# Which Uncertainties Matter for Decision-Making?

## Development of an Integrative Decision-Centered Screening Tool

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## Introduction


Science that aims to support decision-making must be useful, relevant, credible, and legitimate. Typical academic research does not meet all these requirements naturally. Instead it requires active collaboration of scientists and decision-makers to become truly decision-relevant. In the context of climate change, scientific uncertainty can make finding this balance between what decision-makers need and what scientists can credibly provide even more challenging. It is critically important therefore that scientists clearly understand decision needs and effectively communicate the uncertainties associated with the information to practitioners.

This poster offers a heuristic – a simple stepwise procedure – that helps scientists and decision-makers ascertain the decision needs of the practitioner and decide on necessary scientific analyses. It specifically helps to discern what type of information decision-makers may need about uncertainty associated with the provided scientific information.

As such the introduced Decision-Uncertainty Screening Tool (DUST) is educational for the scientists not yet familiar with working with a particular practitioner or in a specific decision context. It also helps practitioners who need to understand what kind of decision support science can realistically provide. Given limited time and computational resources, the tool further helps to efficiently identify the (uncertainty) analyses that are actually needed to be useful in particular decisions.

## DUST – The Decision-Uncertainty Screening Tool

### Purpose

- Create better integrative link between uncertainty analysis in weather forecasts, climate variability, climate change, impact analyses and decision- and policy-making.
- Develop a systematic approach to determining where and when uncertainty matters
- Give scientists and decision-makers a procedure to identify where and how science can most effectively support decision-making

### Premises

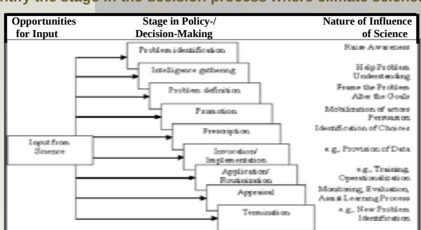
- The decision-maker and the real-world process of making a decision – rather than curiosity-driven science – is at the center
- Credible, relevant, and accessible scientific information can be an important input into decision-making
- Does not assume a particular normative approach to decision-making under uncertainty
- Does not favor a "top-down" or "bottom-up" approach to assessments

### Objectives

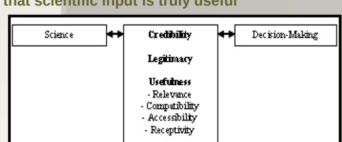
- Should work for all kinds of weather and climate-sensitive decisions, and for a range of decision-makers
- Applicable in a variety of decision-making contexts and a variety of scales

### Procedure

**1** Identify the stage in the decision process where climate science could enter




**2** Ensure that scientific input is truly useful




**3** Identify the type of decision problem the decision-maker faces

OPTIMIZATION - What decisions (i.e., strategies or choices) will produce a desired outcome?

EVALUATION - What outcomes does a given (set of) decisions(s) have?

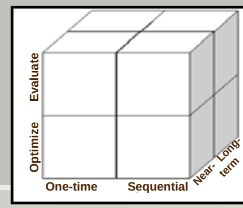
ROBUST ADAPTIVE PLANNING - Which strategies avoid major system failures, breakdowns, or surprises? (hybrid)

OPTIMIZATION: $O_c$ (+E) => $C_a$ f(P, X)?

EVALUATION: $C_a$ => $O_c$ (+E) f(P, X)?

Key:
O: Outcome/Objectives
c: Criteria that would satisfy outcome
C: Choice set/Management options
a: Attributes that describe the choices
P: Present conditions/state variables
X: Decision constraints
E: Externalities

**4** Identify the specific decision challenge: a three-dimensional typology of climate-sensitive decisions



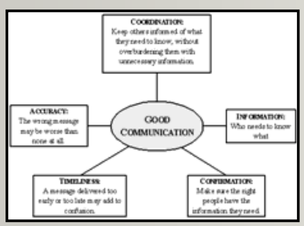

**5** Identify necessary uncertainty analyses

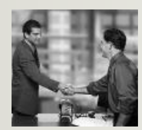
| Types of Decision | Policy Analyses | Remarks |
|---|---|---|
| One-time, near-term optimization | Optimization with resolved (known) uncertainty | Essentially a special case of stochastic dynamic optimization |
| One-time, long-term optimization | Finite-horizon stochastic optimization | |
| Sequential, near-term optimization | Infinite-horizon (dynamic) stochastic optimization | May be too computationally demanding |
| Sequential, long-term optimization | Infinite-horizon (dynamic) stochastic optimization | Quite computationally demanding |
| One-time, near-term evaluation | Single-period (but multiple policies) decision analysis; Single-policy uncertainty analysis | |
| One-time, long-term evaluation | Single-period (but multiple policies) decision analysis; Single-policy uncertainty analysis | |
| Sequential, near-term evaluation | Multi-period decision analysis | |
| Sequential, long-term evaluation | Multi-period decision analysis | |

**6** Conduct identified uncertainty analyses

| Types of analysis | What can be learned |
|---|---|
| Exploratory modeling/Computer-assisted reasoning | → Reveals model-based uncertainties and unknowns; used to explore plausible futures where little is known about them |
| Multi-model comparison | → Reveals model-based uncertainties; important when model structures are less well known |
| Sensitivity analysis | → Reveals the impact of varying model inputs (through single or joint variation); important when model structure is well known |
| Multi-scenario comparison | → Reveals the impacts of different assumptions about the world (can be understood as a subset of the sensitivity analysis) |
| Propagation of uncertainty in input variables through deterministic (or stochastic) modeling | → Reveals the spread (frequency and/or probability) of outcomes due to this uncertainty in the input variable |
| Value of Information, Value of Uncertainty techniques | → Reveal the impact of having perfect knowledge or having knowledge about uncertainty on a specified outcome |
| Model validation/comparison against empirical data or analogues in time or space | → Suggests a level of confidence one can have in model results |

**7** Communicate uncertainties back to the decision-maker



Communication must be mindful of:
Differential familiarity among practitioners with uncertainty concepts and analyses
- Need for variety of formats to present uncertain information
- Need to link back to decision-problem
- Need to explain the nature of uncertainty

### Intended Outcomes

DUST is meant to
- provide scientists and decision-makers with a structured procedure that helps to systematically identify instances where and how science can most effectively support decision-making
- help identify information needs about climate change (impacts) and related decision-relevant uncertainties

DUST is not an assessment or decision-support tool.

Rather DUST is a "boundary object" - a tangible "product" or "tool" that can guide scientist-practitioner interaction. It can help both sides to learn from each other, fine-tune decision-support products, build mutual trust and understanding, but also maintain the necessary boundary between science and decision-making that helps build credibility and trust, increase salience and usefulness, and ensure legitimacy.

## An Application to Coastal Management in California

What scientific information do coastal managers actually need to address the impacts of climate change-driven sea-level rise? In the context of a larger study focused on the coping capacity of coastal California, practitioners' information needs were assessed through a series of semi-structured interviews with key informants in local, state, and federal institutions involved in coastal management.

### Management Challenges


### Current Situation

- No requirement to consider future climate in planning or management decisions
- Most do not use weather-, climate-, or sea level-related information normally in their decision-making today
- Lack the time, staff or financial resources to examine potential impacts of climate change
- Varying degrees of knowledge of or interest in climate change

### Information Needs Regarding Climate Change Impacts

- Translation of projected sea-level rise into shoreline retreat rates, beach erosion rates, and bluff retreat rates expressed for several planning-relevant timeframes (20-25, 50, 75 years)
- Information about potential changes in future coastal storm frequency
- More reliable forecasting of El Niño events, and any changes in the frequency or severity of such events, as they strongly influence the variability in storm frequency, and impacts on shoreline retreat rates
- Remapping of flood zones under different sea-level rise projections
- Information about potential changes in run-off and water temperature, implications for water quality, water availability and aquatic ecology

### Information Needs Regarding Uncertainty

- Provision of uncertainty ranges around projections to indicate scientific confidence
- Distinction between more and less likely impacts (e.g., "at-least SLR" vs. "maybe-as-much-as SLR")
- Provision of scientific basis for uncertainty buffers (e.g., additional setbacks, extra capacity for storm water runoff, different design criteria for shoreline protection structures)

### Information Management/Accessibility Needs

- Exchange of information about possible responses to climate change-related impacts and risks among coastal states and communities
- Better collaboration and exchange of relevant information among all involved agencies (federal, state, local – as needed for different management resorts)
- Integration of existing (and additional) information into common formats, e.g., GIS
- Accessibility of integrated databases at various levels of spatial aggregation/resolution and for different temporal resolutions
- Adequate funding of ongoing monitoring of critical management-relevant variables

## What is DUST good for? - Conclusions

- In California, the greatest obstacles to including climate change related impacts in coastal management at this time is NOT scientific uncertainty per se,
- Instead, lack of awareness, mandate and resources to consider climate change impacts presents the most significant receptivity obstacle (see Step 2).
- Uncertainties in the science become decision-relevant only once climate change and potential impacts have become salient and relevant to decision-makers in a more generic sense.
- Climate change impacts science is most needed in the early stages of policy-/decision-making to enhance the state's coping/adaptive capacity

DUST helps
- streamlining and prioritizing of needed uncertainty assessments
- provide greater transparency and awareness of decision needs and feasible science input
- educate researchers about the decision context in which science may or could be used, and educate decision-makers about the possibilities and limits of science to support decision-making

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