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A Practical Approach to Address Uncertainty in Stakeholder Deliberations

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This article addresses the difficulties of incorporating uncertainty about consequence estimates as part of stakeholder deliberations involving multiple alternatives. Although every prediction of future consequences necessarily involves uncertainty, a large gap exists between common practices for addressing uncertainty in stakeholder deliberations and the procedures of prescriptive decision-aiding models advanced by risk and decision analysts. We review the treatment of uncertainty at four main phases of the deliberative process: with experts asked to describe possible consequences of competing alternatives, with stakeholders who function both as individuals and as members of coalitions, with the stakeholder committee composed of all stakeholders, and with decisionmakers. We develop and recommend a model that uses certainty equivalents as a theoretically robust and practical approach for helping diverse stakeholders to incorporate uncertainties when evaluating multiple-objective alternatives as part of public policy decisions.

KEY WORDS: Alternatives; deliberations; public policy; stakeholders; uncertainty

1. INTRODUCTION

Many decisions made by public agencies or large private firms can have significant impacts on various stakeholders. Examples include the construction and operation of dams, pipelines, or energy facilities; the development of infrastructure such as roads and electrical transmission lines; the building and managing of large retail stores or distribution services or prisons; and environmental projects that affect land or water use and have impacts on humans, flora, and fauna. The decisionmakers on such projects will typically be a senior manager in a public agency, an elected official, a regulatory board, or an executive in a large corporation.

Making a thoughtful and justifiable decision in such situations requires, among other things, understanding what the various stakeholders care about and the consequences of the alternatives. To achieve this understanding, the decisionmaker often employs an independent analyst, or a team, to work with a committee of stakeholders over a specified period of time. Each stakeholder group is a collection of individuals with similar interests who will be impacted by at least some of the alternatives of the proposed decision. The primary stakeholder groups would typically have one or more representative members assigned to the multistakeholder committee, which typically includes community residents, industry, and representatives of other potentially affected interests along with government and/or regulatory staff. In this article, we refer to these participants as stakeholders.

Stakeholder committees are therefore composed of people with diverse interests and skills. Committee mandates vary considerably, from fully making decisions to providing recommendations to simply

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Table I. Illustrative Consequence Table

Objectives	Measure and Direction	Alternative A	Alternative B	Alternative C
Economic costs				
Social				
Environmental				
Health				

communicating concerns to the decisionmaker. Common elements nearly always include the communication of stakeholder values (i.e., objectives of the various stakeholders regarding the proposed decision) and the appraisal of potential alternatives based on the perceived appropriateness of the decision process and information provided about the possible consequences of the alternatives under consideration. A carefully thought through decision also requires attention to communicating estimates of uncertainty across objectives and alternatives in a way that encourages informed discussions among stakeholders and, ultimately, a defensible choice by decisionmakers.

Methods vary widely for obtaining and presenting information about the anticipated consequences of alternatives as part of such decisions.[1,2] Many analysts employ a consequence table, showing the anticipated consequences in terms of the stakeholder values relevant to the decision in rows and the alternatives for achieving these objectives in columns.[3] For example, the table might summarize what matters for a decision context in terms of the economic, social, environmental, and health outcomes of three alternatives under consideration, as shown in Table I. A comparison across any row facilitates assessment of the estimated consequences for that objective for the alternatives; a comparison down any column summarizes the relative strengths and weaknesses of that alternative in terms of the consequences on different objectives. These consequences are usually indicated by quantitative measures—typically numbers such as dollars for costs or greenhouse gas (GHG) emissions for the environment—although verbal and qualitative information also can be used.

When a consequence table becomes sufficiently complex, participants cannot easily compare the consequences either across objectives or across alternatives, and as a result they can become overwhelmed. This typically occurs whenever the number of objectives or alternatives is large. Fortunately, various techniques exist to examine the set of alternatives for dominance (enabling the elimination of some alternatives) and objectives for irrelevance (reducing the number of objectives by eliminating those that fail to distinguish among alternatives), thereby simplifying the choices facing stakeholders.[4,5]

Our focus in this article concerns the complexity introduced when uncertainty about consequences is a part of stakeholder deliberations. This problem is important because it is inevitable that alternatives chosen today will have uncertain future effects on economic, environmental, social, and health considerations that matter to people. This has the practical implication that the entry in most cells of a consequence table should be not a single estimate, but rather a range or distribution of the possible outcomes.

There are logically sound ways to analyze stakeholder evaluations of alternatives involving multiple objectives and uncertainties represented by probability distributions. Harsanyi[6] proved that, subject to accepting the assumptions of expected utility theory[7] and Pareto optimality, the utility function for the stakeholder group should be a weighted-linear sum of the individual stakeholder's utility functions. Harsanyi's result assumed that the stakeholders had the same objectives and that a common probability distribution represented the uncertainties. More recently, Keeney[8] developed a more general prescriptive model that yields the same weighted-linear sum to represent the stakeholder committee's values. This formulation allows the different stakeholders to have different objectives and different probabilities representing the possible consequences of alternatives.

Modelers and technically trained experts have made great strides over recent decades in terms of techniques to deal with uncertainty explicitly in various decision contexts, ranging from climate change[9] to conservation biology[10] and medical decision making.[11] Methods also have been developed for visualizing and communicating uncertainty in single variables.[12] In contrast, methods that could be used to, say, help either public or technical stakeholders deal effectively with uncertainty as part of their deliberations of proposed alternatives have not been widely discussed in the literature and are generally not well known to analysts.[13] As a practical result, many stakeholder committees either ignore uncertainty in consequence estimates or introduce it on an ad-hoc basis. Both cases result in an inaccurate and incomplete representation of possible consequences, which can lead to the choice of an inferior alternative.

There are many reasons why uncertainty might be ignored when a diverse group of stakeholders is asked to help evaluate policy alternatives. The stakeholders may believe the problem is trivial and can be solved quite simply, so that introducing uncertainty is an unnecessary complication. Analysts and technical experts may feel that laypeople lack the knowledge necessary to understand the representation of the uncertainties, particularly if consequence estimates are expressed using probability distributions. Decisionmakers may believe that other elements of the policy choice are more important or they may already have decided on a course of action and are not interested in identifying stakeholders' responses to uncertainties in the possible consequences of alternatives.

This article sets aside these reasons and, because a stakeholder committee has been convened, we accept that decisionmakers consider the problem to be both important and not easily resolved. We also assume that decisionmakers retain an open mind about what should be done and that stakeholders agree to structure the problem explicitly using a consequence table.

The specific problem addressed in this article can now be stated clearly. The general procedures used by analysts working with stakeholder committees with regard to including uncertainties in consequences tend to fall into two extreme categories. One extreme is based on highly technical, logically sound procedures using techniques drawn from risk analysis and decision analysis. However, for many decisions these approaches are too complex, too expensive, and not understandable by most stakeholders. The other extreme involves inadequately simplistic descriptions of the consequences that often use point estimates (e.g., best estimates and averages) or ambiguous verbal descriptions of consequences (e.g., high, medium, or low). This totally neglects one of the main reasons that stakeholders care about, and seek to learn more about, the decisions, namely, the uncertainties (i.e., risks) about the consequences of alternatives. As a result, the stakeholders end up frustrated and feeling deceived and the decisionmaker receives much less useful information for the decision than desired. The purpose of this article is to develop and discuss a procedure between these two inadequate extremes. Our intent is to design a practical procedure to manage stakeholder committees that meaningfully addresses the concerns (i.e., values and uncertainties) of stakeholders, is understandable to stakeholders and the decisionmaker, provides useful information for the decisionmaker, can be managed effectively by most analysts, and can be completed in a reasonable time for a reasonable cost.

A particularly vexing concern in working with uncertainty in the context of stakeholder deliberations is risk tolerance. Different participants will usually accept different amounts of risk and this typically varies across objectives and risk situations. As a result, even if an uncertainty presentation is understood and agreed upon by different participants, the usefulness associated with it and the implications for choices among alternatives may differ across individuals. Although dealing with risk tolerances adds an additional element of complexity, it also is part of a logically sound approach to address the reality of uncertainty in important decisions.

The next sections describe the context for incorporating uncertainty as part of stakeholder deliberations and review past work on the topic. We then discuss what our analyst needs to know about perspectives on uncertainty for each of four different participants typically involved in the decision-making process. These participants are technical experts, individual stakeholders, the stakeholder committee, and decisionmakers. Although each situation has its peculiarities and nuances, we believe the ideas in this article apply to a wide range of circumstances. To present these ideas clearly, we focus on discrete problems for which there is a single decisionmaker or decision-making body (e.g., an elected official, an executive, expert panel, or regulatory board). The principles and suggestions we make are consistent with common sense, logic, and the respectful treatment of stakeholders.

Our primary audience is the analyst tasked by the decisionmaker to both facilitate the stakeholder committee and take a lead role in presenting and communicating the results of technical analyses to stakeholders. This analyst sets guidelines for the deliberative process and determines the agenda for meetings with stakeholders. He or she will face a multitude of choices regarding what to do, how to do it, how much time to spend on each stage of the decision-making process, and so forth. Completion of these tasks requires familiarity with the concerns and capabilities of stakeholders and decisionmakers, access to appropriate methods for depicting uncertainty, and proficiency in techniques for evaluating the relevant alternatives.

2. FORMALIZATION OF THE PROBLEM

Our common sense process for helping stakeholders to address uncertainty in consequence estimates relies on the five-step decision-making model known as PrOACT: define the problem, clarify objectives, identify alternatives, estimate the consequences of each alternative with their associated uncertainties, and identify tradeoffs.[4] Our focus is on the fourth step, involving presentation of consequences and uncertainties.

We distinguish between the *process* recommended for encouraging appropriate incorporation of uncertainty as part of stakeholder deliberations and *technical* considerations emphasizing the development and use of certainty equivalents (CEs). The CE for a probabilistic description of an uncertain consequence is a sure amount such that the decisionmaker is indifferent between that probabilistic description of the possible consequences and the sure occurrence of the CE.[14]

2.1. Process Overview: Incorporating Uncertainty

The analyst's first step is to develop an accurate description of the decision context and then identify the values of the various stakeholders for the problem.[15] Values express what matters to stakeholders and a top priority for the analyst is to identify and understand the stakeholders' values and effectively convey them to decisionmakers. Following clarifying discussions, stakeholders' values can be stated succinctly as objectives in the form of a verb and noun (e.g., minimize environmental impact, provide local employment). The set of objectives that should be in the consequences table are those that are fundamentally relevant to at least one stakeholder. Any objectives that another stakeholder does not think are relevant can be neglected by that stakeholder. As the complete set of objectives represents fundamental values rather than means, there is no double counting of consequences.[16] This is a standard requirement for sound analysis and the adoption of additive utility functions.[3]

An initial set of potentially reasonable alternatives provided by the decisionmaker can be enhanced by stakeholders, using their own objectives to generate new alternatives and refine existing ones. Then a simple appraisal can eliminate irrelevant alternatives, those that are essentially identical to others, do not contribute to the objectives of this decision, or are dominated by other alternatives. The intent is to identify a quality and concise set of alternatives for consideration.

The uncertainties about the consequences of alternatives are relevant to choices made by all of the participants involved in the stakeholder deliberations. The technical experts are responsible for initial estimates of consequences; the stakeholders, who will have varying degrees of technical knowledge or training, need to understand and, in some cases, to revise or augment them; and the decisionmaker uses the consequence estimates for evaluating alternatives.[4] These distinctions among participants matter because it is not sufficient for uncertainty to be handled well at one phase (e.g., eliciting probabilities from experts) and then ignored at another (e.g., when stakeholders as a group evaluate the identified alternatives). For uncertainty to be incorporated appropriately into decisions, it is essential that analysts account for the abilities and interests of each of the participants in the decision-making process.

As currently addressed in stakeholder committees, uncertainty typically describes single events such as estimates of sea-wall strength in reference to rising ocean levels at a coastal location or predictions of energy prices over the next half-century.[12] Our focus is instead on stakeholder deliberations that require participants to review multiple events across a broad set of alternatives. As a result, techniques need to facilitate understanding and discussion of the implications of uncertainty for multiple objectives across multiple alternatives and for multiple stakeholders, using consequence tables to display consequences and facilitate informed deliberations.[1] Yet little guidance is available to analysts regarding how uncertainty should be depicted across the multiple consequences of proposed actions. There is even less guidance about how to manage stakeholder committees when the comprehension, deliberative capability, and training of stakeholders differ greatly. This can result in different interpretations

[3] If only fundamental objectives are used to evaluate alternatives, an additive utility function is an appropriate value model for evaluating those alternatives.[17] If an additive utility function is appropriate, then only the marginal probability distributions over the consequences of any alternative matter,[18] hence the use of a consequences table with cells showing marginal probabilities is appropriate.

[4] Numbers vary, but generally consequence estimates will come from three to five experts and a group may involve 15–25 stakeholders who form four to five coalitions.[1]

of the stated uncertainties, for example, due to variations in stakeholders' beliefs, worldviews, or numeracy capabilities.[13,19] Different understandings of uncertainty also can influence individuals to make additional assumptions about the shape (e.g., bell curve vs. flat) of the underlying distributions for the specified outcomes.[20]

The implication is that there remains a large gap between current practices to depict uncertainty as part of stakeholder deliberations and the prescriptive decision-aiding advice advanced by risk and decision analysts.[21] The logical standard is well defined. First, elicit probability distributions for each consequence that summarize the factual information available at the time decisions must be made. Next, for each stakeholder, develop utility functions for each of their objectives. Then, using the probability distributions and their utility functions, calculate their CEs, which identify the certain consequences that are equally preferred to the probability distributions of the respective consequences.[14]

The practical task is to develop an understandable and efficient version of this approach. It should include the experts' judgments of the uncertainty of the consequences and assist analysts in incorporating this uncertainty into stakeholder deliberations of the proposed alternatives. To do this, analysts may need to overcome reluctance on the part of technical experts or decisionmakers to deal with uncertainty because its introduction into consequence estimates can be viewed as an annoying or needless complication. Analysts also will need to be mindful of not pushing stakeholders beyond their limits. Dealing with uncertainty requires physical energy (including paying attention to fatigue and scheduling sessions at appropriate times), cognitive ability (which requires using accessible language and examples), and emotional sensitivity (with analysts being careful to avoid emotional responses that may not be resolved, thus impeding stakeholder deliberations and constructive progress).

Both stakeholders and decisionmakers also typically find it difficult to deal effectively with the dynamic nature of the problems they address. As a result, many policy choices reflect an overemphasis on short-term outcomes and fail to incorporate strategies that are sufficiently flexible to adapt to changing conditions and adjust estimates of consequence uncertainty in light of new information. Avoiding this dynamic aspect of uncertainty as part of deliberative processes can result in critical information being ignored and lead to the inappropriate evaluation of alternatives, both by stakeholders and the ultimate decisionmaker. In some cases, the lack of attention to adjustments in uncertainty relating to consequence estimates contributes to stakeholders ignoring an entire class of alternatives, such as adaptive management strategies designed specifically to encourage learning over time.[1,22]

2.2. Technical Overview: Incorporating Uncertainty

Despite numerous descriptions of ways to incorporate uncertainty into decisions,[21] many experts remain reluctant to include uncertainty as part of consequence estimates[23] and most deliberative stakeholder processes give only cursory attention to its depiction and presentation over the multiple alternatives under consideration. Thought and communication about uncertainty often is done using relatively imprecise verbal phrases (e.g., an event is described as "reasonably likely" or "rare"), simple ranges showing the low and high end points of the anticipated consequences (possibly with an associated confidence interval), or three-point ranges that also include a "best" or "most likely" estimate.[24] In some cases, more detailed measures of uncertainty are included, such as five-point estimates or "box and whisker" plots, that show means or medians of the distribution along with end points and the 25–75th percentile prediction interval. In rare cases, a full probability density function or a cumulative distribution function is used.

It is typically left to the analyst to decide how fully, and at what level of precision, uncertainty about the consequences of alternatives should be incorporated into deliberations.[5] Consider the example of a senior resource manager or government minister wanting to elicit stakeholder input on his agency's review of different energy generation alternatives. The consequence information shown in Table II provides a simplified depiction of how this problem might be structured after the analyst has completed initial meetings with a stakeholder committee.[6] The table

[5]We assume that for the problem under consideration, the uncertainty associated with key variables can be characterized and is amenable to measurement, in contrast to the assessment conditions associated with what often is termed "severe" uncertainty.[25]

[6]Particularly at early stages of a stakeholder deliberation process, consequence tables often include six to eight objectives and as many as 10–15 alternatives. An important task of the analyst is then to work with stakeholders to identify dominated alternatives (reducing the number of columns) or irrelevant

Table II. Example Consequence Table Showing Best Estimates

Fundamental Objectives	Indicator	Direction of Preference	Alternative A	Alternative B
Maximize electricity production	kw hours	Higher	1,350	1,600
Minimize GHG emissions	tons CO2	Lower	350	420
Minimize costs (present value)	$ millions	Lower	6,900	7,200
Minimize public health risks	Constructed scale	Lower	2	4

includes four fundamental objectives, each with a defined measure and direction of preference, and two leading policy alternatives. The cells under alternatives A and B include consequence estimates elicited from designated experts, showing how well each alternative is estimated to achieve the respective objectives. Entries are shown in the usual manner, which may be in the form of best estimates, expected consequences, or most likely consequences.

This table provides a good start for thinking about how well different alternatives might satisfy the identified objectives and what consequences seem to matter most for the decision. However, it provides no information about uncertainty associated with the consequences. A first cut to include uncertainty could move from point estimates of consequences to either a two-point range (e.g., showing the ends of the distribution, based on an 80% or 90% confidence interval) or a three-point range (end points plus best estimate) as shown in Table III. The new information in this consequence table is more informative. For example, the best estimate and low-end level of electricity expected to be produced are nearly the same for alternatives A and B, as are the low-end associated costs. However, the high-end electricity production estimate for B is significantly greater than for A because a less environmentally friendly fuel is used, which also results in the larger estimated GHG emissions and increased risks to public health.

Unfortunately, this added information may render it more difficult to use the consequence table to provide insight and clarify discussions. One problem is the aesthetics of the revised consequence presentation, now that each row has become more cluttered and the information less visually accessible. It is more difficult to look across each row and determine which alternative performs best in terms of an objective, and it is more difficult to look down each alternatives column to view the overall implications of the consequences.[7] With additional information now included, stakeholders may also focus on different elements in the table. Some may still look only to the best estimate, ignoring information on the estimated range and confidence interval. Some may focus on the lower end of the range for benefits, thinking they are being conservative, whereas others may optimistically focus on the higher end. Research suggests that these tendencies vary systematically, based on the numeracy training of individuals and their motivations, and may in part reflect differences in stakeholders' worldviews.[(26)] These concerns about participants' focus and understanding in the face of uncertainty would also apply to using probability distributions over consequences.

We believe a preferred option in many situations would be to have two consequences tables, displaying complementary information and with distinct names. The first table, possibly called the consequences table of uncertainties, would summarize the uncertainties provided by the experts as thoroughly as appropriate. Examples include Table III or a table with cells displaying probability distributions of consequences. The second table, possibly called the consequences table of CEs, would display CEs calculated from the uncertainties in the first table and the single-objective utility functions of the stakeholders. Such a table would display the pros and cons of each alternative for a particular stakeholder in a succinct and understandable manner. As stakeholders may have different utility functions, they may have different CEs. In such a case, it would obviously result in distinct

objectives (reducing the number of rows), thereby helping to focus the decision-making process on the more important elements of the choice.

[7] Another option is to create "look-up" boxes for each cell of the table that permit additional information to be assessed about the associated uncertainties (e.g., using probability distributions, narratives, or videos). This approach can be helpful in some circumstances, particularly when dealing with technical audiences, but it generally adds additional information and cognitive complexity and fails to facilitate deliberations that incorporate uncertainty among participants.

Table III. Example Consequence Table Showing Uncertainty (Ranges and Best Estimates)

Fundamental Objectives	Indicator	Direction of Preference	Alternative A	Alternative B
Maximize electricity production	kw hours	Higher	1,350 (1,050–1,700)	1,600 (1,100–2,900)
Minimize GHG emissions	tons CO2	Lower	350 (275–435)	420 (300–640)
Minimize costs (present value in dollars)	$ millions	Lower	6,900 (4,750–9,300)	7,200 (4,800–9,500)
Minimize health risks	Constructed scale	Lower	2 (1–3)	4 (2–5)

consequence tables of CEs. However, the ranges of these CEs across stakeholders would likely be much narrower than the original ranges of the experts for possible consequences. CEs have the conceptual advantage of encouraging participants to recognize the full range of impacts, yet the practical advantage of requiring only a single estimate that accounts for the uncertainty of each consequence in each cell of the consequence table.

3. PREVIOUS RESEARCH AND APPLICATIONS

Many topics important to incorporating uncertainty as part of stakeholder deliberations have received a great deal of attention. Problems and opportunities associated with constructing, identifying, and structuring values for choices under uncertainty have been a focus of work in the decision sciences[4,8] and psychology.[27] Making decisions under uncertainty and accurately eliciting probabilities from experts is a central concern of researchers and practitioners in the disciplines of decision analysis[3,5] and behavioral decision theory.[28,29] The communication and understanding of uncertainty by technical and lay groups has been a focus of both basic and applied research,[21,30] with recent applications to diverse fields including environmental management,[1] climate change,[23] physician's clinical choices,[31] and conservation biology.[10,32] Several recent overview papers provide excellent summaries of the role of uncertainty in decision making.[33–35]

Previous work in two areas is particularly relevant to the deliberative focus of this article. The first is prior research relating to the evaluation of utilities over uncertain consequences by individuals, which builds on theories proposed by Ramsey[36] and Von Neumann and Morgenstern.[7] This context, whereby decisionmakers need to make defensible judgments when there exist uncertainties about the consequences of actions, is a focus of the prescriptive guidance provided by multiattribute utility theory[14] and the applied techniques of decision analysis. Values are modeled as multiattribute utility functions (incorporating risk attitudes) or as multiattribute value functions, and are linked to probabilistic beliefs through calculations of the expected utility model.[33]

The second topic concerns problems that can arise when the preferences expressed by individuals fail to accurately reflect their values. This may be because they inadvertently exhibit judgmental biases, such as overconfidence or anchoring,[37] which can lead to errors. In such cases, training to debias stakeholders is often recommended and has been shown to be quite effective. Or it may be that individuals choose to strategically misrepresent information.[38] In this case, the analyst—perhaps along with members of the stakeholder committee—needs to try to realign motivations and obtain a more accurate understanding of the participants' objectives and value tradeoffs before proceeding. A variety of techniques exist for helping analysts present different perspectives to stakeholders and reduce strategizing when they feel that an individual's expressed preferences are not, in fact, his or her "true" preferences.[1,16]

4. WORKING WITH EXPERTS

Best practices in developing estimates of uncertainty begin with the selection of experts, chosen because of their knowledge and experience with respect to understanding consequences associated with the alternatives under consideration. In the ideal case, three to six selected individuals will span a range of views on the topic and agree to engage in a multistage process. To focus the experts on the specific probabilistic assessments, training to reduce the influence of overconfidence and other relevant judgmental biases often is useful.

The detailed elicitations of uncertainty about consequences should take place individually with experts. Analysts typically work one-on-one with each expert to represent their uncertainty judgments in terms of two- or three-point ranges, box and whisker graphs, or a full probability (cumulative or density) function. A variety of tools exist to help conduct such elicitations, including licensed applications and interactive programs available on the Internet that allow experts to state initial probability estimates and make adjustments using sliders or pie charts, with the implications of assessments aggregated and shown in real time. Later, the experts should present and discuss their results with each other to identify areas of agreement and disagreement and to make any desired modifications.[39,40] The goal is to clarify assumptions and to learn, while simultaneously seeking to increase accuracy and reduce the influence of biases on the judgments.[8]

Because of the multistakeholder context for decision making, different experts may have highly varied qualifications and may be more or less trusted by different participants.[9] Some may have extensive practical experience and others may have academic or theoretical understanding. These differences in experience and training can extend to differences in numeracy, language, and communication skills.

The analyst needs to help ensure that the selected experts are willing to provide predictions of uncertain consequences and engage in open discussions with their peers. Not all experts are good choices for these tasks, nor are all experts comfortable with being asked to explain and justify their probabilistic predictions. For critical concerns, however, it is important that an attempt be made to develop consequence estimates from several experts and to understand their thinking and logic. Single-point estimates should only be accepted if the experts are confident that very little uncertainty is associated with the consequences.

5. WORKING WITH STAKEHOLDER PARTICIPANTS

The starting point for clarifying the role and implications of uncertainty is to learn from each stakeholder whether the experts' expressions of uncertainty (e.g., consequence ranges or probability distributions over consequences) are clearly understood. If necessary, the analyst should review the logic behind the assessments and explain to stakeholders what the experts have done. Next, it is important to ascertain whether these expressions of uncertainty accurately represent stakeholders' beliefs. Revisions to experts' consequence estimates, for example, by bringing in additional experts who are more trusted by stakeholders or better represent their understanding of the problem, may be called for when relevant knowledge was not available to (or was ignored by) the initial group of experts. The extent to which this is done reflects the analyst's judgment regarding the rationale for and quality of the new information, the importance of the objective to the decision, and stakeholders' interest in making refinements.

5.1. Placing Uncertainty in Context

Setting an initial context for discussing uncertainty is generally done with the stakeholder committee. This discussion should cover the main sources of uncertainty, including limits to experts' knowledge and measurement techniques as well as anticipated variations in natural processes.[32] If stakeholders are not comfortable with the problem framework into which uncertainty is being introduced, then the analyst needs to clarify the situation by providing clear and sufficient explanations. Analysts also need to be aware that the discussion of uncertainty will require additional time and effort on the part of stakeholders. For this reason, thought needs to be given to both the timing of the discussions and their scope.

The bottom line is that if stakeholders are willing to make the attempt to think about and discuss the material being presented, it is the responsibility of the analyst to provide clear explanations of probabilities and the consequence estimation procedures. If the stakeholders are trying and still do not understand, then it is usually the analyst who is not doing a good job.

An important concern in some circumstances where understanding uncertainty is essential is the existence of probability or risk thresholds. These can be grounded in any of the objectives commonly included in a consequence table. For example, ecological objectives may have a threshold below which the continued existence of a species is threatened, economic objectives may identify a price above which an alternative will not be funded, or legal objectives

[8]As noted by Soll and Klayman:[41] "There is little doubt that overconfidence predominates in interval judgments [of uncertainty]. For example, judges' 90% intervals typically contain the correct answer less than 50% of the time" (p. 299).

[9]Issues relating to expertise are highlighted as part of the adversarial environment created by modern legal systems and their reliance on expert witnesses, which can lead to sharply divergent definitions of expertise; see Burgman *et al.*[42]

may include a standard (e.g., parts per million of a pollutant) that cannot be violated.

5.2. Introducing Certainty Equivalents

Assuming that a consequence table is used to display uncertainty, stakeholders typically will be faced with the task of making sense of the uncertainty about the consequences shown for multiple objectives and multiple alternatives. There are several ways in which CEs for each of the estimated probability ranges can be specified to simplify the display of uncertainty about consequences and permit stakeholders to account for the uncertainty based on their own perspectives.[10] As discussed in Keeney and Raiffa,[(14)] it is straightforward to calculate a CE for each stakeholder given a probability density function and the stakeholder's associated utility function, which the analyst could elicit over the range of consequences for each objective. This has the advantage that if uncertainties subsequently are changed, then it is possible to recalculate the CEs without having to go back to the stakeholders.[11] However, analysts working with a stakeholder committee will rarely have access to single-objective utility functions for each of the stakeholders.

Keeping in mind our practical focus in this article and the intent to demystify expressions of uncertainty, a more common approach is therefore for the analyst to help the stakeholders construct their own CEs. To do this, each stakeholder is asked to review the uncertainty range provided by the experts, and then to adjust the best estimate of consequences either upward or downward based on the individual's risk tolerance and the uncertainty information provided about the best estimate.

In the usual case, an analyst will elicit CEs through direct questioning of stakeholders and bounding of the expressed consequence range. Consider a case study where an analyst is charged with helping policymakers estimate the impacts of changes in water flows to a managed river; objectives include the amount of electricity produced from a hydroelectric dam, the annual number of salmon returning to the river, and construction costs associated with changes to the existing facility.[12] Focusing on uncertainty in the estimate of returning fish (e.g., 400–2,500 salmon), the analyst would ask a series of questions intended to compare a distribution to a point estimate: If you could either have somewhere between 400 and 2,500 returning salmon or a sure thing of 2,200 returning salmon, which would you choose?[13] Depending on the response (assume 2,200 fish in this case), a lower estimate of returns could be introduced. Now suppose you could have 600 fish returning for sure, would you take this over the 400–2,500 distribution? Assuming the individual now says "No," this number could be raised to, say, 1,200. Assuming the person says "Yes" to this, we now know that 600 is worse than the distribution and 1,200 is better. Hence, the CE is somewhere within this range. The process continues within this range until it converges to the CE.

Sometimes, the individual is unsure and cannot settle on a single value for his or her CE, preferring instead to assign lower and upper bounds. The range of these bounds will almost always be much smaller than the 10–90% range of a probability distribution. This range does not reflect uncertainty about the consequences but instead the individual's lack of clarity concerning his or her own preferences.[14]

In light of time constraints that typically characterize the stakeholder deliberation process, eliciting CEs can be done either formally or informally. As part of a recent project, for example, decision-makers (an international advisory board) asked the first author to help incorporate biological uncertainty concerning predictions of how climate change would affect water quality on a large lake shared by the United States and Canada. A task force of leading scientists had worked diligently to come up with estimates of predicted changes in key variables contributing to water quality. However, many of

[10]For a formal explanation of the assumptions involved in deriving certainty equivalents, see Chapter 4 of Keeney and Raiffa.[(14)]

[11]It is not necessary to elicit utility functions for each individual, but it is necessary to know each person's values to get CEs. This means that if you have 15 alternatives then the analyst needs to develop 15 CEs, and if data change then the entire process will need to be done again.

[12]Although the numbers are illustrative, this example is modeled on several case studies where the first author (serving as analyst) was asked to lead or co-lead a multistakeholder group to help participants understand the implications of uncertainty for the development of acceptable alternatives across multiple attributes; see Gregory and Failing.[(43)]

[13]As with other elicitation approaches such as pair-wise comparisons, this could be done either as part of a series of one-on-one elicitations or as part of a group exercise undertaken simultaneously by all stakeholders.

[14]As a general observation, the analyst will need to be vigilant to help stakeholders distinguish clearly between uncertainty in their values, which is to be expected in novel evaluation settings, and uncertainty in the assessment of facts. For more on this point, see NRC.[(44)]

the ranges were very broad and the scientists were stumped in terms of how to help stakeholders and decisionmakers use this uncertain information in making their management choices. As a next step, we introduced the idea of CEs by first asking how each scientist felt about using the average as a simple way to characterize the range. At this point, the agreement among participants disappeared: some felt that the average was too high, some too low, and others that the best estimate would be nearer one of the end points. This lively discussion led to friendly questioning of these different perspectives and resulted in significant insights that the science team was then able to incorporate as part of an adaptive management plan it recommended to policymakers.

Consider the earlier example of a consequence table for energy generation alternatives. In addition to the consequences table of uncertainties showing ranges and best estimates (as in Table III), the process of eliciting CEs would yield a new consequences table of CEs for each stakeholder (see Table IV) that incorporates the uncertainty associated with consequences in the form of a single CE for each cell. For this illustrative individual, the conversion of three-point intervals to CEs is helpful in clarifying key elements of the choice (e.g., the objective "minimize costs" now can be omitted because it fails to differentiate between alternatives) and in clarifying the key value tradeoffs (between increased electricity production and the associated increase in health risks due to higher GHG emissions).

As in the lake water quality example, a stakeholder's CE need not, and often will not, equal the average of the range. However, the use of averages may help as a means for the analyst to probe individuals and to more carefully elicit their CEs. For example, if one objective under consideration by a potential worker is the annual salary to be paid for a new job and the uncertainty range across an alternative is from \$20,000 to \$80,000, it may aid the estimation of a CE for the analyst to first bring up the midpoint of \$50,000. The next step would be to bring in the concept of risk aversion, at which point the individual may say something along the lines of "well, anything below about \$45,000 matters a lot whereas anything above \$70,000 doesn't matter so much." The analyst then can begin to suggest a lower CE, perhaps \$30,000 or \$40,000, and vary the suggested CE until indifference is reached. Posing pairs of possibilities is also helpful: Is \$30,000 or is \$40,000 closer to what you would find indifferent to the range \$20,000–\$80,000? As a more technical note, if the individual is risk averse regarding salary, the corresponding CE for any probabilistic distribution must be less than the calculated average salary.

If an analyst is working with one stakeholder, there will be only one probability distribution and one CE for each objective of an alternative. If there is more than one stakeholder, the analyst will need to document (and later discuss) the range of CEs expressed for each objective by the stakeholders. In all cases, it is important that each stakeholder feels that his or her expressed CE is legitimate. In addition, the analyst should understand the logic used by each stakeholder to arrive at a CE and, given what has been learned, feel that it is an appropriate representation of the individual's values. In the fisheries case study noted earlier, for example, the imperative of CEs to focus judgments (by expressing a single number rather than a range) helped to clarify the logic underlying stakeholders' thinking and to identify areas of agreement and disagreement among stakeholders. This facilitated helpful discussions concerning the consequence estimates and, ultimately, led to greater understanding among stakeholders and improved insights for decisionmakers.

5.3. Dealing with Coalitions

Coalitions often are formed among participants in stakeholder committees with many stakeholders because members recognize similarities in expressed points of view. Analysts can also play a proactive role in encouraging the formation of coalitions, based on the recognition that coalition members are likely to have similar or identical values about the consequences. For stakeholders, joining a coalition can increase the clout of their perspective on the decision and, through conversations among coalition members, help to further refine ideas and concerns. For the analyst, coalitions can aid deliberations because having fewer parties involved (e.g., four to five coalitions of three to four stakeholders each rather than 20 stakeholders operating independently) simplifies the presentation of perspectives on the problem. In addition, the formation of coalitions can allow the analyst to identify information needs more effectively, which hopefully will result in a more informed and better decision.

Once coalitions have been identified and voluntarily formed by participants, the task of the analyst is to help stakeholders in each coalition develop a consequence table of CEs. The inputs to the process are the stakeholder members' CEs and the outputs are

Table IV. Energy Generation Consequence Table Showing CEs for an Illustrative Stakeholder

Fundamental Objectives	Indicator	Direction of Preference	Alternative A	Alternative B
Maximize electricity production	kw hours	Higher	1,225	1,700
Minimize GHG emissions	tons CO2	Lower	335	475
Minimize costs (present value)	$ millions	Lower	$7,400	$7,500
Minimize health risks	Constructed scale	Lower	2	4

their joint coalition CEs. Coalition members need to be willing to entertain discussions on the topic (presumably after having been informed about the associated benefits) and examine an illustrative consequence table that shows the full range of CEs and where each stakeholder is on that range. CEs that are identical or practically equivalent can be combined. Flexibility and a willingness to learn are important to the formation of coalitions because participants need to be willing to consider revising their CEs in light of what others have said.

The logic already has been outlined for technically combining CEs across coalition members.[8] First work with coalition members to weight the stakeholders in the coalition (often equally, although other options are also reasonable), then determine the utility function of the coalition and, as a last step, derive the coalition CE. Because stakeholders in a coalition have similar utility functions, and therefore similar CEs, a practical and much simpler way is for the analyst to use a reasonable modeling judgment and simply specify a coalition CE.

Once completed for each of the coalition groups, the analyst is able to represent the different CEs of each coalition as part of a single consequence table, which then can be shown to and discussed among the entire group. In the best of cases, this will enable calculation of the expected utility of each alternative for each of the coalitions. In the more usual case, where the multiple-objective utility functions have not been specified, each coalition will be able to produce at minimum a ranking of alternatives and, at best, a rating (i.e., relative performance scores) over the set of alternatives. As in the case of the (illustrative) individual stakeholder who completed Table IV, this information enables the analyst to move forward with trying to simplify the decision by reviewing alternatives for dominance and objectives for relevance. This decision-aiding process should help to obtain a collective agreement among stakeholders by eliminating less desirable alternatives from further consideration.

6. WORKING WITH THE STAKEHOLDER COMMITTEE

At this stage of the stakeholder deliberations, the analyst has led individual stakeholders, and coalitions if they exist, to incorporate uncertainty over the consequences and to rank or rate the identified alternatives. The next step is to use this information to help develop preferences over alternatives for the stakeholder committee. If there are several coalitions, this will involve working directly with them and discussing results with the entire group. If there are only a small number of stakeholders (e.g., three or four in total), or if coalitions have not formed, then this step will involve working directly with the individual stakeholders. In either case, the analyst should emphasize the need for each coalition and stakeholder to think carefully about their CEs and to recognize that they can revise these based on learning from the judgments that have been made by the other stakeholders or coalitions.

One way to think about deliberations with the stakeholder committee as a whole is to consider the entire group as a coalition, at least in terms of reporting to the decisionmaker. If individual stakeholders and coalitions agree, then a multiattribute assessment could be conducted in which the utilities of all stakeholders and/or coalitions would be weighted.[15] This extra step, going from the stakeholder or coalition evaluations to a possible committee evaluation, is itself a key decision. What does the committee want to communicate to the decisionmaker and what does the decisionmaker want to know from the group? If committee preferences are desired, how should preferences of the individual stakeholders and/or coalitions be considered? Is it possible for the group as a whole to adopt a single

[15] Alternatively, weights across stakeholders and coalitions could be assigned by the decisionmaker; this is often done implicitly, whereas if the analysts were asked to help by introducing explicit weights and conducting sensitivity analyses it is likely that new insights would be gained.

Table V. Rankings of Alternatives by Stakeholder Coalitions

Coalition Evaluations	S1	S2	S3	S4
Best	A	A	C	B
	B	D	B	A
	C	C	D	C
Worst	D	B	A	D

consequence table with a single set of CEs? Analysts often ignore these challenges and just assume that all members will be weighted the same and proceed accordingly.

Consider Table V, showing rankings of four alternatives (A–D) based on the judgments of four different stakeholders or coalitions (S1–S4). Assume that the stakeholder committee has agreed to adopt a single consequence table of CEs. However, there are significant disagreements concerning uncertainties associated with the health of the restored riparian habitat (one of the primary decision consequences). This has led to differences in the CEs expressed by the stakeholders. After discussion, it turns out that stakeholders or coalitions S1 and S2 prefer alternative A, S3 prefers alternative C, and S4 prefers alternative B. All alternatives except C are ranked lowest by at least one stakeholder. Alternative C is preferred by S3 because it explicitly includes an adaptive management design to address uncertainty, with multiple trials provided for a key concern (e.g., riparian plantings to enhance stream habitat), but it is ranked second-to-last by the other three coalitions due to additional costs associated with including the formal, adaptive management comparisons of methods.

Because uncertainty has been included explicitly when describing the alternatives and stakeholders' utilities are incorporated through their CEs on the environmental habitat objective, these differences can be addressed directly by the analyst and stakeholders as part of the deliberative process. For example, one possibility is to explore ways to adjust alternative C (e.g., with trials) by reducing the associated costs and thereby raising the ranking of the modified alternative C′ by other stakeholders. Another option is to reduce the uncertainty of habitat response (e.g., through collection of additional information) for alternative A, thereby raising the possibility that both the CE and the ranking of the modified alternative A′ by S3 will increase and lead to greater agreement across group members. Various other alternatives also can be suggested, with the goal of creating better alternatives and describing them using a single set of CEs agreed to by all participants. A new consequence table could then be used to suggest a new compromise alternative that all stakeholders perhaps could support.

7. WORKING WITH THE DECISIONMAKER

The analyst is charged with presenting the decisionmaker with a summary of the results of deliberations by the stakeholder committee, both with respect to the process that was followed and participants' evaluations of the alternatives. The role played by uncertainty in the consequences of alternatives, a topic often barely touched upon as part of analysts' summaries, can be more fully described using techniques discussed in this article. As a result, the decisionmaker will not only be provided with summary insights concerning the relative strengths and weaknesses of the different alternatives, but also with a more complete understanding of the significance of uncertainties to the decision, how different stakeholders and coalitions reacted to the presence of these uncertainties, and their importance in the generation, review, and evaluation of alternatives.

Although this discussion has focused on the presentation and analysis of uncertainty in multistakeholder, multialternative contexts, we recognize that decisionmakers are likely to have objectives other than understanding and satisfying the participants on the stakeholder committee. For example, the decisionmaker may want to sequence costs over several years (e.g., to avoid adding to current year deficits) or she may worry about impacts on other workers or citizens beyond those directly involved on the committee. Decisionmakers may also care about the precedent that is being set or effects of the decision on their own reputation or that of other key players in the decision-making process. As a result, the decisionmaker will want to informally or formally consider these other objectives and their associated uncertainties in relation to satisfying the stakeholder committee. Working together with the analyst, the decisionmaker may also need to prepare a justification of the decision process and the resulting decision for his own CEO or a cabinet minister, as well as for stakeholders and the public.

For important policy choices, decisionmakers often will have a window of 6–12 months and sometimes more before announcing a final decision. During this time, new information can come to light reducing critical uncertainties and further refining consequence estimates. Because of the explicit inclusion of uncertainty as part of the stakeholder deliberations, it is reasonable to expect more stability in light of this new information with respect to the expressed preferences of stakeholders. The decisionmaker, in turn, should experience additional comfort in terms of the acceptance and implementation of any agreement.

8. DISCUSSION

Each time that a stakeholder committee is convened as part of a public policy consultation process, analysts and policymakers need to decide about the emphasis that will be given to uncertainty in the estimated consequences of actions as part of analyses and deliberations. The mandate of such stakeholder committees is normally that of providing insights to the decisionmaker or, at most, making a specific recommendation about one or more preferred alternatives. The mandate of the analyst, acting with stakeholders' approval, is to lead the group through a defensible decision-aiding process that identifies their key values, summarizes relevant facts at an appropriate level of precision, clarifies sources of uncertainty and key value tradeoffs, and helps participants to identify one or more preferred alternatives. An important task facing analysts is to facilitate stakeholders' understanding and discussions of the implications of uncertainty across multiple objectives and multiple alternatives, using tools such as consequence tables to display uncertainty about the consequences of alternatives and to facilitate informed deliberations.

At present, uncertainty is often not fully incorporated by analysts leading the deliberations, either because the significance of uncertainty in selection of an alternative is not adequately understood or because it is assumed that many stakeholders would find it difficult to understand and evaluate uncertainty. Even when uncertainty is included, it often is treated in an ad-hoc manner or presented as if stakeholders' judgments reflect only factual concerns. The result is that the uncertainty associated with estimates of consequences is represented in a way that confuses rather than informs stakeholders and, too often, encourages misunderstanding and discord rather than better understanding and a more informed, value-consistent choice.

This article demonstrates a straightforward method for developing and communicating judgments of uncertainty across decision alternatives, in a way that respects individual differences yet encourages clarifying discussions among participants. Summarizing the uncertain consequences of alternatives as CEs provides a theoretically defensible yet practical approach for addressing uncertainty as part of multistakeholder, multialternative deliberations. In many situations, substitution of a CE for the uncertainty about a consequence can facilitate interpretation by stakeholders and decisionmakers of the implications of that uncertain consequence. Because CEs are based both on experts' predictions and stakeholders' value judgments, they encourage active deliberations among participants in a way that recognizes differences yet focuses discussions on a common set of objectives and alternatives. As the process of deriving a CE leads individuals from more complicated expressions of uncertainty (e.g., distributions or five-point ranges) to a single number, it also encourages the use of visual tools that facilitate informed comparisons among different alternatives.

Leaving uncertainty out of stakeholder deliberations about important public policy choices reduces the quality of the results that are obtained and excludes participants from critical aspects of a decision-making process that may vitally affect their lives. In contrast, the careful incorporation of uncertainty helps to inform and empower stakeholders with additional knowledge of the decision, which brings them more meaningfully into policy deliberations regarding choices among alternatives. Including uncertainty is essential at each phase of the deliberative process: eliciting judgments from technical experts, working with individuals or coalitions on a stakeholder committee, reviewing information and preferences with the committee as a whole, and reporting to decisionmakers. No single approach is appropriate for all situations. However, CEs can be a useful option for encouraging deliberations that incorporate uncertainty in a logical and theoretically sound manner that also has the practical advantage of summarizing the range of predicted consequences in a way that helps stakeholders consider their own values as well as the predicted consequences of alternatives.

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