

APPENDIX A

QUALITATIVE FACTORS ASSESSMENT TOOLS

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A.1 Purpose

The purpose of this appendix on the qualitative factors assessment methodology is to provide guidance and best practices for use in estimating intrinsic costs and benefits (i.e., qualitative factors) to improve the clarity, transparency, and consistency of the U.S. Nuclear Regulatory Commission's (NRC's) regulatory, backfit, and environmental analyses. The identification, characterization, and analysis of both monetized costs and benefits (i.e., those measured in dollars) and qualitative (e.g., functional or nonmonetized) costs and benefits are essential for the evaluation and selection of the preferred alternative.

The NRC uses cost-benefit analyses to determine whether a regulatory action is justified on the basis of a comparison of predicted costs and benefits. Consideration of the relative importance of qualitative attributes in the decision rationale is an extremely useful and powerful tool for decisionmakers and stakeholders. It is important to realize that monetary units are not the only way to assign value to outcomes of concern to the general public. A known limitation of cost-benefit analysis is that some outcomes are rarely ever priced or traded in the economy, making it difficult to assign monetary value to some types of costs and benefits.

This appendix captures best practices for the consideration of qualitative factors by providing a number of methods that can be used to support the NRC's evidence-based, quantitative, and analytical approach to decisionmaking. This guidance provides a toolkit to enable analysts to clearly present analyses of qualitative results in a transparent way that decisionmakers, stakeholders, and the general public can understand. However, as directed by the Commission in SRM-SECY-14-0087, "Staff Requirements – SECY-14-0087 – Qualitative Consideration of Factors in the Development of Regulatory Analyses and Backfit Analyses," dated March 4, 2015 (ADAMS Accession No. ML15063A568), analysts are encouraged "to quantify costs to the extent possible and use qualitative factors to inform decision making, in limited cases, when quantitative analyses are not possible or practical (i.e., due to lack of methodologies or data." These methods should only be used when quantification may not be practical; they are not a substitute for collecting accurate information to develop realistic cost estimates and do not constitute an expansion of the consideration of qualitative factors in regulatory, backfit, or environmental analyses.

A.2 Types Of Costs And Benefits

A.2.1 Tangible Costs and Benefits

Quantifiable costs and benefits have numeric values such as dollars, physical counts of tangible items, or percentage change of a quantifiable factor. Monetized benefits are always quantifiable and are measured in dollars or are tangible items with known conversion factors to monetize the variable (e.g., person-rem conversion factor contained in NUREG-1530, Revision 1, "Reassessment of NRC's Dollar per Person-Rem Conversion Factor Policy").

1 Examples of nonmonetized, quantifiable costs and benefits include the following:
2

- 3 • number of commodities or items produced for each alternative
- 4 • maintainability or supportability measures (i.e., mean-time-to-repair or average downtime)
- 5 • accuracy, timeliness, and completeness of data produced by systemic performance and
6 operational effectiveness
7

8 **A.2.2 Intangible Costs and Benefits**

9 Intangible costs and benefits do not easily lend themselves to direct, quantitative measures. In
10 other words, these types of attributes: (1) do not have readily available standard measurement
11 scales, and (2) tend to be subject to great interindividual measurement variability. Although
12 subjective in nature, qualitative measures can make a positive contribution to the cost-benefit
13 analysis. The analysts should use the best analytical practices (e.g., surveys and interviews) to
14 include difficult-to-quantify costs and benefits in the analysis. Some examples of nonquantifiable
15 costs and benefits⁵ include the following:
16

- 17 • defense in depth
- 18 • perception/image
- 19 • aesthetics
- 20 • morale
- 21 • terrestrial or aquatic habitat
- 22 • quality of material or service
- 23 • safeguards and security
- 24 • operational readiness
- 25 • regulatory efficiency
- 26 • improvements in knowledge
- 27 • incorporation of advances in science and technology
- 28 • greater flexibility in practice or less prescriptive requirements
- 29 • greater specificity in existing generally stated requirements
- 30 • correction of significant flaws in current requirements
31

32 While quantifying costs and benefits assists the decisionmakers in understanding the magnitude
33 of the effects of alternative regulatory actions, some benefits may be difficult to quantify in
34 monetary terms. However, they can also be too important to ignore. In this situation, the analysts
35 should use accurate information to develop realistic estimates to quantify parameters and should
36 use the methods contained in this appendix to inform decisionmaking when quantitative analyses
37 are difficult or if not included would provide an incomplete analysis.
38

39 **A.3 The Need For Consistent Methods**

40 Cost-benefit analysis is a tool regulatory agencies use to anticipate and evaluate consequences of
41 regulatory actions. It provides a formal way of organizing the evidence of various alternatives that
42 should be considered in developing regulations. The motivation is to learn if the benefits of an
43 action are likely to justify the costs or discover which of various possible alternatives would
44 provide the greatest net benefit to society.

5 This list of nonquantifiable costs and benefits is based on those listed in SECY-14-0087, "Qualitative Consideration of Factors in the Development of Regulatory Analyses and Backfit Analyses," Attachment 1 or in Appendix D of the Committee to Review Generic Requirements Charter.

1 Regulatory analyses are designed to inform other parts of the Government and the public of the
2 effects of alternative regulatory actions. These analyses sometimes show that a proposed action
3 may not be appropriate for the situation and can also demonstrate that actions are reasonable
4 and justified.

5
6 Where all costs and benefits can be quantified and expressed in monetary units, cost-benefit
7 analysis provides decisionmakers with a clear indication of the most economically efficient
8 alternative (i.e., the alternative that generates the largest net benefits to society). This is useful
9 information for decisionmakers and the public to receive, even when economic efficiency is not
10 the only or primary regulatory objective.

11
12 Unfortunately, it will not always be possible to express in monetary units all of the important costs
13 and benefits. When it is not, the most economically efficient alternative will not necessarily be the
14 one with the largest quantified, monetized net-benefit estimate. In such cases, the analysts should
15 use professional judgment, estimate costs and benefits at a bounding level, or elicit subject matter
16 expertise to determine how important the attributes may be in the context of the overall analysis.
17 This would enable the analysts to clearly explain the nonquantified costs and benefits so
18 decisionmakers can compare them with the monetary costs and benefits.

19
20 For example, one method for eliciting subject matter expertise is the Delphi technique (Ref. A.3
21 and A.4), a forecasting method based on the results of questionnaires sent to a panel of
22 independent experts. During this process, several rounds of questionnaires are sent out, and the
23 anonymous responses are aggregated and shared with the group after each round. The experts
24 are allowed to adjust their answers in subsequent rounds. Because multiple rounds of questions
25 are asked and because each member of the panel is told what the group thinks as a whole, the
26 goal of the Delphi Method is to reduce the range of responses to reach a “common” response
27 through consensus.

28 29 **A.4 Methods**

30 Several tools are available if some attributes do not lend themselves to quantification. Where
31 possible, considerations associated with these attributes should be quantified using market data,
32 shadow pricing, or willingness-to-pay (WTP) techniques. The WTP principle captures the notion of
33 opportunity cost by measuring what individuals are willing to forgo (pay) to enjoy a particular
34 benefit.

35
36 Some potential data sources that may be used for quantifying cost estimates include the following:

- 37
38
- 39 • budget submissions
 - 40 • historical cost data reports
 - 41 • manpower use records/reports
 - 42 • construction materials cost database

43 Because data collection can be a time consuming process, a formal data collection plan may be
44 useful. Such a plan would include tasks to identify the types of data available; to acquire the data
45 with supporting documentation; to determine which estimating methods and models will be used
46 with which data set; and to verify, validate, and normalize the data.

47
48 If the consideration does not lend itself to monetized costs and benefits, then the analyst should
49 describe it in sufficient detail that the decisionmaker can properly incorporate the impact of the effect

1 into their decision, based on the guidance that net benefits need to be positive for an alternative to be
2 acceptable. Some methods are briefly described here, with references provided. The selection of an
3 appropriate method depends on the issues being considered and the desired objectives. The
4 sophistication of the method selected should be commensurate with the complexity of the issue.

5
6 Analysts should remember that, because these alternatives do not estimate the net benefits of a
7 policy or regulation, they fall short of a cost-benefit analysis in their ability to identify an
8 economically efficient policy. Such shortcomings should be discussed when presenting results.

9 10 **A.4.1 Narrative**

11 When there are potentially important effects that cannot be quantified, the analysts should include a
12 discussion of benefits results. The analysts should discuss the strengths and limitations of the
13 information. This should include information on the key reason(s) why they are difficult to quantify. In
14 one instance, the analysts may know with certainty the magnitude of a risk to which a substantial,
15 but unknown, number of individuals are exposed. In another instance, based on highly speculative
16 assumptions, a postulated consequence may result in highly uncertain magnitude of risk.

17
18 For cases in which these costs or benefits affect a recommendation, the analysts should provide a
19 clear explanation of the rationale behind the choice. Such an explanation could include detailed
20 information on the nature, timing, likelihood, location, and distribution of the costs and benefits.
21 Also, the analyses should include a summary table that lists all the quantified and unquantified
22 costs and benefits. The careful consideration of these factors using techniques described in this
23 appendix should be used to document and highlight (e.g., with categories or rank ordering) those
24 factors that are most important for decisionmaking. Examples identified in OMB Circular A-4,
25 "Time Preference for Non-Monetized Benefits and Costs," under "Benefits and Costs that Are
26 Difficult to Quantify" are "the degree of certainty, expected magnitude, and reversibility of effects."

27
28 While the focus is often placed on difficult-to-quantify benefits of regulatory actions, some costs
29 are difficult to quantify as well. For example, in its document, "Informing Regulatory Decisions:
30 2003 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded
31 Mandates on State, Local, and Tribal Entities," the U.S. Office of Management and Budget (OMB)
32 stated that certain permitting requirements (e.g., U.S. Environmental Protection Agency's New
33 Source Review program, and Clean Power Plan) "restrict the decisions of production facilities to
34 shift to new products and adopt innovative methods of production. While these programs may
35 impose substantial costs on the economy, it is very difficult to quantify and monetize these effects.
36 Similarly, regulations that establish emission standards for recreational vehicles, like motorcycles,
37 may adversely affect the performance of the vehicles in terms of drivability and zero to 60 miles
38 per hour acceleration." The cost associated with the loss of these attributes may be difficult to
39 quantify and monetize, so they need to be analyzed qualitatively.

40 41 **A.4.2 Cost-Effectiveness Analysis**

42 Cost-effectiveness analysis can provide a rigorous way to identify options that achieve the most
43 effective use of the resources available without requiring the monetization of all of the relevant benefits
44 or costs. Generally, cost-effectiveness analysis is designed to compare a set of regulatory actions with
45 the same primary outcome (e.g., an increase in the acres of wetlands protected) or multiple outcomes
46 that can be integrated into a single numerical index (e.g., units of health improvement). This type of
47 analysis is commonly used to compare alternatives when the value of costs or benefits cannot be
48 adequately monetized. If it can be assumed that the benefits are the same for all alternatives being
49 considered, then the task is to minimize the cost of obtaining them through a cost-effectiveness

1 analysis. This method may be used in cases where uncertainties are substantial or where important
 2 values are difficult to quantify. For such instances, alternatives that yield equivalent benefits may be
 3 evaluated based on their cost-effectiveness. A regulatory analysis incorporating this method may also
 4 be used, if there are multiple ways to achieve compliance or reach a level of adequate protection and
 5 the Commission finds it necessary or appropriate to specify the way to achieve that level of protection.
 6 A cost-effectiveness analysis of the various alternatives under consideration improves technical
 7 efficiency toward achieving a desired outcome that may be valuable to a decisionmaker.

8
 9 The cost-effectiveness of an alternative is calculated by dividing the present value of total costs of
 10 the option by the nonmonetary quantitative measure of the benefits it generates. The ratio is an
 11 estimate of the amount of costs incurred to achieve a unit of the outcome from a particular policy
 12 option. For example, in a security scenario, what are the costs expressed in dollars incurred to save
 13 a person's life or mitigate a security event? Presumably, there are alternative ways to achieve these
 14 objectives and determine their costs. The analysis does not evaluate benefits in monetized terms
 15 but is an attempt to find the least-cost option to achieve a desired quantitative outcome.

16
 17 One technique for comparing and prioritizing a list of alternatives is the decision matrix. It is a flexible
 18 technique that may be used to evaluate most quantitative and nonquantitative costs and benefits.

19
 20 In this example, some decision elements are monetized but others are evaluated subjectively
 21 because they were not readily quantifiable. While both types of decision elements could be
 22 evaluated directly using a decision matrix, it is recommended that only nonmonetized data be
 23 evaluated using this technique to avoid weakening or degrading the value of that quantified data.
 24 The optimum approach is to use a decision matrix to evaluate the nonmonetized criteria, evaluate
 25 the monetized data separately, and then consider both monetized and nonmonetized data to
 26 develop a recommendation. An example of this technique is provided in Tables A-1 and A-2 in
 27 which weighting factors are assigned based on the importance of the attribute in meeting the
 28 regulatory objective and the rating factor is a measure assigned to determine the overall
 29 performance with respect to the decision element.

30
 31 **Table A-1 Example of a Decision Matrix - Quantification of Intangible Benefits**

Decision Element	Normalized Weighting Factor	Alternative 1			Alternative 2			Alternative 3		
		Data	Rating	Score	Data	Rating	Score	Data	Rating	Score
Maintenance Downtime	.40	7 hrs.	9	3.6	10 hrs.	7	2.8	14 hrs.	4	1.6
Reduced Error Rate	.25	5 per 100	5	1.25	2.5 per 100	7	1.75	8 per 100	2	.50
Suitability	.20	Very Good	4	.80	Good	2	.40	Excellent	6	1.20
Improved Productivity	.15	240 per cycle	8	1.20	230 per cycle	7	1.05	200 per cycle	6	.90
Total Weight	1.00	Total Score		6.85	Total Score		6	Total Score		4.2

1 For each criterion, the score is determined by multiplying the weighting factor for the criterion by
2 the rating for the alternative (the weighting factor and rating being subjective numbers). The cost
3 of the alternatives would be divided by the total scores in the bottom row to produce a cost-benefit
4 index to arrive at a recommendation. An example is provided in Table A-2.

5 **Table A-2 Example of a Cost-Benefit Index**

Cost-Benefit Index	Alternative 1	Alternative 2	Alternative 3
Cost	24	20	19
Benefit Score	6.85	6	4.2
Cost-Benefit Index	3.50	3.33	4.52

6
7 Cost-effectiveness results based on averages need to be considered carefully. They are limited by the
8 same drawbacks as cost-benefit ratios. The alternative that exhibits the smallest cost-effectiveness
9 ratio, or the alternative with the highest cost-benefit ratio, may not be the preferred alternative that
10 maximizes net benefits. Incremental cost-effectiveness analysis can help avoid mistakes that can
11 occur when proposed regulatory actions are based on average cost-effectiveness. The incremental
12 cost-effectiveness ratio determines the marginal or incremental cost for an additional unit of benefit
13 when choosing between mutually exclusive alternatives.

14
15 A cost-effectiveness analysis can also be misleading when the “effectiveness” measure does not
16 appropriately weigh the consequences of the alternatives. For example, when effectiveness is
17 measured in a quantity of reduced emissions, cost-effectiveness estimates may be misleading,
18 unless the reduced emission outcomes result in the same health and environmental benefits.

19
20 Likewise, if the range of alternatives considered results in different levels of stringency, the
21 analysts should determine the cost-effectiveness of each option compared with the baseline, as
22 well as its incremental cost-effectiveness compared with successively more stringent
23 requirements. The analysts should attempt to prepare an array of cost-effectiveness estimates
24 that would allow a comparison across different alternatives. However, if analyzing all possible
25 combinations is not practical, because there are many alternatives or possible interaction effects,
26 then the analysts should use professional judgment to choose reasonable alternatives for
27 consideration.

28
29 Some caveats exist for the measurement of the associated costs using the cost-effectiveness
30 technique:

- 31
- 32 • The marginal cost-effectiveness should be calculated. It is the marginal or incremental
33 cost-effectiveness of the alternative that should be compared with the baseline
34 cost-effectiveness alternative (i.e., status quo). The policy that has the lowest marginal cost
35 per unit of effectiveness will be the most efficient way to use resources.
 - 36 • The costs include all compliance costs incurred by both the private and public sectors. Such
37 costs should be based on resource or opportunity costs, not merely the monetized costs of
38 goods and services.
 - 39 • The costs should be properly defined and measured in the calculation of cost-effectiveness.
 - 40 • The costs incurred may be private (i.e., capital or operating expenditures) or societal costs
41 that are spread over many years. Both the costs and benefits should be discounted to a
42 common time period in order to compare alternative options.
- 43

1 There are shortcomings inherent in the cost-effectiveness approach. It is a poor measure of the
2 consumers' WTP principle, because there is no monetary value placed on the benefits. WTP is
3 defined as the amount of money that, if taken away from income, would make an individual
4 exactly indifferent between experiencing the specified outcome and not experiencing either the
5 improvement or any change in income.
6

7 Moreover, in the calculation of cost-effectiveness, the cost numerator does not take into account
8 the scale of alternative options. Nevertheless, the cost-effectiveness ratio is a useful criterion for
9 selecting alternative regulatory options when the benefits cannot be monetized.
10

11 OMB does not require agencies to use any specific measure of effectiveness. In fact, OMB
12 encourages agencies to report results with multiple measures of effectiveness that offer different
13 insights and perspectives. The regulatory analysis should explain which measures were selected
14 and why and how they were implemented (Ref. A.6).
15

16 **A.4.3 Threshold Analysis**

17 A break-even analysis is one alternative that can be used when either risk data or valuation data
18 are lacking. Analysts who have per-unit estimates of economic value but lack risk estimates
19 cannot quantify net benefits. They can, however, estimate the number of cases (each valued at
20 the per-unit value estimate) at which overall net benefits become positive, or where the regulatory
21 action will break even. OMB Circular A 4 refers to these values as a "switch point" in its discussion
22 of sensitivity analysis.
23

24 Consider a proposed regulatory action that is expected to reduce the number of cases resulting in
25 outcome X with an associated cost estimate of \$1 million. Further, suppose that the analysts
26 estimate that the WTP to avoid a case resulting in outcome X is \$200, but because of limitations in
27 data, it is difficult to generate an estimate of the number of cases of this outcome reduced by this
28 regulatory action. In this case, the proposed regulatory action must reduce the number of cases by
29 5,000 to "break even." This estimate then can be assessed for plausibility quantitatively.
30 Decisionmakers should determine if the break-even value is acceptable or plausible.
31

32 Similar analyses can be performed when analysts lack valuation estimates that produce a
33 break-even value requiring assessment for credibility and plausibility. Continuing with the example
34 above, suppose the analyst estimates that the proposed policy would reduce the number of cases
35 of endpoint X by 5,000 but does not have an estimate of WTP to avoid a case of this outcome. In
36 this case, the policy can be considered to break even if WTP is at least \$200.
37

38 One way to assess the credibility of economic break-even values is to compare them to effects
39 that are more or less severe than the outcome being evaluated. For the break-even value to be
40 plausible, it should fall between the estimates for these more and less severe effects. For the
41 example above, if the estimate of WTP to avoid a case of a more serious effect were only \$100,
42 the above break-even point may not be considered plausible.
43

44 A break-even analysis is most effective when there is only one missing value (i.e., unknown) in
45 the analysis. For example, analysts missing estimates for two different unknowns (but having
46 valuation estimates for both), should consider a "break-even frontier" that allows the values of
47 both unknowns to vary. Using this approach, it is possible to construct such a frontier, but it is
48 difficult to determine which points on the frontier are relevant for regulatory analysis.
49

1 In 1992, the NRC used a regulatory break-even analysis to evaluate the adoption of a proposed rule
2 (Ref. A.7) regarding air gaps to avert radiation exposure resulting from NRC-licensed users of
3 industrial gauges. The NRC found insufficient data to determine the averted radiation exposure. To
4 estimate the reduction in radiation exposure, the NRC performed a break-even analysis. The NRC
5 assumed a source strength of one curie for a device with a large air gap, which produces 1.3 rem
6 per hour at a distance of 20 inches from a cesium-137 source. Assuming half this dose rate would
7 be produced, on average, in the air gap, and that a worker is within the air gap for 4 hours annually,
8 the NRC estimated the worker would receive a radiation dose of 2.6 rem per year. The NRC
9 estimated that adopting the proposed air-gap rule would be cost effective if 347 person-rem per year
10 were saved. At an averted occupational radiation dose of 2.6 person-rem per year for each gauge
11 licensee, incidents involving at least 133 gauges would have to be eliminated. Given the roughly
12 3,000 gauges currently used by these licensees, the proposed rule would only have to reduce the
13 incident rate by roughly 4 percent, a value the NRC believed to be easily achievable. As a result, the
14 NRC staff recommended adoption of the air-gap rule.

15 **A.4.4 Bounding Analysis**

17 A bounding analysis is an analysis designed to identify the range of potential impacts or risks in
18 order to calculate best-case and worst-case results. Such an approach might be used in a
19 cost-benefit analysis as a screening tool to simplify assumptions and modeling, address
20 uncertainty, or to address unavailable or unknown data. These bounding analyses (or enveloping
21 scenarios) should be chosen so that they present the greatest possible extremes and are limiting
22 values for the inputs to the analysis. For the best-case scenario, the analyst would use
23 assumptions and inputs that maximize the benefits and minimize the costs. For the worst-case
24 scenario, the analysts would use assumptions and inputs that minimize the benefits and maximize
25 the costs. The results of such bounding analyses can be used to inform the decisionmakers of the
26 extent or of the severity of the results. If the sign of the net benefit estimate is positive across this
27 range, there is confidence that the proposed regulatory action is beneficial. Analysts should
28 carefully describe judgments or assumptions made in selecting appropriate bounding input values
29 to describe whether absolute limits or reasonable maximum limits were used. In explaining the
30 results, the analyst should communicate to the decisionmakers that using bounding analysis
31 results may be unnecessarily conservative.

32 **A.4.5 Rank Order/Weight-Based Analysis**

34 This analysis allows for selection based on quantifiable and nonquantifiable costs and benefits
35 and allows the Commission to adjust criteria based on perceived importance. A major drawback to
36 this method is that it implies objectivity when there is no reliable basis for the ranking, which may
37 garner criticism as it is difficult to make quantitative statements about the actual difference
38 between alternatives.

39 **A.4.6 Maximin and Maximax Analysis**

41 The maximin and maximax analyses are two criteria of decision theory where multiple alternatives
42 can be compared against one another under conditions of uncertainty. In the maximin analysis,
43 the analyst looks at the worst that could happen in each alternative for a given outcome and then
44 chooses the least worst alternative (i.e., select the alternative where the loss is the better loss of
45 all other alternatives, given the circumstances at hand). This decisionmaking is based on
46 pessimistic loss, where the analyst assumes that the worst that can happen will happen, and
47 chooses the alternative with the best worst-case scenario. In the maximax analysis, the analyst

1 looks at the best that can happen in each alternative for a given outcome and then chooses the
 2 alternative that is the best of the best (i.e., the alternative where the gain is the best of the best of
 3 all other alternatives, given the circumstances at hand). This decisionmaking is based on
 4 optimistic gain, where the analyst assumes that the best that can happen will and then chooses
 5 the alternative with the best case scenario.
 6

7 An example of a maximin and maximax analysis is to apply it to the modification of drug testing for
 8 fitness for duty. In this hypothetical regulatory action, there are three alternatives for drug testing,
 9 with the first alternative representing the status quo. These alternatives have to do with modifying
 10 the procedures and cutoff levels for drug testing to reduce false positives. The exception is the
 11 first alternative (the status quo), which represents the current procedures for conducting drug
 12 testing. The three possible alternative frequencies for drug testing are:
 13

- 14 (1) Test 10 times a year.
- 15 (2) Test 15 times a year.
- 16 (3) Test 20 times a year.

17
 18 For each alternative, the expected number of false positives for each outcome of drug testing is
 19 determined by a panel of medical experts and given in the Table A-3 below.

20 **Table A-3 Expected Number of False Positives for each Outcome of Drug Testing**

Frequency of Drug Tests Per Year ----->	10	15	20
Alternative 1	3	4	5
Alternative 2	1	2	5
Alternative 3	2	3	4

21
 22 In the maximin analysis, the analyst looks at the highest number of false positives (worst gain) for
 23 each alternative over all possible outcomes and chooses the alternative with the lowest number of
 24 false positives (best of the worst) for some outcome. Looking at each alternative results in the
 25 following:
 26

- 27 (1) For alternative 1, the highest number of false positives is 5 for testing 20 times a year.
- 28 (2) For alternative 2, the highest number of false positives is 5 for testing 20 times a year.
- 29 (3) For alternative 3, the highest number of false positives is 4 for testing 20 times a year.

30
 31 According to the maximin analysis, the analyst would choose alternative 3 for testing 20 times a
 32 year, because this alternative has the lowest of the three highest number of false positives (i.e., 4
 33 is smaller than 5).
 34

35 In the maximax analysis, the analyst looks at the lowest number of false positives (best gain) for
 36 each alternative over all possible outcomes and chooses the alternative with the lowest number of
 37 false positives for some outcome. Looking at each alternative results in the following:
 38

- 1 (1) For alternative 1, the lowest number of false positives is 3 for testing 10 times a year.
- 2 (2) For alternative 2, the lowest number of false positives is 1 for testing 10 times a year.
- 3 (3) For alternative 3, the lowest number of false positives is 2 for testing 10 times a year.

4
5 According to the maximax analysis, the analyst would choose alternative 2 for testing 10 times a
6 year, because it has the lowest number of false positives (i.e., 1 is smaller than 2 and 3).

7
8 The choice (maximin or maximax) depends on the personal preference of the decisionmaker. The
9 maximin criterion involves selecting the alternative that maximizes the minimum payoff
10 achievable, and so a decisionmaker who values a guaranteed minimum at the risk of losing the
11 opportunity to make big gains would opt for the maximin result. The maximax criterion involves
12 selecting the alternative that maximizes the maximum payoff available and, hence, this approach
13 would be more suitable for an optimist, or "risk-seeking" investor, who seeks to achieve the best
14 results if the best happens.

15 16 **A.4.7 Conjunctive and Disjunctive Analysis**

17 The conjunctive and disjunctive analysis method requires a satisfactory performance, rather than
18 the best, in each decision criterion. The conjunctive step requires an alternative to meet a minimal
19 performance threshold for all criteria. The disjunctive step requires the alternative to exceed the
20 given threshold for at least one criterion. Any alternative that does not meet the conjunctive or
21 disjunctive rule is deleted from further consideration. These screening rules can be used to select
22 a subset of alternatives for analysis by other, more complex methods.

23 24 **A.4.8 Lexicographic Analysis**

25 This analysis involves lexicographic ordering, which ranks alternatives one at a time, starting with
26 the most important and heavily weighted criterion. If two or more alternatives are preferentially tied
27 for the most important criterion, then they are compared on the second most important criterion.
28 The surviving alternatives are then compared on the third most important criterion, and so on, until
29 the tie is broken, resulting in the chosen alternative. This method is appealing because of its
30 simplicity; however, it will require subjective agreement by participants on the ordering of criteria
31 and the assumption of independent assessments when considering two or more criteria
32 simultaneously.

33
34 One example of lexicographic ordering would be the evaluation of alternatives where attributes of
35 each alternative are considered. For example, such an evaluation could consider six attributes
36 over three alternatives. This can be represented by a 6 x 3 matrix of potential evaluative
37 information, where the information can be contained on six attributes for three alternatives. An
38 example of a set of attributes could consist of the following:

- 39 (1) averted occupational exposure
- 40 (2) reduction in core damage frequency
- 41 (3) training and certifications
- 42 (4) required operator actions outside the control room
- 43 (5) nuclear consequence management
- 44 (6) standard operating procedures

45
46

1 Using this information, questionnaires can be prepared that will collect and present evaluative
 2 information in a format similar to that found in product ratings summaries. The questionnaires can
 3 then be distributed to a populace, where subjects can be asked to evaluate the information provided
 4 by the questionnaire and rank order the attributes in terms of decreasing preference. In addition to
 5 the ranking task, the subjects can be asked to assign importance weights to various characteristics
 6 of each attribute, rate each alternative's characteristics on a desirability scale, and identify a
 7 minimum acceptability limit on each attribute's characteristic contained in the questionnaire.

8
 9 **A.4.9 Decision Matrix**

10 The decision matrix is a popular method for comparing and prioritizing a list of alternatives. It is a
 11 highly flexible tool that effectively evaluates nonmonetized and difficult to quantify costs and benefits.

12
 13 Decision criteria are monetized, which are objective and quantifiable, or nonmonetized, which are
 14 subjective and not directly quantifiable. While both types of criteria are considered when preparing
 15 a cost-benefit analysis, the monetized criteria demand a more rigorous analysis, specifically
 16 because they are objective and quantifiable and less influenced by subjective assessment. If the
 17 monetized criteria and nonmonetized criteria are used in a single decision matrix, then the
 18 analysts would have to apply subjective evaluation to the monetized data, which would weaken or
 19 degrade the value of that data. Therefore, quantified costs and benefits should be kept separate
 20 from nonmonetized costs and benefits and not combined in a single decision matrix. The best
 21 approach is to use a decision matrix to evaluate the subjective criteria, evaluate the quantified
 22 monetized data separately, and then consider both monetized and nonmonetized data to develop
 23 a staff recommendation.

24
 25 When considering a regulatory issue in generalized form with m qualitative criteria and
 26 n alternatives, let C_1, \dots, C_m and A_1, \dots, A_n denote the difficulty in quantifying criteria and alternatives,
 27 respectively. As shown in Figure A-1, each row belongs to a criterion and each column describes
 28 the performance of an alternative. The score a_{ij} describes the performance of alternative A_j
 29 against criterion C_i . For the sake of simplicity, the specified convention is that a higher score value
 30 means a better performance, since any goal of minimization can be easily transformed into a goal
 31 of maximization.

32
 33

			x_1	.	.	x_n
			A_1	.	.	A_n
	w_1	C_1	a_{11}	.	.	a_{m1}

	w_m	C_m	a_{m1}	.	.	a_{mn}

34
 35
 36
 37 **Figure A-1 The Decision Matrix**

38 As shown in Figure A-1, weights w_1, \dots, w_m are assigned to the criteria. Weight w_i reflects the relative
 39 importance of criterion C_i to the decision and, by convention, is assumed to be positive. The weights
 40 of the criteria are usually determined on a subjective basis and represent the opinion of the analysts
 41 or the synthesized opinions of a group of experts using a group decision technique.

42
 43 The values x_1, \dots, x_n associated with the alternatives in the decision table are the final ranking
 44 values of the alternatives. By convention, a higher ranking value means a better performance of
 45 the alternative, so the alternative with the highest ranking value is the best of the alternatives.

46

1 This technique can partially or completely rank the alternatives: a single most preferred alternative
2 can be identified or a short list of a limited number of alternatives can be selected for subsequent
3 detailed appraisal using other methods.

4
5 The multiattribute utility theory (MAUT) and outranking methods are two main techniques for
6 assigning weights in decision matrices.

7 8 *A.4.9.1 Multiattribute Utility Theory Technique*

9 The family of MAUT methods consists of aggregating the different criteria into a function, which is
10 maximized. Thereby, the mathematical conditions of aggregations are examined. This theory
11 allows for the complete compensation between criteria (i.e., the gain on one criterion can
12 compensate for the loss on another) (Ref. A.1).

13
14 In most of the approaches based on the MAUT, the weights associated with the criteria can
15 properly reflect the relative importance of the criteria only if the scores a_{ij} are from a common,
16 dimensionless scale. The basis of MAUT is the use of utility functions. Utility functions can be
17 applied to transform the raw performance values of the alternatives against diverse criteria, both
18 factual (objective, quantitative) and judgmental (subjective, qualitative), to a common,
19 dimensionless scale. In practice, the intervals $[0, 1]$ or $[0, 100]$ are used for this purpose. Utility
20 functions play another very important role: they convert the raw performance values so that a
21 more preferred performance obtains a higher utility value. A good example is a criterion reflecting
22 the goal of cost minimization. The associated utility function should result in higher utility values
23 for lower cost values.

24
25 It is common for some normalization to be performed on a nonnegative row in the matrix of the a_{ij}
26 entries. The entries in a row can be divided by the sum of the entries in the row, by the maximum
27 element in the row, or by a desired value greater than any entry in the row. These normalizations
28 can also be formalized as applying utility functions.

29 30 *A.4.9.2 Simple Multiattribute Rating Technique*

31 The simple multiattribute rating technique (SMART) is the simplest form of the MAUT methods.
32 The ranking value x_j of alternative A_j is obtained simply as the weighted algebraic mean of the
33 utility values associated with it, as shown in the equation below:

34
35
$$x_j = \frac{\sum_{i=1}^m w_i a_{ij}}{\sum_{i=1}^m w_i}, j = 1, \dots, n.$$

36 where:

37 a = alternative

38 m = number of criteria (i.e., 1 to m)

39 n = number of alternatives (i.e., 1 to n)

40 w = weights (i.e., w_1 reflects the relative importance of criteria a_1 to the decision)

41 x_j = ranking value of alternative A_j .

42
43 In addition to the above additive model, another method is to assess weights for each of the
44 criteria to reflect the relative importance to the decision. First, the criteria are ranked in order of
45 importance and 10 points are assigned to the least important criterion. Then, the
46 next-least-important criterion is chosen, more points are assigned to it, and so on, to reflect their
47 relative importance. The final weights are obtained by normalizing the sum of the points to one.

1 However, comparing the importance of the decision criteria is meaningless, if it does not also
2 reflect the range of the utility values of the alternatives.

3

4 A.4.9.3 Generalized Means Technique

5 In a decision problem, the vector $x = (x_1, \dots, x_n)$ plays a role of aggregation, taking into account the
6 performance scores for every criterion with the given weight. This means that the vector x should
7 fit into the rows of the decision matrix as well as possible. Mészáros and Rapcsák (1996) showed
8 that the optimal solution is a positive multiple of the vector of the weighted geometric means of the
9 columns; consequently, with:

10

$$w = \sum_{i=1}^m w_i$$

11

12

13 with the values

14

$$x_j = \prod_{i=1}^m a_{ij}^{w_i/w}, i = 1, \dots, n$$

15

16 where:

17 a_{ij} = the alternative listed in the i th row and j th column

18 w = total of all weighting factors, w_i

19 x_i = ranking value of alternative a_i .

20

21 A.4.9.4 Analytic Hierarchy Process

22 The basic idea of the analytic hierarchy process (AHP) is to convert subjective assessments of
23 relative importance to a set of overall scores or weights. The AHP is one of the more widely
24 applied multiattribute decisionmaking methods.

25

26 The AHP methodology is based on pairwise comparisons of the following type: "How important is
27 criterion C_i relative to criterion C_j ?" Questions of this type are used to establish the weights for
28 criteria, and similar questions are to be answered to assess the performance scores for
29 alternatives on the subjective (judgmental) criteria.

30

31 To derive the weights of each criteria, the analyst should respond to a pairwise comparison question
32 asking the relative importance of the two criteria. The analyst's responses use the following
33 nine-point scale to express the intensity of the preference for one criterion versus another:

34

35 1 = equal importance or preference

36 3 = moderate importance or preference of one over another

37 5 = strong or essential importance or preference

38 7 = very strong or demonstrated importance or preference

39 9 = extreme importance or preference

40

41 If the analyst judges that criterion C_j is more important than criterion C_i , then the reciprocal of the
42 relevant index value is assigned.

43

1 Let c_{ij} denote the value obtained by comparing criterion C_i to criterion C_j . Because the analyst is
2 assumed to be consistent in making judgments about any one pair of criteria and since all criteria
3 will always rank equally when compared to themselves, then:
4

$$5 \quad c_{ji} = \frac{1}{c_{ij}} \text{ and } c_{ii} = 1$$

6
7 This means that it is only necessary to make $\frac{1}{2} m (m-1)$ comparisons to establish the full set of
8 pairwise judgments for m criteria. The entries c_{ij} , $i, j = 1, \dots, m$ can be arranged in a pairwise
9 comparison matrix C of size $m \times m$. Therefore, the analyst should perform 15 pairwise judgments
10 to establish the full set of pairwise judgments for 6 criteria.
11

12 The next step is to estimate the set of weights that are most consistent with the relativities
13 expressed in the comparison matrix. Note that, while there is complete consistency in the
14 (reciprocal) judgments made about any one pair, consistency of judgments between pairs (i.e., $c_{ij}c_{jk}$
15 $= c_{ik}$) for all i, j, k , is not guaranteed. Thus the task is to search for an m -vector of the weights such
16 that the $m \times m$ matrix W of entries w_i/w_j will provide the best fit to the judgments recorded in the
17 pairwise comparison matrix C . The weighting method is one of the simplest multiobjective
18 optimizations that has been widely applied to find the noninferior optimum solution.
19

20 This method may not be capable of generating the efficient solutions of the efficient frontier. Also,
21 the optimal solution of a weighting problem should not be used as the best compromise solution, if
22 the weights do not reflect the Commission's preferences or if the Commission does not accept the
23 assumption of a linear utility function.
24

25 As in calculating the weights for the criteria, AHP uses the same technique based on pairwise
26 comparisons to determine the relative performance scores of the decision table for each of the
27 alternatives on each subjective (judgmental) criterion. Now, the pairwise questions to be
28 answered ask about the relative importance of the performances of pairs of alternatives relating to
29 the considered criterion. Responses use the same set of nine index assessments as before, and
30 the same techniques can be used as when computing the weights of criteria.
31

32 With the weights and performance scores determined by the pairwise comparison technique
33 above, and after further possible normalization, alternatives are evaluated using any of the
34 decision table aggregation techniques of the MAUT methods. The so-called additive AHP uses
35 the same weighted algebraic means as SMART, and the multiplicative AHP is essentially based
36 on the computation of the weighted geometric means.
37

38 **A.4.10 Outranking Methods Technique**

39 The outranking method is based on evaluating each pair of alternatives by considering two
40 conditions as follows. Alternative A_i outranks A_j if, generally, the criterion A_i performs at least as
41 well as A_j (concordance condition), while worse performance is still acceptable on the other
42 criteria (nondiscordance condition). After having determined, for each pair of alternatives, whether
43 one alternative outranks another, these pairwise outranking assessments are combined into a
44 partial or complete ranking. Contrary to the MAUT methods, where the alternative with the best
45 value of the aggregated function can be obtained and considered as the best one, a partial
46 ranking of an outranking method may not render the best alternative directly. A subset of
47 alternatives can be determined such that any alternative not in the subset is outranked by at least
48 one member of the subset. The aim is to make this subset as small as possible. This subset of

1 alternatives can be used to screen a long list of alternatives into a short list, within which a good
2 compromise alternative could be found by using other methods.

3
4 The principal outranking methods assume data availability broadly similar to those required for the
5 MAUT methods. This method requires that alternatives and criteria be specified and uses the
6 same data of the decision table; namely, the values represented by a_{ij} and w_i .

7 **The ELECTRE I Method**

8
9
10 The ELECTRE I methodology is based on the concordance and discordance indices defined as
11 follows. The analyst starts with the decision matrix data and normalizes the weighting so that the
12 sum of the weights of all criteria equals 1. For an ordered pair of alternatives (A_j, A_k), the
13 concordance index c_{jk} is the sum of all the weights for those criteria where the performance score
14 of A_j is least as high as that of A_k . This is shown mathematically as:

$$15 \quad c_{jk} = \sum_{i: a_{ij} \geq a_{ik}} w_i, j, k = 1, \dots, n \text{ where } j \neq k$$

16
17
18 where the concordance index lies between 0 and 1.

19
20 The computation of the discordance index d_{jk} is a bit more complicated. The discordance index is
21 zero if A_j performs better than A_k on all criteria. Otherwise, for each criterion where A_k outperforms
22 A_j , the ratio is calculated between the difference in performance level between A_k and A_j , and the
23 maximum difference in score on the criterion concerned between any pair of alternatives. This is
24 shown mathematically as:

$$25 \quad d_{jk} = 0 \text{ if } a_{ij} > a_{ik}, i = 1, \dots, m$$

26
27 or

$$28 \quad d_{jk} = \max_{i=1, \dots, m} \frac{a_{ik} - a_{ij}}{\max_{j=1, \dots, n} a_{ij} - \min_{j=1, \dots, n} a_{ij}}, j, k = 1, \dots, n, j \neq k$$

29
30 The maximum of these ratios is the discordance index, which has a value between 0 and 1.

31
32 A concordance threshold c^* and discordance threshold d^* are defined such that $0 < d^* < c^* < 1$. Then,
33 A_j outranks A_k if the $c_{ij} > c^*$ and $d_{ik} < d^*$ (i.e., the concordance index is above its threshold and the
34 discordance index is below its threshold, respectively).

35
36 This outranking defines a partial ranking on the set of alternatives by identifying the set of
37 alternatives that outrank at least one other alternative and are themselves not outranked. By using
38 this method, the analyst identifies the most promising alternatives. By interactively changing the
39 level thresholds, the analyst can also change the size of this set.

40
41 As shown, the ELECTRE I method may be used to construct a partial ranking and choose a set of
42 promising alternatives. See Figueira et al (2004) for more details regarding the ELECTRE methods.

43

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