CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES TECHNICAL OPERATING PROCEDURE	Proc. TOP-015 Revision 0 Page 1 of 25

Title

TOP-015 PROCEDURE FOR DECISION ANALYSIS

EFFECTIVITY AND APPROVAL

Revision 0 of this procedure became effective on 6/29/90. This procedure consists of the pages and changes listed below.

Page No.	Change	Date Effective
ALL	-	6/29/90

Supersedes Procedure No. NONE

Approvals

Written By	Date	Technical Review	Date
for R. WEINER	6/29/90	W. PATRICK	6/29/90
Quality Assurance	**Date**	**Cognizant Director**	**Date**
B. MABRITO	6/29/90	A. WHITING	6/29/90

CNWRA Form TOP-1

TOP-015 PROCEDURE FOR DECISION ANALYSIS

1. PURPOSE

The purpose of this CNWRA technical operating procedure (TOP) is to describe methods for analyzing a decision by attributes and for ranking decision alternatives against weighted attributes, and to provide direction for use of the analysis. This TOP is particularly applicable where a ranking or prioritization of more than two alternatives is involved, as distinct from decisions involving a choice between two alternatives. In the latter case, as well as in cases where there may be more than two alternatives but there is no ranking or prioritization, the assignment of attributes is valuable in clarifying the decision process, but ranking is unnecessary. Quantitative weighting may also be unnecessary, although in most decisions a relatively simple intuitive form of weighting takes place anyway, and should be documented.

2. RESPONSIBILITY

2.1 The Director of SE&I and the Technical Director are jointly responsible for determining the need to perform decision analysis in a particular situation and for selecting the decision analysts and reviewers.

2.2 Decision analysts and decision makers are responsible for implementing the decision analysis procedure in accordance with this TOP.

3. DEFINITIONS

The definitions in this section are taken from three works on decision analysis.

- Keeney, R. L. Siting Energy Facilities, Academic Press, 1980.
- Keeney, R. L. and Raiffa, H. Decisions With Multiple Objectives, John Wiley, 1976.
- Trueman, R. E. An Introduction to Quantitative Methods for Decision Making, Holt Rinehart Winston, 1974.

3.1 ATTRIBUTE

Attributes are salient characteristics of the candidates which provide measures of the extent to which a decision objective has been met. An attribute has an associated scale, which may be natural or constructed. In the decision analysis procedure, candidates are ranked against appropriately written attributes.

The role of attributes in decision analysis is:

- To provide a basis for decision making; i. e., to remove the element of arbitrariness from a decision.
- To provide consistency among judgments of individuals in making the decision.
- To make the bases on which judgments are made explicit rather than tacit.

There are no generic attributes; attributes are written to be specific to the objective or quality being characterized as well as to the candidates for the decision.

3.2 CANDIDATES

Candidates are the items about which the decision is being made, or the subject of the decision. Candidates are not decision alternatives but can sometimes be confused with them. For example, in a decision about whether an uncertainty is regulatory or technical, the **candidate** for the decision is the uncertainty, while the **two alternatives** are its classification as a regulatory uncertainty or a technical uncertainty.

Candidates are ranked against attributes in decision analysis.

3.3 CONSISTENCY CHECK

A consistency check is a method for evaluating the results of the decision analysis in order to assure that the analysis is both repeatable and verifiable. Consistency should be determined by having two groups of analysts perform the analysis independently, although consistency checks may be developed within a single group of decision analysts.

3.4 DECISION ALTERNATIVE

Decision alternatives are the possible outcomes for a candidate.

3.5 DECISION ANALYSIS

Decision analysis is a systematic and logical procedure for rational analysis of complex decision problems. Decision analysis quantifies both the possible consequences of a decision and the decision maker's preferences for those consequences, and incorporates the quantified results formally into the step by step analysis of a problem. However, the decision analysis described in this TOP is not a complete multi-attribute utility analysis (MUA) because it does not include a complete procedure for quantifying utilities.

3.6 DECISION ANALYST

Decision analysts are the individual or individuals performing the decision analyses, who provide documentation of both the method and the decision process itself. A decision maker may use the assistance of decision analysts or may function as his or her own decision analyst.

3.7 DECISION MAKER

The decision maker is the individual or organization responsible for the decision in question: the one making the actual decision.

3.8 NORMATIVE EXPERT

A normative expert is one who is familiar with the substance of the decision being made as well as with the techniques of decision analysis and with theories and concepts of probability.

3.9 OBJECTIVE

An objective is a goal of the decision. A decision may be based on one or more objectives. An objective has two characteristics: it identifies a concern about alternatives and it allows for the expression of preference, or choices among alternatives.

3.10 OBJECTIVES HIERARCHY

An objectives hierarchy links objectives and attributes by their relative primacy and their relationship to each other.

3.11 RANK

Rank is the extent to which an attribute applies to a candidate. The rank of a candidate against an attribute will be reflected in the scale associated with that attribute. Ranking is the act of assigning a rank to a candidate for a specific attribute.

3.12 SCALE

A scale is used when candidates are ranked against attributes. There are two types of scales: "natural" scales (which enjoy common use and meaning) and constructed scales (which are developed to address a specific attribute or problem for which no natural scale exists). For example, the attribute of "cost" has a natural scale of dollars, while the attribute of "environmental damage" would use a constructed scale which would index relative damage by assigning numerical values ranging from "no damage" to "severe damage."

3.13 SENSITIVITY ANALYSIS

Sensitivity analysis is an investigation of the decision. This investigation is made by systematically changing relative weights assigned to the attributes and comparing variations in the results of the decision analysis. A sensitivity analysis determines the relative influence which an attribute or specific objective has on the final result of the decision analysis. For a sensitivity analysis, the weights assigned to attributes must be relative, and the total sum of the weights shall not vary.

3.14 WEIGHT

The weight assigned to an attribute indicates the relative importance of that attribute to the decision maker. Different attributes may be weighted differently or have different degrees of importance to the decision maker. For example, one attribute may be three times as important to the decision maker as another attribute, which may in turn be only half as important as another attribute. Weighting is the act of assigning weights to attributes.

4. THE DECISION ANALYSIS PROCEDURE

4.1 INITIAL DEVELOPMENT AND ACCEPTANCE OF APPROACH

Attributes shall be constructed in a systematic way, and shall be independent of each other. In this approach to decision making, the candidates are ranked against attributes.

The procedure for decision analysis includes the following steps:

1. Selection of analysts
2. Identification of the candidates
3. Selection of the objectives
4. Construction of the objectives hierarchy
5. Formulation of the attributes for each objective
6. Identification or construction of a scale for each attribute
7. Ranking each candidate with respect to each attribute
8. Assigning weights to attributes

The decision analysis process is accomplished by assessing how well the objectives have been met. The assessment includes combining weighted ranks of the candidates, sensitivity analysis, and a consistency check.

The example given in Appendix A illustrates the procedure. The example focuses on one objective, prioritization, and delineates the decision analysis for that objective; it is also an example of a relatively complex application of decision analysis. Attributes may be used in decision analyses which are considerably simpler, including the straightforward use of selection criteria.

4.2 SELECTION OF ANALYSTS

The criteria for selecting decision analysts are as follows:

(1) The decision analysts shall have appropriate technical qualifications and be well informed about the subject of the decision, about the candidates under consideration and about the high-level radioactive waste repository program. The possibility of a skewed decision analysis is minimized if at least two decision analysts perform the analysis. Consistency requires at least two analysts and at least two additional individuals with similar expertise to review the analysis.

(2) At least one of the decision analysts shall be a normative expert (see definition 3.8) familiar with the techniques of decision analysis and this procedure.

(3) The decision analysts should also be familiar with the theories and concepts of probability.

(4) A decision maker may perform the entire decision analysis, including selecting and formulating the attributes. This is part of the decision-aiding method and may be done by any decision analyst sufficiently familiar with dimensions of the problem. However, the analysis is likely to be more thorough and consistent if normative experts who are not making the decision assist in the analysis.

The rationale for selecting decision analysts, with appropriate supporting documentation, shall be prepared by the Director of WSE&I.

4.3 IDENTIFICATION OF THE CANDIDATES

The candidates for the decision analysis shall be clearly identified. The identification of those items for which a decision needs to be made or is being made about--the candidates--is the primary step in any decision analysis. The candidates for decision analysis are often self evident, but a clear statement identifying them is essential to the analysis.

4.4 SELECTION OF THE OBJECTIVES

Each decision analysis shall fulfill certain specific objectives and the number of potential specific objectives may be large. Selection of the general and the specific objectives precedes actual decision analysis; attributes are written for the set of objectives at the lowest level of the objectives hierarchy. The objectives for the decision analysis shall be clearly documented.

The criteria for including specific objectives are given below, and objectives which do not meet all of these criteria shall not be used in the decision analysis.

(1) The decision alternatives must result in a difference in the degree to which the objective may be achieved.

(2) This difference must be significant relative to other differences between decision alternatives.

(3) This difference must have a significant likelihood of occurrence.

The decision maker may also exclude any specific objectives from the decision analysis.

An objective which does not meet all three criteria or which the decision maker wishes to exclude shall not be considered in the analysis. Methods or means to achieve an objective should not be overly restrictive. For example, specific quantitative limits are inappropriate for an objective.

4.5 CONSTRUCTION OF THE OBJECTIVES HIERARCHY

An objectives hierarchy shall be prepared and charted, which shall have a general or overall objective at the top and specific objectives, which are components of the general objective, at lower levels. The number of specific objectives at the lowest level in the hierarchy shall be necessary and sufficient to provide support for the decision. Attributes shall be written for each of the lowest level specific objectives.

The suite of objectives which forms the lower levels of the hierarchy shall meet all three of the criteria listed in Section 4.4 above. Each level of the objectives may not be a unique or complete set but must be constructed to add specificity to the higher level objective.

4.6 FORMULATION OF THE ATTRIBUTES FOR EACH OBJECTIVE

There are no generic attributes; attributes should be specific to the objective or quality being characterized as well as to the candidates for the decision. The guidelines for formulation and documentation of attributes are:

(1) The number of attributes shall be the minimum necessary to make the decision analysis. Unnecessary attributes do not enhance the decision analysis, and may subvert it.

(2) The attributes must be written to mean the same thing in all cases, so that the ranking of candidates for a specific

attribute means the same thing (e.g., a "high" rank should be favorable in all cases).

(3) There shall be no redundancy among attributes.

(4) The attributes shall be independent of each other.

(5) Different rankings of the candidates against the attributes shall make a difference in the decision, and should be anticipated.

(6) The set of attributes shall be complete and shall include all pertinent aspects of the decision analysis.

Formulating attributes may be made easier by first selecting the general topics or objectives which the attributes could address. As initially formulated, the attributes may still not qualify as final proper attribute statements. Each attribute must be re-examined with respect to the following question: "what does ranking the candidates (e.g., as 'very high,' 'high,' 'moderate,' 'low,' 'very low') mean with respect to this attribute?" until the meaning is clear and a given rank is clear and consistent with respect to all the candidates. If the rank is not clear and consistent, the attribute shall be re-evaluated and rephrased, before proceeding further with ranking the candidates.

4.7 IDENTIFICATION OR CONSTRUCTION OF A SCALE FOR EACH ATTRIBUTE

A natural or constructed scale shall be identified and documented for each attribute. The same or different scales may be identified for the attributes. A natural scale is preferable because there is no problem of interpretation associated with its use. Often there are no appropriate natural scales, so that a constructed scale must be identified.

It is possible to construct a different scale for each attribute, which may then be combined using MUA. One scale could be identified which ranks all candidates to several attributes. A generally applicable scale is particularly useful for decision analysis.

A scale may be as finely divided as desired for the qualitative considerations of decision analysis. A five-point ranking scale appears to serve well, although different decision-makers prefer different scales. The scale shall facilitate the ranking of candidates for

decision analysis, and a little experimentation helps in selecting useful gradations. A three-point scale seems to make ranking decisions more difficult, and a scale with more divisions may be unnecessarily complex and give the appearance of unwarranted accuracy.

Assigned numerical equivalents are virtually always a feature of a constructed scale, and are used for averaging and taking weighted averages. A five-point constructed scale with numerical equivalents follows:

Very high = 9
High = 7
Moderate = 5
Low = 3
Very low = 1

If the attribute does not apply to the candidate being ranked, no rank shall be given or included in the final overall ranking.

A five-step scale has considerable flexibility, but there are many decisions for which a three-step scale (high, moderate, low) is perfectly adequate. Numerical ranking may or may not be helpful when a three-step scale is used. There are also decisions for which a two-step scale, indicating "yes" or "no, or "go" or "no go," is more appropriate. In such a case, numerical ranking is neither necessary nor particularly meaningful.

4.8 RANKING OF EACH CANDIDATE WITH RESPECT TO EACH ATTRIBUTE

Rank with respect to each attribute shall be assigned to each candidate by the decision analyst, the decision maker, or both. Decision analysis is improved and expedited if two or three decision analysts participate. Decision analysis possesses a high degree of subjectivity, as do all processes using expert judgment, but use of normative experts will reduce the degree of subjectivity.

Different rankings of the candidates against the attributes shall make a difference in the decision or prioritization and shall be anticipated. Also, if the attribute does not apply to a candidate, no rank shall be given nor included in the final overall ranking.

The subjective assignment of rank to the relationship of each candidate to each attribute, using the above five-point scale, is made using the following steps:

(1) The candidate is clearly described in a statement.

(2) The attribute is posed as a question related to the candidate.

(3) The candidate is ranked by the determining the applicability of the scale for the attribute as follows:

Definitely or absolutely	=	Very high	- 9
Yes, but without absolute certainty	=	High	- 7
Probably or mostly yes	=	Moderate	- 5
Probably not or usually not	=	Low	- 3
Never or not at all	=	Very low	- 1

Ranking may be expedited by using spreadsheet software with automatic calculations. Both electronic and hard copy records of all calculations shall be preserved.

4.9 ASSIGNING WEIGHTS TO ATTRIBUTES

The weights to be assigned to attributes shall be determined and documented by the decision maker. The method, criteria and rationale used to assign weights shall also be determined and documented by the decision maker. Each weight is the value or measure of importance placed on an attribute by the decision maker. Weights are assigned independently of identifying the attributes and ranking the candidates. Weights assigned at this stage of the analysis are absolute, and may be assigned independently.

There are a number of methods for determining different weights, ranging from very formal to very informal. Varying weights gives a first approximation to a sensitivity analysis.

Weighting may be expedited by using spreadsheet software with automatic recalculation capability (Lotus 123, Quattro, VPPlanner, or similar software). Both electronic and hard copy records of all calculations shall be preserved. Calculations for ranking and weighting summations or averages, and calculations for sensitivity analyses and decision analysis shall be verified independently by someone familiar with the decision analysis method but not a participant in the decision analysis project.

5. RESULTS OF ATTRIBUTE ANALYSIS

After the analysis of Section 4 has been completed, further analysis steps may be conducted to assess achievement of the objectives. These steps are as follows:

1. Assessing how well the objectives have been met
2. Conducting a sensitivity analysis
3. Checking for consistency

5.1 ASSESSING HOW WELL THE OBJECTIVES HAVE BEEN MET

After ranking the candidates against all the applicable attributes (weighted or unweighted), achievement of the objectives may be assessed by interpreting the results from preceding sections. When constructed scales are used for ranking, direct interpretation of qualities like importance and priority is possible. In general, the higher the rank for any objective, the better that objective is met.

The results of the analysis shall be interpreted by the decision maker. Decisions on candidate priority, importance, desirability, risks, benefits, classification, etc. may be assessed by using appropriate sums or averages of the rankings derived in Section 4.

The attribute rankings for each candidate may be summed, or averaged, or the attribute ranking against each objective may be summed or averaged separately. When candidate rankings are summed or averaged only in relation to lower-level specific objectives, more useful analytical information may be obtained. This separation of the candidates by specific objective categories may be somewhat arbitrary, and usefulness is diminished with an increased number of attributes.

An assessment of objectives may be expedited by using spreadsheet software with automatic calculations. Both electronic and hard copy records of all calculations shall be preserved.

5.2 CONDUCTING A SENSITIVITY ANALYSIS

Assigning arbitrary weights to the attributes, including zero weight, may give an indication of the sensitivity of the result to any attribute. However, arbitrary weight assignment will not constitute a true sensitivity analysis unless the sum of the weights remains constant as individual weights are changed.

To conduct a sensitivity analysis, the weights assigned to attributes must be relative, and the total sum of the weights must be constant. Sensitivity is assessed by determining the relative influence which each attribute has on the final result. Precise assessment of sensitivity may be obtained by systematically varying the relative weight of one or more attributes.

In general, the more attributes there are, the less sensitive the decision analysis will be to the rank of a candidate for any one attribute. Also, the higher the rank of a candidate for any one attribute, the greater the sensitivity of the candidate to weighting.

A sensitivity analysis may be expedited by using spreadsheet software with automatic calculations. Both electronic and hard copy records of all calculations shall be preserved.

5.3 CHECKING FOR CONSISTENCY

A consistency check may be carried out in two ways. First, the decision analysts may revisit earlier decisions afresh, and determine if the same results are obtained. Second, an independent set of decision analysts may either carry out the same analysis or spot-check the analysis that was done. The use of independent analysts is generally preferable. Consistency does not require identical results, since a certain amount of individual variation is inevitable.

A consistency check may be expedited by using spreadsheet software with automatic calculations. Both electronic and hard copy records of all calculations shall be preserved.

6. RECORDS

Records generated as a result of this procedure, including statements of the attributes, weighting of the attributes, the ranking scale used, the ranking of candidates related to each applicable attribute, calculations, consistency checks, and sensitivity analyses shall be maintained and retained as QA records in accordance with CQAM Section 17 for six years.

APPENDIX A

AN EXAMPLE OF THE APPLICATION OF DECISION ANALYSIS

A decision analysis was carried out for some of the uncertainties identified in 10 CFR Part 60, and is described in CNWRA 89-003. The present example considers two regulatory uncertainties from that analysis.

The candidates for this analysis are two of the regulatory uncertainties developed in the intensive analysis of 10 CFR 60.122(a), and applied to the 24 potentially adverse conditions of 10 CFR 60.122(c). The uncertain language is highlighted in the statements of the uncertainties given below:

> UN1: **10CFR60.122(a)(2)(i)** The potentially adverse human activity or natural condition has been investigated, including the extent to which the condition may be present and still be undetected **taking into account the degree of resolution achieved by the investigation...**
>
> UN2: **10CFR60.122(a)(2)(iii)(A)** The potentially adverse human activity or natural condition is shown by analysis...**not to affect significantly** the ability of the geologic repository to meet the performance objectives relating to isolation of the waste...

The decision under consideration in this example will be prioritization: which uncertainty to resolve first. This decision will be used throughout the ensuing discussion. The candidates for this discussion are UN1 and UN2, identified above.

Figure 1 shows the objectives hierarchy for the decision. The suite of objectives which forms the second layer of the hierarchy meets all three of the criteria identified in Section 4.3, though it is not a unique or complete set. A third hierarchical layer may be drawn to add specificity to the second layer of objectives.

This example focuses on the third objective - prioritization of uncertainties for reduction. The "sub-hierarchy" for prioritization is expanded in Fig. 2. This "sub-hierarchy" for prioritizing the uncertainties is expressed as three lower-level objectives: determining the relative <u>importance</u> of reducing the uncertainty, determining the relative <u>desirability of timely reduction</u> of the uncertainty, and

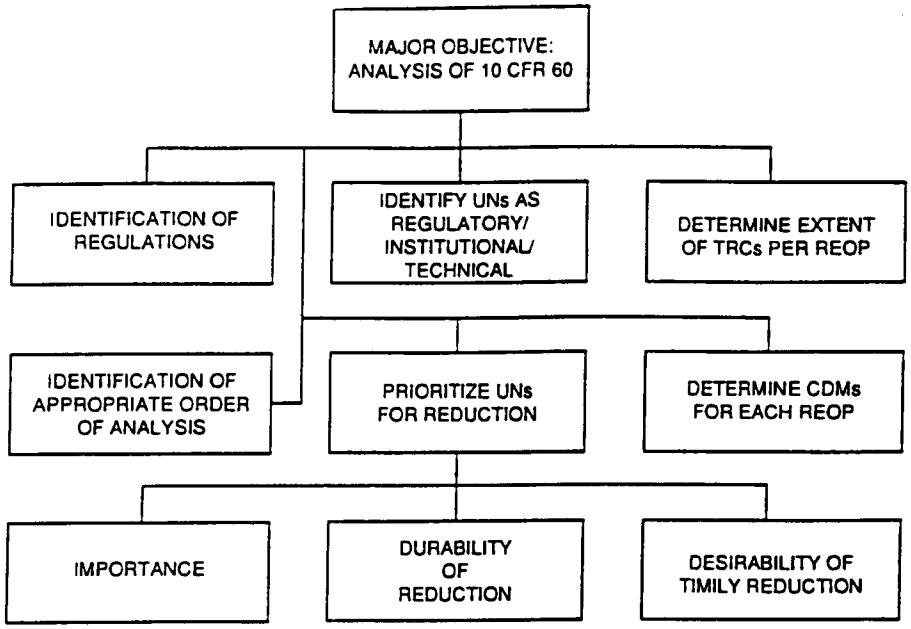

Figure: 1. Objectives Hierarchy for the Major Objective of Uncertainty Attribute (decistion) Analysis.

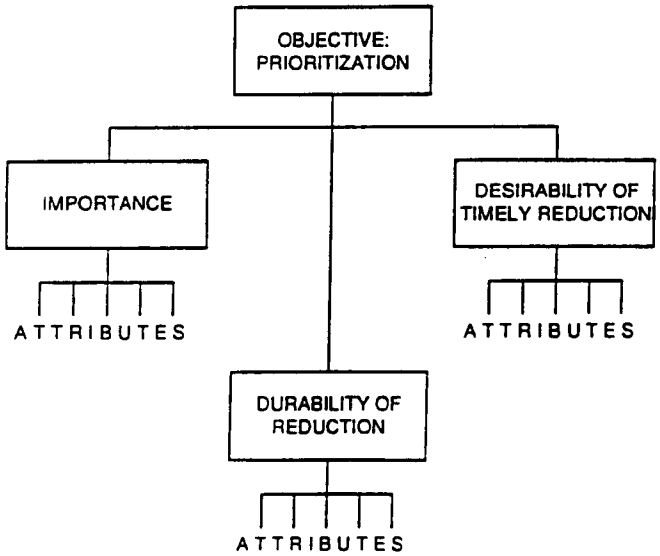

Figure: 2. Objectives Sub-Hierarchy for the Major Objective of Prioritizing the Uncertainties for Reduction.

determining the need for durability of the uncertainty reduction. Attributes must be written which provide a basis of ranking the uncertainties with respect to importance and the desirability of a timely reduction.

Attributes may be formulated for "importance" by identifying what makes the items being prioritized important, or why one item would be more important than another. Statements of attributes are possible endings to the sentence "This [reduction of a regulatory uncertainty, analysis of a regulatory requirement, etc.] is important because..." A similar basic statement may be made for "desirability if a timely reduction."

Topics related to the **importance** of resolving these two uncertainties are:

i. Affecting the overall repository performance

ii. The potential for radioactive contamination during the operational phase.

iii. Possible disqualification of the site

Topics related to the **desirability of a timely reduction** are:

iv. Expediting the licensing process

v. Affecting DOE site characterization activities

The topics i. through v. are then expanded into full attribute statements, though the first statements of attributes are often rough drafts which are subsequently improved upon. A first draft of attribute statements these topics yields the following five statements:

1. **Resolving the uncertainty will affect the overall repository licensing process.**

2. **Resolving the uncertainty will reduce the potential for radioactive contamination during the operational phase.**

3. **Resolving the uncertainty will result in possible disqualification of the site.**

4. **Resolving the uncertainty will expedite the licensing process.**

5. **Resolving the uncertainty will affect DOE site characterization activities.**

Hereinafter, the attribute statements will be referred to as Attribute 1, Attribute 2, etc.

For Attributes 2 and 4, the meaning of a ranking (e.g., 'very high,' 'high,' 'moderate,' 'low,' 'very low') is immediately clear, and the statement can stand as a final proper attribute statement. In Attributes 1 and 5, however, the phrase "will affect" does not allow unequivocal ranking, since resolving the uncertainty can "affect" either positively or negatively. Restatements of Attributes 1 and 5 will be tried until a clear, unequivocal statement results.

The only possible restatement of Attribute 1 - **resolving the uncertainty will affect the overall repository licensing process** - is:

1. **Resolving the uncertainty will expedite the overall repository licensing process.**

This restatement makes Attribute 1 identical with Attribute 4. One of these two can therefore be eliminated. We turn then to the rewriting of Attribute 5 - **resolving the uncertainty will affect DOE site characterization activities**. In this statement, the notion of "will affect" may have several possible interpretations, for example:

5a. **Resolving the uncertainty will expedite DOE site characterization activities.**

5b. **The uncertainty must be resolved in order to give appropriate guidance to DOE during site characterization.**

5c. **If the uncertainty is not resolved before site characterization begins, repository performance may be adversely affected.**

Attribute 5c may be refined further to include the notion of mitigation of the adverse effect on repository performance (can it be mitigated or not):

5c'. **If the uncertainty is not resolved before site characterization begins, repository performance may be adversely affected, but any adverse effects can be mitigated.**

5c". **If the uncertainty is not resolved before site characterization begins, repository performance may be adversely affected, and resulting adverse effects can not be mitigated.**

Attributes 5a, 5b, 5c' and 5c" are independent statements which can be used to rank the uncertainty. Attribute 5a, however, is one that is not germane to this particular decision maker (the NRC), and may thus be eliminated.

Attribute 3, as written, also does not allow unequivocal ranking. The following restatement does:

3. **Resolving the uncertainty will expedite determination of whether or not the site is disqualified.**

Attribute 3 is thus a statement of the desirability of timely reduction rather than a statement of importance. The distinction between importance and desirability of timely reduction is somewhat arbitrary, and is made primarily for classification purposes.

The "importance" attributes as now stated are:

2. **Resolving the uncertainty will reduce the potential for radioactive contamination during the operational phase.**

5b. **The uncertainty must be resolved in order to give appropriate guidance to DOE during site characterization.**

The "desirability of timely reduction" attributes as now stated are:

1. **Resolving the uncertainty will expedite the overall repository licensing process.**

3. **Resolving the uncertainty will expedite determination of whether or not the site is disqualified.**

5c'. **If the uncertainty is not resolved before site characterization begins, repository performance may be adversely affected, but any adverse effects can be mitigated.**

5c". **If the uncertainty is not resolved before site characterization begins, repository performance may be adversely affected, and resulting adverse effects can not be mitigated.**

These attributes are stated so that a given rank (e.g., "high") means the same thing with respect to all the attributes (e.g., that reduction of the uncertainty is important).

UN1 is ranked with respect to Attribute 5b by asking the question: is a detailed definition of "degree of resolution" needed to give DOE appropriate guidance during site characterization?

Answer: Since this language defines the degree of precision of the research into virtually all of the potentially adverse conditions, the definition is needed early during site characterization, though not necessarily at its inception.

Rank = High = 7

UN2 is ranked with respect to Attribute 3 by asking the question: will determination of "significance" in the phrase "affect significantly the ability of the repository to meet the performance

objectives relating to isolation of the waste" expedite determination of whether or not the site is disqualified?

Answer: Definitely, since this phrase essentially determines whether or not a potentially adverse condition is a disqualifying condition.

Rank = Very high = 9

UN1 is ranked with respect to Attribute 1 by asking the question: will defining the "degree of resolution achieved by the investigation" expedite the overall repository licensing process?

Answer: Definitely; the definition is key to the licensing process.

Rank = Very high = 9

UN2 is ranked with respect to Attribute 5c" by asking the question: if "significantly" in the phrase "affect significantly the ability of the repository to meet the performance objectives relating to isolation of the waste" is not precisely defined before site characterization begins, is repository performance likely to be affected in such a way that effects cannot be mitigated?

Answer: Although the definition is needed early in site characterization, it is not likely that absence of the definition will cause some site characterization activity to be undertaken that will irreversibly degrade repository performance.

Rank = Low = 3

This ranking was repeated for both uncertainties against all of the attributes. The results are displayed in tabular form in Fig. 3, below. This analysis treats all of the attributes as having equal weight; the results are thus "unweighted."

ATTRIBUTE	UN1	UN2
2	7	1
5b	7	7
1	9	9
3	5	9
5c'	7	3
5c"	9	1

Figure 3. Tabulated Results of Unweighted Ranking of the Two Uncertainties Against the Attributes.

The unweighted average rankings of each of these three uncertainties with respect to the seven attributes considered here are:

Eq. 1a $UN1_{av} = 38/6 = 6.3$

Eq. 1b $UN2_{av} = 30/6 = 5$

The "importance" and "desirability of timely reduction" averages are:

Eq. 2a $UN1_I = 14/2 = 7$ $UN1_T = 24/4 = 6$

Eq. 2b $UN2_I = 8/2 = 4$ $UN2_T = 22/4 = 5.5$

Up to this point in the example all attributes have been given equal weight or importance. In this section, weighting factors will be assigned arbitrarily to the attributes. The following weighting factors will be assumed:

Eq. 3 $Wt_{Attribute5b} = 3Wt_{Attribute2}$

Eq. 4 $$Wt_{Attribute3} = 1.5Wt_{Attribute1} = 2Wt_{Attribute5c'} = 3Wt_{Attribute5c''}$$

The weighted "importance" and "desirability of timely reduction" averages are calculated as follows:

For Uncertainty UN1:

$Wt_{Attribute2}$ is set = 1

Eq. 6 $$UN1_{Iw} = \frac{(1)(7) + (3)(7)}{4} = 28/4 = 7$$

$Wt_{Attribute5c''}$ is set = 1

Eq. 7 $$UN1_{Tw} = \frac{(2)(9)+(3)(5)+(1.5)(7)+(1)(3)}{7.5} = 46.5/7.5 = 6.2$$

For Uncertainty UN2:

$Wt_{Attribute2}$ is set = 1

Eq. 8 $$UN2_{Iw} = \frac{(1)(1) + (3)(7)}{4} = 22/4 = 5.5$$

$Wt_{Attribute5c''}$ is set = 1

Eq. 9 $$UN2_{Tw} = \frac{(2)(9)+(3)(9)+(1.5)(3)+(1)(1)}{7.5} = 50.5/7.5 = 6.7$$

Rankings for "importance" and "desirability of timely reduction" are a bit more telling when averaged separately, though the separation into these two categories is somewhat arbitrary. If a priority decision were to be made on the basis of these averages, additional objectives might be formulated, and additional attributes written, to make finer distinctions. For example, one or more additional attributes could be written to address the <u>possibility</u> of timely reduction as distinct from the <u>desirability</u> of timely reduction.

In the example discussed above, using equally weighted attributes, the decision analyst finds the following:

- Reduction of UN1 is considerably more important than reduction of UN2.

- Timely reduction of UN1 and timely reduction of UN2 are about equally desirable, though timely reduction of UN1 ranks higher.

- On the basis of equally weighted attributes, reduction of UN1 appears to take priority over reduction of UN2.

The following weights were applied to the attributes: (1) guidance to DOE during site characterization was weighted three times as heavily as potential for radioactive contamination, and (2) expediting the licensing process and determining disqualification were weighted more heavily than the potential for adverse effects of site characterization. When the attributes are weighted as indicated, the decision analyst finds the following:

- The desirability of timely reduction of UN1 is considerably closer to the desirability of the timely reduction of UN2.

- Reduction of UN1 is still considerably more important than reduction of UN2.

Thus, the weighted averages in this example do not reverse either the "importance" rankings or the "desirability of timely reduction" ranking for the two uncertainties considered. Since weights were assigned arbitrarily, this result has no intrinsic significance other than showing the effect of weighting.

Sensitivity of the "importance" rankings to each of the "importance" attributes may be assessed from the effect of weighting, since there are only two "importance" attributes in this example. Sensitivity of the "timeliness" rankings may be assessed by varying the weighting of each attribute in turn.

The sum of the coefficients of Equation 4 - 7.5 - remains the same throughout the sensitivity analysis, as do the ratios of the coefficients to each other. However, if $Wt_{Attribute1}$ is set equal to zero, the weighted "desirability of timely reduction" averages may be calculated. The coefficients of the pertinent equations are shown in Fig.4.

ATTRIBUTE	WEIGHT		SENSITIVITY ANALYSIS WEIGHT	WEIGHT	WEIGHT
1	2		0	2.5	3.33
3	3		4.1	3.75	0
5c'	1.5		2.05	0	2.5
5c"	1		1.36	1.25	1.67
UN	AV. RANK		AV. RANK	AV. RANK	AV. RANK
$UN1_{TW}$	6.2		5.2	6.0	7.0
$UN2_{TW}$	6.7		5.9	4.7	5.2

Figure 4. Partial Sensitivity Analysis Showing How Weights and Ranks Change When One Attribute is Given Zero Weight.

When Attribute 1 is given zero weight, Equation 7 becomes

Eq. 7a $$UN1_{Tw} = \frac{(4.1)(5)+(2.05)(7)+(1.36)(3)}{7.5} = 38.9/7.5 = 5.2$$

and Equation 9 becomes

Eq. 9a $$UN2_{Tw} = \frac{(4.1)(9)+(2.05)(3)+(1.36)(1)}{7.5} = 44.4/7.5 = 5.9$$

When Attribute 5c' is given zero weight, Equation 7 becomes

Eq. 7b $$UN1_{Tw} = \frac{(2.5)(9)+(3.75)(5)+(1.25)(3)}{7.5} = 45/7.5 = 6.0$$

and Equation 9 becomes

Eq. 9b $$UN2_{Tw} = \frac{(2.5)(9)+(3.75)(3)+(1.25)(1)}{7.5} = 35/7.5 = 4.7$$

When Attribute 3 is given zero weight, Equation 7 becomes

Eq. 7c $$UN1_{Tw} = \frac{(3.33)(9)+(2.5)(7)+(1.67)(3)}{7.5} = 52.5/7.5 = 7.0$$

and Equation 9 becomes

Eq. 9c $$UN2_{Tw} = \frac{(3.33)(9)+(2.5)(3)+(1.67)(1)}{7.5} = 39.1/7.5 = 5.2$$

Figure 4 shows that assigning zero weight to Attribute 1 does not change the result qualitatively, in the sense that the ranks of UN1 and UN2 for desirability of timely reduction bear the same relationship to each other as before the sensitivity analysis - the rank of UN1 is about 10% lower than the rank of UN2. Assigning zero weight to Attribute 5c', however, gives UN1 about a 25% higher rank than UN2 for desirability of timely reduction. The latter difference is even greater - about 33% - when Attribute 3 is given zero weight. This initial analysis indicates that the outcome is very sensitive to Attribute 3 and Attribute 5c' but relatively insensitive to Attribute 1. Because the two uncertainties ranked the same with respect to Attribute 1, giving this attribute zero weight would not be expected to make a qualitative difference is the relative ranks. Since both of the uncertainties considered ranked low with respect to Attribute 5c", one may assume relative insensitivity to this attribute.

No consistency check is made here because the example discussed in this section is just that - an example.

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES TECHNICAL OPERATING PROCEDURE	Proc. TOP-015 Revision 0 Page 1 of 25

Title

TOP-015 PROCEDURE FOR DECISION ANALYSIS

EFFECTIVITY AND APPROVAL

Revision 0 of this procedure became effective on 6/29/90. This procedure consists of the pages and changes listed below.

Page No.	Change	Date Effective
ALL	-	6/29/90

Supersedes Procedure No. NONE

Approvals

Written By	Date	Technical Review	Date
for R. WEINER	6/29/90	W. PATRICK	6/29/90
Quality Assurance	**Date**	**Cognizant Director**	**Date**
B. MABRITO	6/29/90	A. WHITING	6/29/90

CNWRA Form TOP-1