Risk and Uncertainty in the Policy Choices for the National Forests: the Sierra Nevada Case

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Proposed Project Strategy

This document provides an overview of the approach proposed by a panel of scientists and policy experts from George Mason University and Ohio State University in response to the inquiry made by the Regional Forester from the USDA Forest Service, Pacific Southwest Region, regarding the Sierra Nevada Forest Plan Amendment Final Environmental Impact Statement, Record of Decision, and Appeal Decision. The document is divided into several sections designed to respond to the three issues outlined in the charge to the panel. These sections include:

- A characterization of the decision problem facing the Forest Service in the Sierra Nevada
- An initial description of the uncertainties inherent in the current decision situation
- A preliminary statement of the risks involved
- An outline of the project objectives
- A summary of the proposed approach to be taken in the analysis
- A schedule of project deliverables, a suggested time frame, and a proposed budget
- Names, contact information and abbreviated CVs for the principal research team

Characterization of the Decision Problem Facing the Forest Service in the Sierra Nevada

> *I affirm the Regional Forester's decision. However, I believe opportunities exist for refining the decision while further advancing consistency with current agency policy. Therefore I will instruct that certain aspects of the decision be subject to additional review and analysis.*[1]

To place the project appropriately in the context of this mandated "additional review and analysis," it is important to understand the structure of the decision problem facing the Forest Service in managing the Sierra Nevada, the uncertainties that exist around the decision, and the risks the Forest Service faces.

The attached Figure 1 provides a schematic representation of the problem. In this characterization, three sets of factors have a direct influence on the forest ecosystems in question.

- *External human factors.* These are factors external to the Sierra Nevada lands under Forest Service ownership and management, and external to the Forest Service as an organization. Examples would include adjoining and nearby communities and private forestlands, national and state parks, commercial interests, and other private and governmental entities.
- *Natural events and processes*. Again, these are naturally occurring events beyond human control, such as lightning strikes, drought, and climate change.
- *Management strategy*. This box represents the management alternative selected and implemented by the Forest Service. One example would be Modified Alternative #8, the current option.

The effect of these three sets of factors on the ecosystem is characterized by

- Level of fuel buildup and hazards
- Wildlife habitat status and sustainability
- Capacity to sustain old-forest-dependent species
- Amount and quality of forest-based recreation
- Resilience to disturbances

For example, a particular management strategy may judge that current levels of fuel build-up require timber harvesting as a mechanism for controlling fuel levels. Or, urban development in proximity to the forest may increase the demand for forest-based recreation. Or, drought may reduce the forest's resilience against disturbances.

The combination of external human factors, natural events and processes, and management strategies acting on the current ecosystems will combine to produce changes in those systems. These changes we call outcomes, and they include:

[1] Dale N. Bosworth, "Decision for Appeals of the Record of Decision for the Sierra Nevada Forest Plan Amendment and its Final Environmental Impact Statement," November 16, 2001.

- Wildfire acres burned
- Habitat for old-forest-sensitive wildlife species
    - Owl-nesting habitat
    - Old growth late seral stage (all types)
    - Number of large trees
    - Number of very large trees
    - Number of snags
- Incidence of large-scale severe disturbances
- Stand replacement acres burned
- Cumulative watershed effects
- Net cost of management implementation, treatments and emergency response

Clearly the exact nature of each outcome dimension resulting from a given management strategy is not knowable in advance because of the uncertainties inherent in the management of the Sierra Nevada. However, this project will presume that there is some agreement among experts on the distribution of natural events and external human factors, and the likely distribution of effects of those events on the ecosystem under alternative management actions. This set of consequences of management actions is what the EIS process was intended to identify.

Returning to Figure 1, whatever the management decision selected and resulting outcome set, the combination will be assessed and evaluated by the various stakeholders, in light of their preferences. Stakeholder preferences for an alternative depend upon several characteristics:

- *Historical precedent*: for some stakeholders, past practice produced acceptable outcomes and they will tend to prefer a continuation of those practices.
- *Outcomes*: other stakeholders would prefer to shift the focus to a different set of outcomes or they desire a different level of each outcome dimension (acres burned, habitats, disturbances, etc.).
- *Principles*: some stakeholders will see focusing on outcomes as too uncertain, and will prefer instead to focus on the guiding principles in the management decision. They will prefer alternatives that are consistent with their preferred principles.
- *Social norms and preferences*: some stakeholders will view the popular will as the characteristic that should determine the alternative selected, and the standard by which it should be evaluated.

Whether or not there is a formal process for collecting and evaluating stakeholder preferences, stakeholders will evaluate the management strategy followed by the Forest Service and will find both formal and informal mechanisms for providing their feedback to forest managers. In our view, the best management decision is the one that achieves the broadest approval among stakeholders over the long term. It seems clear that this may not be a single decision reached today and then implemented for years to come. Because of the uncertainties inherent in this decision, and because of changing social priorities and new scientific understanding, we fully anticipate that the best decision will

change and evolve over time in response to these changing conditions. Nonetheless, the basic structure of the decision will remain stable.

To complete the description of the feedback loops: clearly outcomes will modify the ecosystem and such changes will have an effect on external communities and interests.

Uncertainty

Within this framework, there are quite a number of uncertainties that will influence the implementation and effectiveness of any management strategy. By uncertainty, we mean an event, relationship or important consideration that is either unknown or has itself a distribution of possible values, and is not under the immediate control of Forest Service decision makers. There are three broad categories of uncertainty in the decision context facing the Forest Service: scientific, administrative (or implementation) and stochastic.

To say that something is scientifically uncertain is to acknowledge that these are complex systems, and that our knowledge of them is incomplete. As a result, no one can state with certainty the outcome of any management strategy, including maintaining the status quo. Administrative or implementation uncertainty refers to the vagaries of managing in a political environment with changing public goals and priorities, changing societal needs and conditions, and uncertain organizational capacities over time. Finally, stochastic uncertainty refers to those events that are largely random, unpredictable and uncontrollable, such as lighting-caused ignitions or random changes in species populations.

Each of the sets of factors identified above and in Figure 1 is associated with specific uncertainties. In addition, the assessment of outcomes by stakeholders also involves uncertainties. The multiple uncertainties in this decision are summarized in the following table.

Table 1: Uncertainties in the Sierra Nevada Management Decision

	Scientific	Administrative or Implementation	Stochastic
Ecosystem	❑ Representativeness of sample inventory	❑ Sampling and inventory implementation	❑ Measurement error in the initial inventory
Natural events and processes	❑ Climate change	❑ Lack of access to affected areas ❑ Lack of understanding of the interaction between administrative action and naturally occurring stressors	❑ Number, size & location of ignition events ❑ Drought conditions and related disease and insect-produced stresses
External human factors	❑ Incidence of invasive species	❑ Adjacent development in surrounding areas	❑ Changing societal needs and priorities
Management or strategic interventions	❑ Externalities (e.g., air quality, economic impacts) ❑ Long-term effects	❑ Funding levels and timing ❑ Institutional capacity (data, models, expertise, organization) ❑ Public perceptions	❑ Short term resource availability, e.g. firefighters from other jurisdictions
Stakeholder assessments	❑ Understanding of scientific explanations and logic	❑ Representativeness of stakeholder groups ❑ Desired and minimum acceptable outcome levels and the relative importance of each ❑ Stability of stakeholder preferences over time ❑ Willingness of stakeholders to compromise	❑ Changing societal needs and priorities

Some key areas of scientific uncertainty include the acreages of old-growth forest and old-growth forest habitat developed under the various alternatives as projected by the vegetation models; the population of old-growth dependent species associated with these projected acreages and the resulting probabilities of viability as projected by the California Wildlife Habitat Relations Model and viability models; and the annual or decadal acreages burned and severity of burn as projected by the such models as FLAMMAP, SPECTRUM and FARSITE. Further, there are interactions between some of the outcomes, such as acres burned x acres of old-growth habitat. And, clearly, there are uncertainties associated with effectiveness and levels of implementation for the various alternatives.

Obviously, there is much that is uncertain and largely uncontrollable in this decision environment. There is no analytical solution to this decision problem. It is truly in the "wicked problem" category. Consequently, any course of action needs to leave open the possibility of modifying the decision as time and experience provide additional scientific

and management insights. This incremental approach is consistent with the concept of "adaptive management."

Risk

In *Managing Wildland Fire: Enhancing Capacity to Implement the Federal Interagency Policy Phase II Report: Study of the Implementation of the Federal Wildland Fire Management Policy*, produced by the National Academy of Public Administration (2001), the NAPA panel finds that many Federal risk assessment methods consider mostly the magnitude of hazards. The panel argues that it is necessary to develop methods that clearly include all three components of risk:

- *Hazard*: an area's fuel loading and dryness conditions. In Figure 1, this component is captured in the description of the ecosystem, and is updated over time as the ecosystem conditions change.
- *Risk or exposure*: the probability of ignition. In the framework proposed here, these probabilities are indicated as $P_i = P_1, P_2, \ldots, P_N$ in Figure 1.
- *Value*: the physical, social and economic costs of the potential damage. In this framework, these values are determined through the stakeholder assessment process.

The NAPA discussion is useful in helping to characterize the risks facing the Forest Service in this context, which are somewhat broader than fire management:

- *Short-term Risk*: given observed ecosystem conditions, existing external human factors and future natural events and processes, the probability that the adopted management strategy will be seen as unacceptable by the majority of stakeholders over the near term (10 years), either because
  - It results in a preponderance of unacceptable outcomes, or
  - It violates accepted historical precedents, or
  - It violates widely held principles and standards of practice, or
  - It violates broadly held social preferences.
- *Long-term Risk*: given observed ecosystem conditions, existing external human factors and future natural events and processes, the probability that the adopted management strategy will result in a preponderance of unacceptable outcomes to the majority of stakeholders over the long term (beyond 10 years).

What emerges from this characterization is the observation that short-term risks involve much more than simply concern about uncertain outcomes, or the product of the decision. Attention must also be paid to process or the decision maker runs the risk of failing, even though the likelihood of desirable outcomes is enhanced.

This characterization in terms of short-term and long-term risk is also useful from an adaptive management perspective. The learning that occurs in the short term can be used to make adjustments that could potentially reduce long-term risks. Of course, it is

essential to hold open the possibility that strategies for reducing short-term risks may be at odds with reducing long-term risk.

Project Outline

The result of this project will not be an endorsement of the selected alternative or a recommendation to change to a different alternative. Rather, the objectives of this project can be grouped into those focused on the uncertainties and risks facing the Forest Service and those objectives focused on stakeholders and stakeholder responses to risk and uncertainty. More specifically the project objectives are:

I. Summarize best practice and scholarship regarding the characterization and treatment of risk and uncertainty in environmental conservation and closely related decisions.
II. Evaluate the implications, including strengths and weaknesses, of alternative approaches to dealing with risk and uncertainty.
III. Summarize and evaluate
    A. Risk and uncertainty communication practices in environmental decision making;
    B. The scholarly literature on stakeholder attitudes toward risk and uncertainty; and
    C. The role of stakeholders in managing and resolving wicked problems.
IV. Within the framework established by I, II and III above, evaluate the treatment of risk and uncertainty in the FEIS and ROD, focusing on alternatives 4, 6, 7 and modified 8.
V. Assure that the processes and outcomes desired by the various stakeholder groups are correctly identified.
VI. Provide a defensible method for communicating risk and uncertainty to stakeholders, and assessing the desired level and relative importance of each decision dimension to each stakeholder group.
VII. Provide a defensible method for incorporating stakeholder preferences (desired processes and outcomes, minimum or maximum acceptable outcome levels and strength of preferences) into an overall assessment of the acceptability of each alternative.

The focus of this project will thus be on two key aspects of the overall decision problem represented in Figure 1. First, we will draw upon existing science and modeling efforts to summarize best practice with regard to the treatment of risk and uncertainty in environmental decision-making, and then assess how risks and uncertainties were recognized and evaluated in the FEIS and ROD. Second, we will carefully consider the best way to educate stakeholders and incorporate their preferences in the decision process.

Proposed approach

Paralleling the objectives identified above, we propose to organize the project in four stages. In the **first stage**, we will prepare a two-part scholarly report that provides the following:

Part I

- A general discussion of uncertainty and risk in many environmental conservation decisions, including a discussion of the possible means to recognize and deal with risk and uncertainty.
- A discussion of examples of environmental policy decisions that involve significant risks and uncertainties as defining elements of the problems. We will also address the concepts of competing risks and tradeoffs among risks even when the goals or ends of policy choices are the same.
- A discussion of different approaches to dealing with risk and uncertainty, including at least
    - Safe Minimum Standards,
    - Regulatory certainty under ESA,
    - Adaptive management,
    - The precautionary principle, and
    - Best Management Practices.
- A discussion of stakeholder attitudes toward risk and uncertainty. This section will also include a review of scholarship and practice regarding assessing and incorporating stakeholder attitudes and values in environmental deliberations in the face of substantial risk and uncertainty. (See for example, Lee, 1993)

Part 2

- An explanation of how risks and uncertainties were recognized and evaluated in the FEIS (focusing on alternatives 4, 6, 7, and mod 8) and ROD.
- An assessment of the decision made in the ROD with regard to its approach to dealing with competing risks and short- versus long-term risks and uncertainties.
- An assessment of the proposed adaptive management approach to risk and uncertainty and its intended implementation.
- An assessment of the level of recognition and evaluation of risks and uncertainties associated with the other alternatives.

The **second stage** of the project will be carried out in tandem with the presentation of the Final Review Team recommendations. We will present our findings in a workshop for an interagency group of public officials. The workshop will provide a setting to both explain the nature of the risks and uncertainties involved in the recommendations, and allow participants to discuss and frame the risks and rewards associated with those recommendations. Part of our effort will include both a pre- and post-workshop assessment of participant attitudes toward the risks, uncertainties, process and outcome dimensions of the decision.

The **third stage** of the project will involve presentation of our findings to a group of non-public stakeholders in order to both educate and assess their attitudes regarding:

I. Is there broad agreement on the process and outcomes of concern to the various stakeholders?
II. Do the recommendations address the process and outcome dimensions of greatest concern to stakeholders?
III. How important is each decision dimension to each stakeholder group?
IV. What are the desired and minimum or maximum acceptable outcomes on each dimension for each stakeholder group?

In addition to the scientific uncertainty associated with any management decision in this context, there are also uncertainties associated with how different stakeholder groups will view any recommendations forthcoming. The stakeholders will evaluate these recommendations in terms of their preferences for historical precedent, the principles guiding the methods to be employed, the perceived likely outcomes and the degree of popular support for the recommendations.

Answering questions I through IV will require that we gain substantial insight into how different stakeholder groups will react to the recommendations and alternatives considered. We will attempt to obtain the preferences of the different stakeholder groups for each alternative as part of the public meeting with representatives of the different stakeholders. The analytical tool we will be using for eliciting and analyzing these preferences is called *conjoint analysis*.

Conjoint analysis is a technique that has been developed and used extensively in marketing to determine which products consumers are most likely to purchase. To obtain the preferences of the stakeholders for each set of recommended actions we will first identify the dimensions of these actions, in terms of damage due to fire, loss of habitat, loss of recreational opportunities, potential harvest and so forth. The logic underlying conjoint analysis is that individuals view each set of actions in terms of its dimensions and that people place different values and importance on these dimensions.

Once the dimensions of the recommended actions have been identified, we face two tasks. We need to establish whether any stakeholder group would judge an alternative unacceptable because it represents an outcome or set of dimensions that does not meet a particular threshold. So, the first task would be to establish the thresholds for these dimensions such that a recommended action not attaining that threshold would render an alternative unacceptable.

The second and subtler task is to infer the stakeholders' utilities or valuations from the preferences they express for various combinations of these dimensions.

For a simple illustration of how conjoint analysis works in practice see Appendix A.

Following the collection of this data, a simulation model will be developed to provide guidance in assessing how stakeholder groups will likely view the alternative futures represented by the different management alternatives and recommendations.

The model development will use the following logic:

i. Using the best available probabilistic distribution of outcomes, model the result (outcomes) of each management strategy (alternative) under each event scenario.

ii. Simulate the response of each stakeholder group to each set of outcomes from (i). Using the elicited priorities, their relative importance to each group, and the outcomes occurring under each event scenario, it should be possible to calculate whether a given group would find a given process and outcome acceptable or not. Conceptually, the objective is to develop a distribution of approval ratings for each strategy that would incorporate the stakeholder responses to each management strategy (alternative) under different management and outcome scenarios. The result of this step will be a stakeholder-specific rating of each alternative strategy under the different event scenarios.

iii. Evaluate the approval rating of each strategy, using the information developed in (ii). Given that the aspiration levels of some groups may be unrealistic (i.e., some outcome combinations may be unattainable under all strategies), it may be useful to include "learning" in the simulation model. With learning, group aspiration levels will be adjusted over time to reflect what is attainable (see the feedback shown in Figure 1 between stakeholder preferences and stakeholder assessment).

    With or without learning, the collective assessment of each alternative can be characterized in terms of the percent of groups willing to accept the outcomes implicit in that strategy. In the aggregate, the result will be a form of "collective satisficing."

    If it proves difficult or undesirable to use a single dimensioned rating, Data Envelopment Analysis can be used to obtain a multi-dimensional index.

The effort to answer these questions related to stakeholder preferences will allow us to identify the key variables and uncertainties in the decision characterization, and to suggest a focus for future research.

The **fourth and final stage** of the project will consist of preparing a final report summarizing our findings and recommending to the Forest Service both an approach to dealing with risk and uncertainty, and a method for incorporating stakeholder preferences into an overall management implementation strategy.

Following this project, it is the intention of the panel to aggressively pursue academic publication of the findings and results of the effort. We are strongly of the opinion that

this project could benefit the Forest Service beyond Region 5 and other public entities as well.

Schedule of Deliverables

This schedule assumes that authorization to proceed is received no later than January 1, 2003, and is calculated to coincide with the Framework Review Timeline provided by Mike Ash. It is also assumed that the Forest Service will designate an advisory board to work with the research panel by early January, 2003.

Upon receipt of authorization to proceed, we will immediately begin to prepare part one of the preliminary scholarly report.

Feb 17	We receive draft recommendations from Mike Ash's team
Mar 10	Initial draft of Parts I and II of the preliminary report delivered to advisory board for review and comment
Mar 24	(week of) Research panel holds workshop to present and discuss findings with IAT and other public stakeholders. Revised draft of preliminary report is delivered.
Apr 15	(week of) Research panel holds workshop for other stakeholders using participation list compiled in cooperation with Forest Service.
May 1	Summary of stakeholder attitudes and preferences based on conjoint analysis is delivered.
Jul 1	Draft final report delivered to advisory board for review and comment
Aug 15	Final report delivered and exit interview held.
June and beyond	Project panel will prepare a series of papers reporting on the study for submission to and publication in academic journals

Research team

Ronald E Stewart, Department of Environmental Science and Policy, George Mason University

Brings extensive expertise in forest management, natural resource policy and an understanding of the complexities of the issues underlying this project having served for thirty years with the USDA Forest Service in various capacities in the field and in conducting and managing research.

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Brings expertise in statistics and operations research to assist in the identification and assessment of stakeholder preferences and the analysis of the simulation models.

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All the members of the team will be involved in the development of the research approach, the interpretation of the results and the writing of the final report.

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Green, P.E. and D. S. Tull (1978) *Research for Marketing Decisions* (4th ed.) Englewood Cliffs, NJ: Prentice- Hall

Luce, R. D. and J. W. Tukey. "Simultaneous Conjoint Measurement: A New Type of Fundamental Measurement," *Journal of Mathematical Psychology*, 1 (February 1964), pp 1-27.

Some Web resources include:

http://marketing.byu.edu/htmlpages/tutorials/conjoint.htm

http://www.surveysite.com/newsite/docs/conjoint-intropage.htm

http://www.dobney.com/Conjoint/Conjoint_analysis.htm

Readings on risk and uncertainty

National Academy of Public Administration. (2001) *Enhancing the Capacity to Implement the Federal Fire Management Policy*, Phase II Report, Study of the Implementation of the Federal Wildland Fire Management Policy. Washington, DC: National Academy of Public Administration.

Todd, Charles R and Mark A Burgman. (1998) “Assessment of Threat and Conservation Priorities under Realistic Levels of Uncertainty and Reliability,” *Conservation Biology*, 12 (October, 1998), pp. 966-974.

Wise, Charles R and Christian M. Freitag. “Balancing Accountability and Risk in Program Implementation: the Case of National Fire Policy,” *Journal of Public Administration Research and Theory*, 12(October, 2002), pp 493-523.

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Salwasser, Hal. (2002) “Navigating Through the Wicked Messiness of Natural Resource Problems: Roles for Science, Coping Strategies and Decision Analysis.” Sierra Science Summit, Kings Beach, CA., October 8, 2002.

Walters, Lawrence C., James Aydelotte and Jessica Miller (2001) “Putting More Public in Policy Analysis,” *Public Administration Review*, 60(4): pp 349-359.

On agent-based simulation models

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Appendix A: Brief Introduction to Conjoint Analysis

What is Conjoint Analysis?

A number of techniques, such as conjoint analysis, analytic hierarchy process (Saaty, 1980), and multidimensional scaling (Shepard, 1964) have been developed for measuring human perceptions and preferences. Data collection for these techniques is based on obtaining *subjective* information regarding the respondents' preferences. Our decision to use conjoint analysis here is based on a variety of criteria including ease of use and the quality and nature of the information that can be obtained from eliciting stakeholder preferences.

How does Conjoint Analysis Work?

Conjoint analysis involves the measurement of psychological judgments (such as stakeholder preferences, or acceptable thresholds) or perceived similarities or differences between choice alternatives. Conjoint analysis is a technique in which respondents are given various choices (stimuli) for which they express their preferences. These choices are selected, in advance, to incorporate all the outcome dimensions that result from the selection of a particular alternative. The responses thus obtained result in a preference structure for the stakeholders. By analyzing these responses, it is possible to create a profile for each group of stakeholders that will provide insights into not only the subjective judgments regarding the choices they were offered but also regarding various other combinations of outcome dimensions and different levels of these dimensions.

How are data collected?

Data may be collected in a variety of ways. Marketers, who are among the main users of this technique, have used mail surveys, telephone surveys, internet based surveys as well as individual or group interview or focus group settings to obtain data.

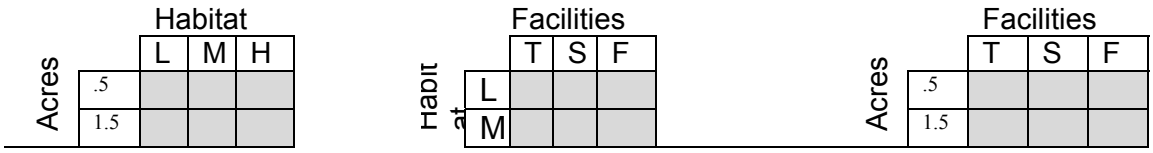
Type of Data

There is no single set of procedures for obtaining data on individual preferences. Suppose, for illustrative purposes, that the following three outcome dimensions and their corresponding levels are being compared:

- Wildfire acres burned — 0.5 million, 1.5 million, 3 million
- Loss of owl nesting habitat — Low, Medium, High
- Loss of recreational facilities — Temporary, Short term, Forever

Some of the earliest conjoint analysis projects asked the respondents for pairwise comparisons which entailed filling out matrices like those shown below for each pair of comparisons:

Pair-wise Approach to Data Collection



The data from these pairwise comparisons can be combined to create preference profiles of different stakeholders for the different alternatives.

A more common approach is to use paired comparisons in which two alternative outcomes are considered at a time. For instance, the question would be put forth as:

Which alternatives would you prefer given the following outcomes:

0.5 Million acres burned	1.5 million acres burned
Medium loss of owl habitat	Medium loss of owl habitat
Recreational facilities lost forever	Short-term loss of recreational facilities

Strongly Prefer Left	1 2 3 4 5 6 7 8 9	Strongly Prefer Right

The paired comparison technique is easier for most respondents to conceptualize. However, the number of comparisons can very quickly become large, but statistical techniques exist that can help reduce the actual number of choices that have to be evaluated. Statistical analyses of these paired comparisons would yield the required preference profiles of the stakeholders.

Methods of Presenting Stimuli

In our context, the most effective approach to seeking stakeholder responses would be to create written descriptions of possible outcome scenarios to which the stakeholders would respond in terms of their preferences.

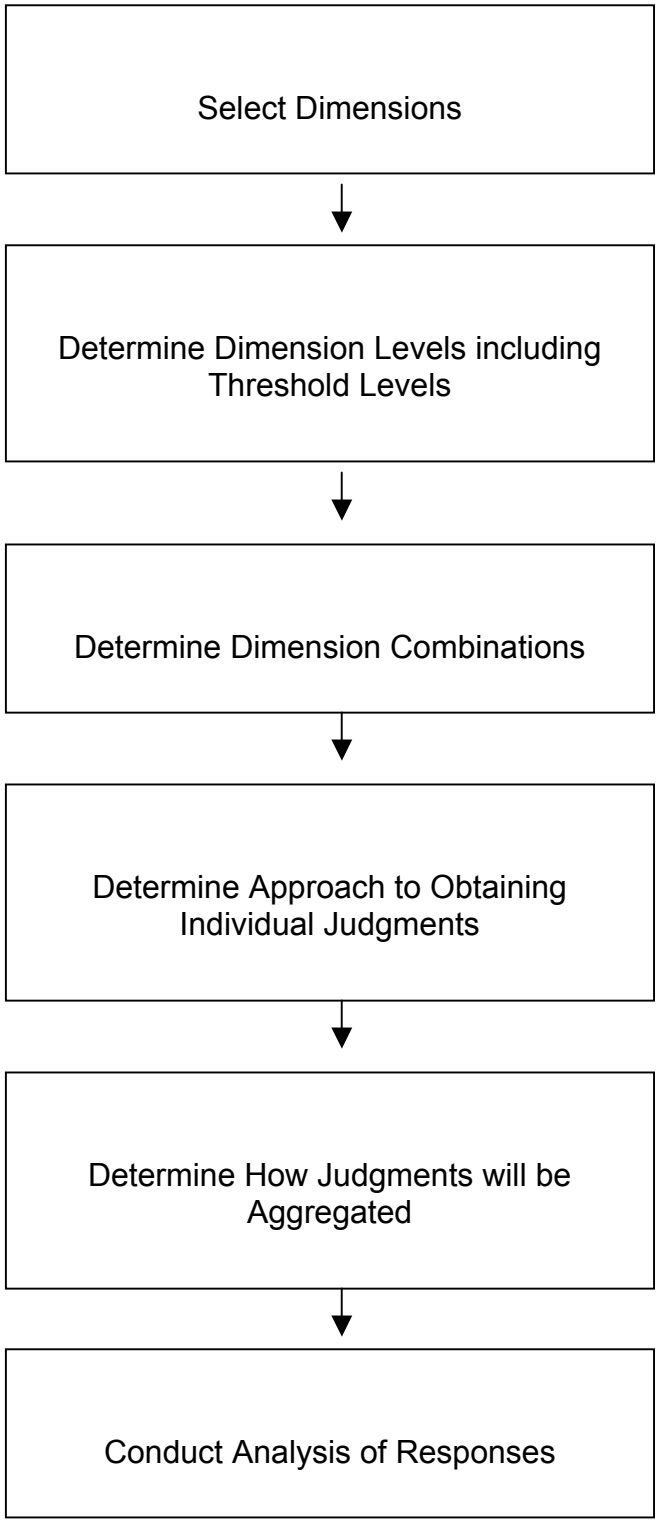
Nature of judgments

Responses can be solicited in a number of ways. As shown in the illustration above, one could ask for the respondent's preferences. Judgments in terms of liking, similarity or "can live with this outcome" can also be solicited.

Nature of Task

Depending upon the nature of the information solicited, the task would entail asking for a rank ordering, pairwise comparisons or a number on a rating scale.

Figure A-1: Schematic of Conjoint Analysis Process



Source: Adapted from Churchill and Iocabucci, (2002)