in area of problem

The Problem Definition Worksheet, Figure B-1 (page 34), presents some probing questions which can be used to refine the problem. Often, the initial problem description is not adequate to ensure that a full solution will be found. These questions are not the only probing questions, just a sampling of some of those used by DOE in the past.

Such questions are the essence of the tradeoffs that may be found and discussed in the evaluation.

1.3 Aid to Identify Requirements and Goals

The essential task in this step is to segregate the requirements from the goals. Requirements are used to screen inadequate alternatives from further evaluation. The true test is to ask the question, "If an otherwise good alternative does not meet this requirement, should it be dismissed or considered?" If the answer is to dismiss the alternative, this is truly a requirement. If the answer is to consider the alternative, then this requirement must be changed to a goal. Goals are negotiable desirables. Tables B-1 and B-2 (page 35) provide some examples of requirements and goals.

Requirements may contain both strategic and functional elements that may or may not apply to a specific problem. Applicable strategic objectives can generate either requirements or goals. Table B-3 (page 35) gives the strategic requirements to be considered for the INMM Program.

1.4 Aid to Define Alternatives

Alternatives are distinct potential solutions, which convert the initial state to the desired state. Alternatives should differ from each other in how they achieve the desired state.

Alternatives can be discovered in many ways. They can be developed through brainstorming, or from examining / challenging constraints or requirements. This requirement challenging can also lead to the discovery that a requirement is really a goal.

Alternative definition typically occurs in two phases: generation and refinement. In the generation phase, the decision support team focuses on the goals and requirements in an effort to produce ideas on how to perform the identified function. Each goal and requirement is evaluated and alternatives focused on meeting these goals and requirements are suggested. The generation phase often results in infeasible concepts.

Next, in the refinement phase, the decision support team combines and completes the concepts so that they become alternatives worthy of consideration.

Alternatives must be defined in such a way as to clearly explain how they will solve the particular problem. Alternatives must be defined at a level that enables comparative analysis. This may take a good written description and a diagram of the specific functions performed to remedy the problem. A simple functional diagram, as seen in Figure B-2 (page 36), can clarify an alternative. The diagram should be adequately detailed to describe the differences between this and the other alternatives. Each definition should enable the decision support team to understand how that alternative solves the problem and how it differs from the other alternatives.

1.5 Aid to Defining Discriminating Criteria

Each goal is something desired from the alternative. Criteria are measures of effectiveness for each goal. The job of the criteria is to discriminate between the alternatives. Some goals may require more than one criterion to fully capture the discrimination. Other goals may not have anything measurable or estimable that discriminates. These goals need to be set aside. Each criterion will need a description and a unit of measure/estimation definition. These definitions must be sufficient for sharing with the decision-maker(s) and/or allow the team to perform an initial qualitative evaluation. Goals and criteria must be reviewed and approved by the decision-maker(s) prior to alternative evaluation.

Table B-4 (page 36) shows an example correlation between some goals and criteria along with criteria descriptions and an initial attempt as to what should be measurable or estimable. Maintaining the association of the goals and criteria is important for two reasons. First, it is important to remember why and what a criterion is supposed to be measuring. Second, the association helps answer the question, "Are these all the criteria, and how do you know all the essential criteria are identified?" Answering this question requires two steps: (1) confirm that all goals are identified, and (2) confirm that discriminating criteria have been identified for each goal.

Ultimately, criteria selection greatly influences the selection of an alternative. A good way to begin is to list all the advantages (pros) and disadvantages (cons) of each alternative. These pros and cons are then used to suggest discriminating criteria for each goal. Each goal should have one or more criteria. Each criterion should measure something important, and not be directly dependent on another criterion.

Many DOE decisions are driven by similar forces, which results in similar criteria for decisions. Generally, one or a few criteria are selected for each goal as alternatives are developed and potential discrimination discussed. Fewer real discriminators will result in a clearer, more understandable decision analysis product. Table B-7 (page 39) contains an initial set/starting point of goals and potential discriminating criteria for INMM Program decisions. Other programs and projects need to define their own/other goals and associated criteria as appropriate.

1.6 Aid to Screening Alternatives against Criteria

Alternative evaluation can be performed in many ways, using many methods and tools. Be aware that the size of the team needed is proportional to the quality of the data available – the more intangible and qualitative the data, the greater the number of people that should be involved. It is important to have a team with broad based expertise and to perform enough analysis to support a recommendation or decision. Evaluations need to 1) avoid completion of analysis too soon such that the recommendation or decision is not defensible but 2) avoid too much evaluation and delaying the decision longer than necessary. It is important to realize that as the detail in an analysis increases, more detailed data are required that generally costs time and money. Maintaining a balance between further evaluation and being technically defensible deserves a lot of attention.

As alternatives are evaluated the criteria can be either qualitative or quantitative in form. The first evaluation step is the screening out of alternatives because requirements cannot be met. If a decision-maker(s) determines that one or more screened alternatives should be retained and evaluated, the requirement causing it to be initially screened out is moved to the goal list and discriminating criteria defined for the new goal. If after the requirement screening there are still too many alternatives to fully evaluate, a qualitative analysis may be needed to reduce the number of alternatives needing data collection.

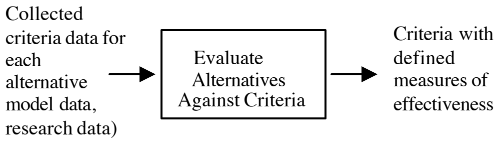
An example of screening requirements is shown in Table B-5 (page 37). This example is excerpted from an analysis of DOE owned spent nuclear fuel, which might be a candidate for Savannah River Site canyon processing. There are two requirements for evaluating the fuels as potential canyon candidates:

1. Compatibility with current canyon processes. There must be a flow-sheet available to process the fuel in an SRS canyon.
2. Not currently qualified for the repository. DOE owned commercial fuel, for instance, is identical with commercial spent nuclear fuel, and so there should be no technical questions about its repository disposal.

Based on these two requirements oxide commercial, oxide disrupted (TMI), metal (UZr), metal (U,UMo), N Rx and graphite fuel are screened out of the analysis because they do not meet one or both of the requirements.

Evaluation of alternatives can occur in one to three phases depending on complexity.

Phase I--Qualitative Analysis:



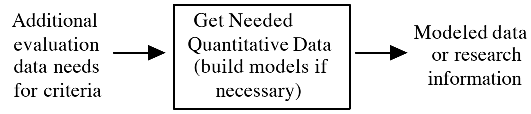
Phase I is generally performed first and may include the Pro-Con method where the advantages (pros) and disadvantages (cons) of an alternative are described.

If knowledgeable experts make up the evaluation team, it can be useful to perform a subjective analysis using qualitative scoring by each team member. Several of the evaluation methods can support this initial evaluation. This initial assessment evaluates where perceptions of the criteria scores differ across the decision support team. These areas of disagreement become the minimum set of criteria that need quantitative data or information collected. For those criteria where there is good agreement across the decision support team, it may not be necessary to collect any additional data, depending on the types of review expected and how uncontroversial the discrimination.

The qualitative analysis can also be used to identify dominating alternatives. A knowledgeable team can set aside alternatives that are clearly dominated by other alternatives prior to more sophisticated analysis. This process is called elimination by dominance.

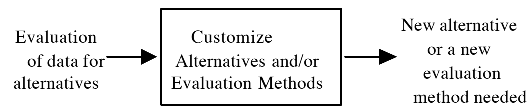
A selection can be made based on this analysis if the winning alternative is very clear and there is a single decision maker with no external review expected. If this is true, the evaluation step is complete and the supporting information for the decision is the results of the pro/con or qualitative analysis. If the pro/con analysis identified tradeoffs then a more sophisticated method of analysis is required.

Phase II--Quantitative Analysis:



Criteria judgements may require improvement through data collection and quantitative analysis. The need for these data to be more quantitative depends on the importance of the data to the evaluation of the alternative. If the qualitative data is well understood with little uncertainty, then generating additional information may not be warranted. However, if there is significant uncertainty in one or more alternative's performance, or the criterion is an important discriminator, generating more quantitative information may be essential to the credibility of the alternative's evaluation. Researching already existing data, performing a cost estimate, or modeling may be used to increase the certainty of information used to enhance the perceptions and judgments of experienced individuals.

Phase III--Customize Alternatives and/or Evaluation Tools:



As alternatives are evaluated, the team may want to enhance an alternative by combining it with other alternatives or redefining it to address areas of poor performance. This action essentially creates a new alternative. The new alternative must meet the requirements.

The team may also desire a better understanding of a criterion. The team may determine that another decision method is required to better reflect the criteria. Occasionally, a team may need to create a custom-tailored tool (or model) to get better understanding of the system behavior of each alternative.

1.7 Criteria Weighting Method Options

After information is collected and incorporated into the alternative analysis, weighting factors can be used to rank the alternatives against the criteria. This analysis may lead to a clear preference or may identify additional analysis needed to aid the final selection.

Weighting has advantages and disadvantages. The advantage is that the decision maker or decision support team can provide the relative importance of the criteria. Performing multiple weightings to analyze different viewpoints on the importance of the criteria can facilitate understanding of the robustness of potential solutions. The disadvantage of weighting is that it is limited by the understanding and potential bias of those performing the weighting.

Although weighting of criteria is not required for all alternative selection processes, in complex decisions it may be helpful because it is unlikely that all criteria are equally important. Criteria can be weighted in several ways:

- Direct decision and input of constant values for criteria weights;
- Weight Ratios and AHP pair-wise comparisons;
- Partial Weight Ratios;
- Weight computation through importance ordering;
- Weight computation based on "swing weights";
- Weighted scores (KT).

Each method is described below.

1.7.1 Direct Decision and Input of Constant Values for Criteria Weights

Criteria weights can be provided directly by the decision maker or may be established through expert judgment. Generally criteria should receive weights normalized to 100%.

1.7.2 Weight Ratios and Analytic Hierarchy Process

The weight ratio (WR) method uses pair-wise ranking and relative value to weight criteria. In a pair-wise ranking each of the criteria is ranked or evaluated against each of the other criteria. Team members decide which of two criteria is more important in selecting an alternative and by how much. The WR process can be completed either manually or by using various computer software tools.

A scale of one to nine is well recognized. One represents equal importance of the criteria; nine represents an order of magnitude difference between the two criteria. Once established, this relative value score is summed for each criterion and is normalized to a total of 100%. An advantage of simplified manual pair-wise comparisons is that for a small number of criteria, it can be completed quickly during an interactive session. A disadvantage of this method is that consistency checks must be done separately (i.e., if A>B and B>C then A>C must be true). With larger numbers of criteria, total consistency is difficult to achieve and to check (e.g., how much >C is A).

1.7.3 Partial Weight Ratio

The partial weight ratio method uses pair-wise comparisons except that only enough pair-wise comparisons are completed to ensure that each criterion has been included at least once. This process is supported through some software tools. An advantage of this method is that it is quick to implement. The disadvantage is that comparisons are minimized, which provides no consistency checks.

1.7.4 Weight Computation Through Importance Ordering

In weight computation through importance ordering, team members define an alternative with the least preferred level of acceptability against all criteria. Team members then select the one criterion that they would choose to improve, given this alternative. This criterion becomes the most important criterion. The process continues until all criteria have been ranked. This method offers an advantage when comparison of criteria on a one-to-one basis is difficult. All weights are established on a binomial selection process rather than a relative value process. It is recommended that this method, like weight computation, be implemented using available software.

1.7.5 Weight Computation Based on Swing Weights

Weight computation based on swing weights is a combination of ordering preference and direct decision and input. In this method, as with ordering preference, team members define an alternative with the least preferred level of acceptability against all criteria, then select the one criterion that they would choose to improve. This criterion is then given a swing weight of 100. Team members similarly select the next criterion and determine the relative importance of swinging it over its range compared with swinging the first criterion over its range, as a percentage of the first criterion's 100 point swing weight. The process continues until all criteria have been ordered. The advantages of this method are similar to those for ordering preference, except that criteria ranking is adjusted to reflect evaluators' judgments on relative criteria importance. This method is implemented by adjusting the absolute weights to sum to one. This can be done manually or with supporting software. For large matrices a software tool is helpful.

1.7.6 Weighted Scores (KT)

The KT weighting method requires the team to weight each criterion from one to ten by consensus. (See K-T Decision Analysis, section 3.2, page 6.)

1.7.7 Summary of Weighting Methods

Table B-6 (page 38) summarizes various weighting methods, describes their limitations and strengths, and suggests potential applications appropriate for each.

1.8 Sensitivity Analysis

Both sensitivity and uncertainty analyses can be useful to the decision makers to help them evaluate their values (Criteria/Goal Weights) to make sure they select the alternative that best meets their values (honesty check). Such analyses are used to increase the clarity of alternative selection. The purpose of a sensitivity analysis is to validate the alternative evaluation and alternative rankings that result from the decision process by demonstrating that small changes in the alternative scores against the decision criteria or decision criteria weights do not change the alternative ranking.

First the decision criteria weights are checked for sensitivity. The decision team changes each of the decision criteria weights by 10% while maintaining the 100% sum of the weight factors. If these changes do not result in a change in the alternative rankings, the decision analysis is considered robust.

Another sensitivity analysis evaluates the outcomes when the alternative scores are adjusted up and down by either a percentage or the potential error of the scored value. If these ranges do not change the overall results, the analysis is insensitive to the alternative scores.

If recommended alternatives do change with the variations investigated, the decision analysis support team may choose to collect additional information or describe the impact of the potential error on the alternative selection to the decision-maker(s). Most of the software available for decision making allows sensitivity analyses to be performed very simply. AHP software, for example, generates excellent graphs to analyze the decision sensitivity and allows for dynamic sensitivity analysis. Sensitivity analysis examples are shown in Figure B-3 (page 37) and Figure 5 of Appendix A.

1.9 Aid to Validate Solution(s) against the Problem Statement

Compare the solution to the original problem statement, requirements, goals, and criteria. A final solution should resolve all issues, meet all requirements, and most closely achieve all goals.

2.0 Outline for Decision Analysis Reports and Presentations

A final report to the decision maker(s) must be written documenting the decision process and recommending the final solution. The following is a suggested outline:

2.1 Problem Statement:

Describe the mission, initial conditions, desired conditions, and any stakeholder needs. Discuss why the team was convened and who participated in the decision or input to the team. List all Team Members and Subject Matter Experts involved and describe their credentials.

2.2 Requirements Identification

List requirements and discuss all decision assumptions, system functions, and constraints that were used in defining what was needed to be achieved. Discuss how these were arrived at and any dissenting opinions.

2.3 Goals

List all goals and discuss the genesis of their development.

2.4 Alternatives evaluated

List all alternatives considered and screened out. Include a good written description and diagram of the specific functions performed by each alternative considered in the final anlaysis. Discuss what tradeoffs were identified for the alternatives and how they were investigated/evaluated.

2.5 Decision Criteria:

List the criteria used and discuss how they related to the corresponding goals and why.

2.6 Methodology used:

Discuss what methodology was used for the decision and why that method was chosen. Outline how the methodology was applied.

2.7 Evaluation Results:

Discuss the results of the analysis. If appropriate, discuss the decision criteria weights, what they are and how they were chosen. If appropriate to the method chosen, discuss how sensitive the results are to criteria weights or any other assumptions (Sensitivity Analysis). Provide figures, tables, and graphs as appropriate to explain both the process and the results.

2.8 Conclusions and Path Forward:

Based on the results of the analysis, explain why the recommended alternative is the best solution to the problem and what the next steps the team recommends be taken to implement a decision.

Figure B-1

PROBLEM DEFINITION WORKSHEET

Problem / Issue Short Title: ____

- Summary statement of the unacceptable or undesirable condition (identified problem)

- Define the initial state:
  1. What are the symptoms pertinent to the problem?

  2. What are current conditions?

  3. What are potential causes for the condition?

  4. What assumptions are appropriate for the analysis?

- What happens if the problem or issue is not solved? Why fix it?

- What historical causes or barriers may be important to alternative development?

- What is the desired state? Describe the expected characteristics of the system after the problem is properly solved.

- Who or what is affected? (interfaces)

- What is included in the system boundary of this problem?

Table B-1. Example of Requirements

Sodium Bearing Waste (SBW)Alternative Requirements
Alternatives shall process concentrated liquid waste transferred to the tank farm through 2005 (i.e. boiled down SBW) and newly generated liquid waste (NGLW) through operational shutdown of the alternatives process.
All primary and secondary waste streams shall have disposition paths or plans identified and assumptions associated with those waste streams validated.
Heel flushes (including any solids moved in heel flushing process) shall be included in the processing scope.
Alternatives shall not return waste to existing tank farm.
Each alternative scope shall include ultimate treatment of all tank waste; i.e., movement of waste with no subsequent treatment does not qualify as disposition in 2.
All alternatives reviewed shall be bounded by the EIS.
Each alternative shall meet all DOE and regulatory requirements, including the Settlement Agreement milestone of removing the SBW from the tank farm by 2012.

Table B-2. Example of Goals

Sodium Bearing Waste Alternative Goals
Maximize Meeting Schedule Commitments
Minimize Cost
Minimize Technical Risk
Minimize ES&H Impacts
Maximize Operability
Maximize Utilization by Other Wastes
Maximize Ability to Dispose
Minimize Program Risk

Table B-3.
INMM Program Strategic Requirements

Nuclear Weapons: Maintain sufficient nuclear weapons and infrastructure for national defense.
Arms Control: Reduce worldwide stockpile of nuclear weapons.
Nonproliferation: Prevent spread of nuclear materials and weapons
Nuclear Energy: Ensure nuclear energy as a dimension of a viable energy future
Environment: Treat remaining legacy materials, facilities, and waste
Science: Preserve and supply nuclear materials for future scientific, defense, and medical research, development, and other needs.
Naval Propulsion: Ensure adequate supply of highly enriched uranium (HEU) and testing capabilities.

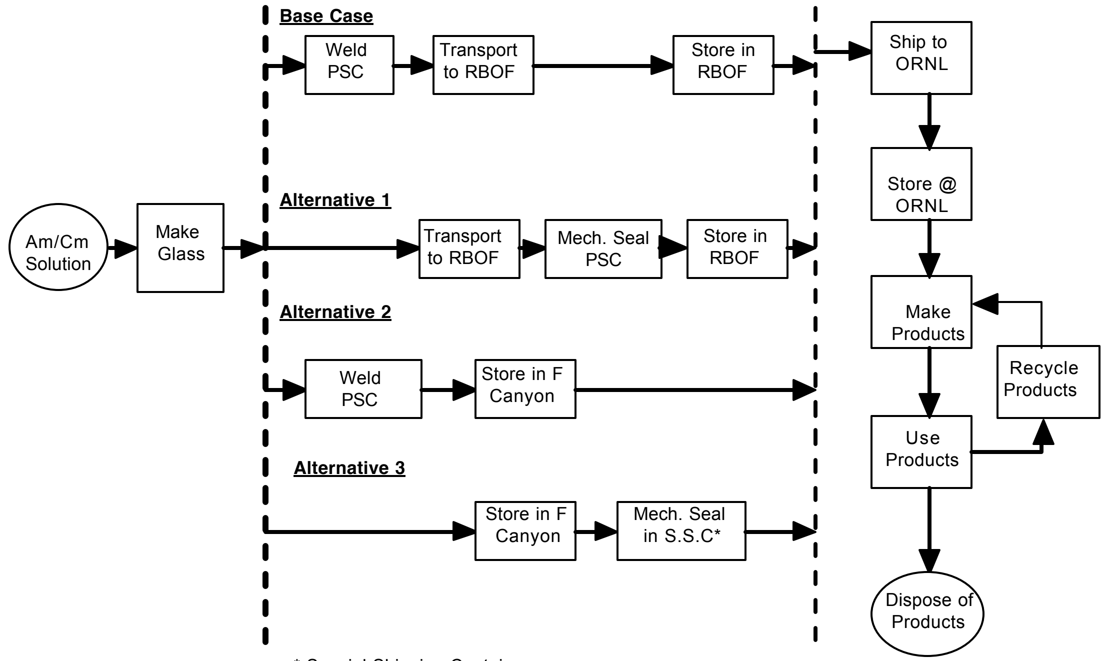


Figure B-2, Am-Cm Disposition Flow Diagram

Table B-4
An Example of Goals, Criteria, Criteria Descriptions, and Unit of Measures

Goal	Criteria	Criteria Description	Unit of Measure or Estimate
Meet Schedule	1. Schedule risk	(Work and uncertainties); duration in time to support the technical uncertainty integrated with the work	Potential schedule slip (years)
Minimize Cost	2. Project reduction potential	Potential dollar savings to the total project cost	Potential project savings in FY 2000 constant dollars
	3. Lifecycle costs through decontamination and decommissioning (D&D)	Total costs to implement complete alternative (including high level waste [HLW] system costs) broken down between alternative implementation and the system	Total costs in FY00 Constant dollars
Minimize Technical Risk	4. Technical maturity	Apply EM50 gate model to technologies in each alternative for each unit's operations and summarize	Average maturity against gate model (gate level 17)
	5. Implementation confidence	Amount of relevant process experience in the complex and industry for the technology.	Average equipment maturity using gate model (17)

Table B-5
Example of Screening Against Requirements

Fuel Type	Compatible with Canyon Processing	Not Qualified for the Repository
Oxide Commercial	Yes	No
Oxide Non-Commercial	Yes	Yes
Oxide, U-Th	Yes	Yes
Oxide Disrupted (TMI)	No	No
Metal (U, U-Mo,)/Na	Yes	Yes
Metal (U-Zr)	No	Yes
Metal (U,U-Mo), N Rx	Yes	No
Al-Clad U-Metal	Yes	Yes
Al Clad Al Matrix	Yes	Yes
Graphite	No	No

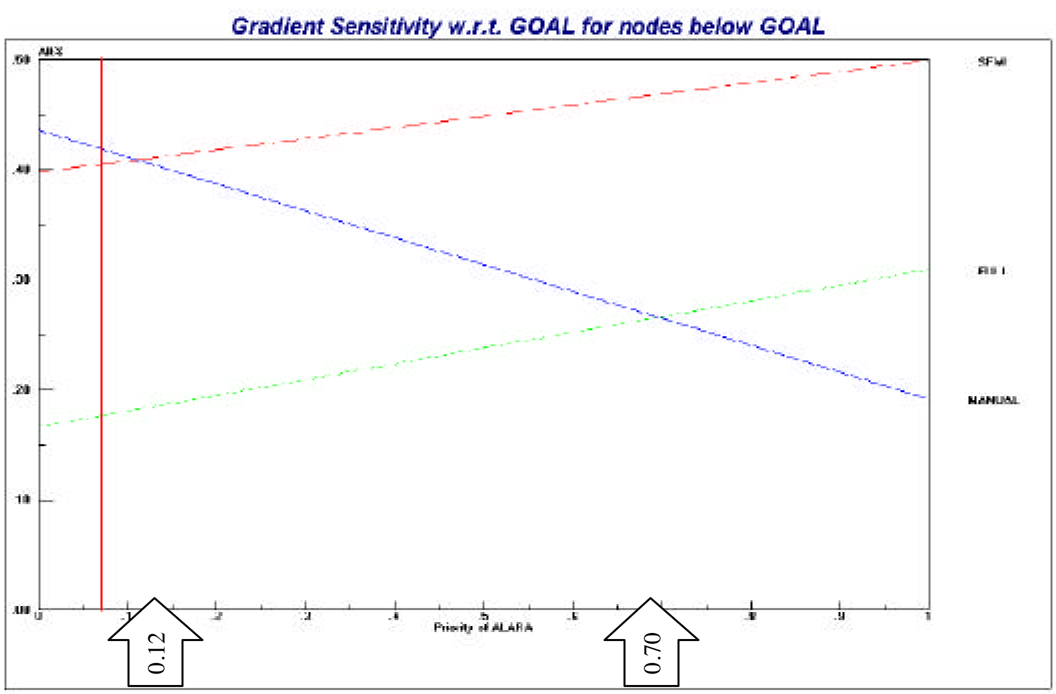


Figure B-3
Gradient Sensitivity for Packaging and Stabilization Automation Study for ALARA

This sensitivity graph was produced by commercially available software. Based on the priority of ALARA of about 0.075 the graph shows that a fully manual system is preferred. When the ALARA priority rises above a 0.12, a semi-automatic system becomes preferred. Above a priority of 0.70, the fully automatic alternative becomes preferable to the manual alternative, but the fully automated system is never preferred under any ALARA priority to the semiautomatic system.

Table B-6 Summary of Criteria Weighting Methods

Method	Limitations	Strengths	Recommended Use
Direct Decision and Input	More prone to introduction of individual bias	Simple – No evaluation team effort required to select and weigh criteria. Incorporates highlevel decisions not otherwise apparent to evaluators	When the decision maker has expertise to determine the relative importance of criteria.
Weight Ratio AHP	May need software for efficient application. Requires hardware and data input when results are required during an interactive session.	Accommodates numerous criteria, some of which are derived from others (hierarchical structure). Conducive to inputting some decision factors and adjusting the others accordingly.	When sensitivity evaluations are desired. When activity is complex. When consequences of decision result in high risk to activity.
Partial Weight Ratio	Cannot perform check on consistency of inputs.	Eliminates need for criteria comparisons that are difficult.	When evaluators have difficulty in comparison of several criteria.
Swing Weights	Requires more time than ordering importance. Abstract concept.	Direct comparison of criteria is not required. Conducive to input from experts and decision maker	When a one-to-one comparison of criteria is not feasible and more representative weights are desired
Weighted Scores	Does not perform comparisons or consistency checks.	Simple to use. Does not require computers.	When a structured method is desired for a relatively simple problem.

Table B-7
INMM Goals and Potential Criteria

Goal	Criteria
Minimize Cost	Total capital or project cost Total life-cycle cost Net Present Value cost Short-term costs Disposal costs Operation and maintenance cost Infrastructure modification cost
Minimize Impact to Environment, Worker Safety, and Public Health	Hazardous releases Radiological releases Impact to burial performance assessment Waste generation (quantity and type) Worker radiological exposure Worker hazard exposure Active safety system requirements (engineered/administrative features) Risk of transporting materials/wastes Public exposure (radiological or hazardous)
Maximize Safeguards and Security of Nuclear Material	Attractiveness of materials for weapon production Attractiveness of materials for sabotage Control level of materials (guns, gates, and guards)
Minimize Technical Risk	Technology maturity Equipment maturity Constructability Difficulty to obtain acceptance for disposal (ease of certifying)
Minimize Programmatic Risk	Interface to other programs Stakeholder involvement needed Interface with multiple sites Ease of funding (operations vs. capital) External agreements Level of NEPA compliance required Regulation difference
Maximize Requirements and Management Focus	Supports management direction and focus Supports other DOE priorities
Maximize Operability	Operational simplicity Operating staff level of expertise required Interfaces to other systems, structures, and sites Maintainability, including mean time to repair Dependability/reliability (mean time to failure) Transportation availability (packages and transport sy stems) Flexibility to expand easily (without capital investment) in throughput Equipment availability
Accelerate Completion Schedule	Schedule risk Completion date Site closure schedule Time needed to resolve issues Requirement for policy changes

TABLE B-8 DECISION SUPPORT PERSONNEL CONTACTS

Name	Site	Phone	Email
Joseph (Joe) F. Krupa	WSRC/SRS	(803) 952-8084	joseph.krupa@srs.gov
James Murphy	INEEL	(208) 526-4453	jamesm@inel.gov
Ray F. Holdaway	ORNL	(865) 576-2509	ray@ornl.gov
William (Bill) Jackson	WSRC/SRS	(803) 952-7218	bill.jackson@srs.gov
Timothy Wheeler	SNL	(505)845-9540	tawheel@sandia.gov
Regina L. Hunter	SNL	(505) 844-5837	rlhunte@sandia.gov
Joe Schelling	SNL	(505)844-1792	fjschel@sandia.gov
Ken B. Sorenson	SNL	(505) 844-0074	kbsoren@sandia.gov

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