Choosing a decision-making framework to manage uncertainty in climate adaptation decision-making: A practitioner’s handbook

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A Practitioner’s Handbook

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The role of NCCARF is to lead the research community in a national interdisciplinary effort to generate the information needed by decision-makers in government, business and in vulnerable sectors and communities to manage the risk of climate change impacts.

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1. ABOUT THIS HANDBOOK

This Handbook is intended to help people choose a decision-making framework to manage the uncertainty inherent in climate change adaptation decision-making. Climate change introduces additional sources of risk and uncertainty into many decision problems. Decision-making frameworks and decision tools can help people identify sources of uncertainty and the information they require to make decisions.

Choosing a decision-making framework is itself a decision-making problem, so we have structured this Handbook to guide the reader through the process of choosing a decision-making framework. This is intended to reinforce the basic role of a decision-making framework; that is, to help the decision-maker organize their thinking and to provide a structure for the decision-making process.

Accordingly, we begin by discussing the problem of managing risk and uncertainty in climate change adaptation decision-making, we introduce a number of the many available decision-making frameworks, and suggest a few ways to compare these alternatives. The Handbook then seeks to provide some guidance on how to select a decision-making framework that suits individual needs, and provides a guide to implementing and evaluating a decision-making framework.
2. CHOOSING A DECISION-MAKING FRAMEWORK

This Handbook is intended to help people choose a decision-making framework to manage the uncertainty inherent in climate change adaptation decision-making. Choosing a decision-making framework is itself a decision-making problem. Therefore we have structured this Handbook according to the general steps of any decision-making process:

1. Problem formulation
2. Generate alternatives
3. Compare alternatives
4. Apply decision criteria
5. Implement
6. Evaluate

1. Problem formulation: Why choose a decision-making framework to manage uncertainty in climate adaptation decisions?

The problem is to choose a decision-making framework that helps you manage risk and uncertainty in climate change adaptation decision-making.

This section of the Handbook will help you work out whether a decision-making framework would be useful for you. When should people consider using a decision-making framework for dealing with uncertainty in climate change adaptation and why?

2. Generate alternatives: What decision-making frameworks are available?

This section of the Handbook introduces a selection of alternative decision-making frameworks that illustrate some of the different approaches to managing risk and uncertainty. You may choose to implement one of these frameworks, or one of the many related frameworks not reviewed here. You might even choose to adapt some of these frameworks, perhaps by combining their elements to create a new decision-making process that is uniquely suited to your needs.

3. Compare alternatives: What are the advantages and disadvantages of different decision-making frameworks?

Decision-making frameworks commonly combine a conceptual framework that implements a particular approach to decision-making and a procedural framework that provides a step-by-step guide to implementation – we often call this procedural component a decision tool. In particular, decision frameworks differ in how they approach risk and uncertainty. This section of the Handbook provides a broad comparison of decision-making frameworks and shows how different frameworks may combine elements of two meta-frameworks, (1) cost-benefit analysis and (2) adaptive management, and provides examples of how different frameworks seek to manage risk and uncertainty in decision-making.
4. **Apply decision criteria: How can you choose a decision-making framework that suits your needs?**

There are pros and cons of all the available decision-making frameworks, because they make different assumptions about risk and uncertainty and require different kinds and amounts of information and different levels of expertise and investment into the decision-making process.

This section of the Handbook helps you think about what matters to you as the potential end user of a decision-making framework for managing the uncertainty inherent in climate change adaptation decision-making.

5. **Implement: How do you use a decision-making framework?**

Each decision-making framework suggests its own general set of procedures to help guide the decision-making process. Practitioners of these frameworks tend to use them differently and there is also flexibility in the extent the frameworks are used informally, just to structure decision-making, and more formally, to include quantitative methods of decision analysis. There are also a number of decision aids, such as decision trees, influence diagrams, and even brainstorming, which can be used constructively as part of particular decision frameworks, or can provide help more informally at various stages of decision-making.

This section of the Handbook provides a guide to using the selected decision-making procedures, including some links to further information.

6. **Evaluate: Did I choose a useful decision-making framework?**

If decision-making takes place as part of an adaptive and ongoing process then it is useful to evaluate the decision-making process itself so that the practitioner can learn lessons to improve future decision-making processes and provide guidance to others.

This section of the Handbook lists questions people can ask to determine what worked well and what didn’t as they followed their chosen decision-making framework.
3. PROBLEM FORMULATION: WHY CHOOSE A DECISION-MAKING FRAMEWORK TO MANAGE UNCERTAINTY IN CLIMATE ADAPTATION DECISIONS?

Climate adaptation decisions are complicated by uncertainty, multiple and conflicting objectives, different perspectives, and a multitude of adaptation options to choose from. Decision-making frameworks can provide people with a systematic approach to managing all these factors in climate change adaptation decision-making. This Handbook focuses on the problem of choosing a framework to help deal with uncertainty in adaptation decision-making.

People make decisions under conditions of uncertainty every day, but not always at the level of reasoned decision-making\(^1\). At the level of routine, decisions are made quickly and without conscious deliberation. People often deal with uncertainty unconsciously by following rules of thumb, by imitating others, or even by waiting for others to act and thereby provide a vicarious source of experimentation. At the level of imagination, people start to visualize future events and the consequences of alternative actions. At the level of reasoning, decisions involve conscious deliberation.

This Handbook aims to help people with decisions at the level of reasoning. We try to help you with the problem of choosing a decision-making framework that can help you to manage uncertainty in climate change adaptation decision-making. The idea is that choosing a decision-making framework can help people adopt a more conscious and rigorous approach to managing uncertainty in adaptation decision-making.

3.1 Uncertainty in climate change adaptation decision-making

One of the reasons it is useful to use a decision-making framework to explicitly manage the role of uncertainty in decision-making is that there are many alternative systems of terminology for describing different kinds of uncertainty. Various sources of uncertainty are open to manipulation, especially when there are differences of opinion about alternative responses to climate change\(^2\). It is important to consider how you are defining different kinds of uncertainty in your own thinking as you work through the choice of a decision-making framework.

For the purposes of choosing a decision-making framework, we refer to three different kinds of uncertainty in this Handbook. In his book, *Risk and Precaution*\(^3\), Alan Randall captured the general idea of risk and uncertainty by three sources of “chance”:

1. Outcomes are generated by a random process
2. We do not understand the system that generates outcomes
3. The system that generates outcomes is itself changing

These sources of uncertainty affect information about the climate, the ways that the climate impacts upon the things people care about, and the costs and benefits associated with alternative responses to these impacts.
3.2 Reducing uncertainty

There has been some debate about whether or not it is essential to reduce uncertainty at regional scales for the purpose of climate change adaptation decision-making. The idea that reducing this uncertainty is essential for effective decision-making by the end users of climate information appears to have been driven by some physical climate scientists. Although it is clear that decision-makers would often prefer greater certainty, especially if it can be had cheaply, researchers in fields related to decision-making and social science do not place the same emphasis on reducing uncertainty for adaptation decision-making.

In general, identifying the sources of uncertainty that affect a decision-making problem can help us manage the costs associated with these uncertainties and help us determine whether it is desirable, or even possible, to reduce these uncertainties for the purposes of adaptation decision-making. Even where it is theoretically possible to reduce uncertainty, the desirability of doing so depends on the relative costs and benefits and the kind of uncertainties that affect the decision-making context.

If the source of uncertainty is the first kind of chance, where outcomes are generated by a known random process, and if the costs of delaying a decision are sufficiently small, then a rational approach may be to wait until nature resolves the uncertainty. However, it can be dangerous to assume that historically observed variability can always be interpreted as random variation within a stable and well-behaved probability distribution.

Empirical models based on historical regularities are important for many decisions, but if we do not understand the system that generates outcomes, then future events can only be anticipated by a deeper understanding of underlying processes. We can only resolve the uncertainty by conducting research to better characterize the system that generates outcomes. It is common in many contexts to assume that uncertainty is due to the second kind of chance, and that more research will resolve the uncertainties.

If the system that generates outcomes is itself changing, the system can be described as non-stationary and, most likely, complex. In simple and well understood systems, the probability distribution of a particular event is characterized by its mean (the average outcome) and its variance. When the mean or variance of a probabilistic process changes over time it is said to be non-stationary. This leads to problems for forecasting because standard statistical modelling techniques strictly assume stationarity, that is, a constant mean and variance. A violation of these assumptions can lead to highly spurious statistical results. Climate change introduces forms of non-stationarity, thereby increasing the uncertainty at every level, from global projections, through to every kind of prediction and modelling, and the construction of climate scenarios.

The third kind of chance (the kind generated by non-stationary systems) may lead us into the realm of unknown unknowns. In such cases, not all of the uncertainties that influence the system have been identified, which implies that the system is capable of literally surprising us. In decision-making contexts with this kind of chance, opportunities for reducing uncertainties are limited in the absence of major scientific
break-throughs, and the decision-making process is more about learning to live with uncertainty than seeking to reduce it.

4. GENERATE ALTERNATIVES: WHAT DECISION-MAKING FRAMEWORKS ARE AVAILABLE?

There are many alternative decision-making frameworks and we present a number of these that illustrate some key differences, but there are many others not considered explicitly here. You might also find that it is a good idea to adapt an existing decision-making framework (or even combine elements of several decision-making frameworks) to suit your own purposes.

For this Handbook we have selected decision-making frameworks that demonstrate how different frameworks deal with uncertainty in decision-making. We recognize two decision making meta-frameworks: cost-benefit analysis and adaptive management. Many, perhaps most, decision-making tools contain elements, in various degrees, of these two meta-decision-making frameworks.

Each meta-framework is based upon a “big idea” that spawns whole families of related frameworks and tools. The big idea underpinning cost-benefit analysis is that if we repeatedly implement policies and projects likely to make us better-off, we will in the end become better-off. This idea is implemented by constructing outcome scenarios for each action under consideration and evaluating actions in terms of their likelihood of making us better-off or worse-off. The big idea underpinning adaptive management is that we don’t know enough to map outcome scenarios with any confidence, and we are fearful of committing to paths that might lead to disaster. So we move incrementally through a long sequence of plan-implement-monitor-adjust cycles, a process intended to encourage learning, improve management, and limit risk exposure.

Both of these meta-frameworks have spawned many variants, more or less sophisticated in their treatment of risk and uncertainty. There are even instances of convergence between these meta-frameworks, represented here by real options analysis which introduces the idea of sequential information gathering and decision making into the cost-benefit meta-framework.

The frameworks examined in this Handbook are abbreviated as follows:

- **CBA**  Cost-benefit analysis
- **INFFER**  Investment Framework for Environmental Resources
- **ROADs**  Real Options for Adaptive Decisions
- **RAM**  Resilience Analysis and Management
- **SAM**  Strategic Adaptive Management
Choosing a decision-making framework to manage uncertainty in climate adaptation decision-making

We use the abbreviation CBA here to refer to traditional, simplified application of cost-benefit analysis, distinct from the meta-framework of cost-benefit analysis.

Over the next paragraphs, we briefly introduce the decision-making frameworks compared in this Handbook. Later sections of the Handbook compare how the different frameworks deal with uncertainty in decision-making.

4.1 Cost-Benefit Analysis (CBA)

Simplified CBA compares the net benefits of alternative public projects with a business-as-usual scenario, by taking into account all costs and benefits for a defined community or society as a whole. CBA aims to compare all costs and benefits, estimated using market prices and monetary estimates of non-market values. CBA prescribes choosing the alternative with the highest net benefit, evaluated in monetary terms and adjusted into present values by discounting future net benefits for the purpose of comparison.

Externalities and other forms of market failure mean that market prices may not accurately measure the value of scarce resources; non-market valuation methods can be used to measure differences in values associated with the alternative scenarios compared with the business-as-usual scenario. Various methods are used to estimate of costs and benefits associated with use and non-use values, including the costs and benefits associated with option, bequest, and existence values. Valuation is based on people’s individual preferences measured as their willingness-to-pay, aggregated to obtain a value for society.

4.2 Investment Framework for Environmental Resources (INFFER)

INFFER is essentially a version of Cost-Benefit Analysis and is designed to provide a systematic framework for the prioritization of assets (usually environmental) for investment of scarce resources (time, money, etc.). INFFER is a proprietary decision support tool, and application of the framework requires the use of accredited consultants. Basically, it serves as a consolidation of some of the basic principles of CBA. It’s a step-by-step application for the management of environmental assets. The main differences between INFFER and CBA are that INFFER does not estimate benefits in dollar terms and is specifically designed for environmental management projects.

4.3 Real Options for Adaptive Decisions (ROADs)

Real options analysis is a modern analytical method for flexible decisions under uncertainty, including deciding when to act. We use the abbreviation ROADs here to refer to the specific framework developed by Hertzler (2007) to examine questions of the optimal timing of decisions, specifically, in applications to agricultural and resource decisions in climate change adaptation. Real options approaches examine the trade-off between responding now, based on available information, and retaining the option to respond later, based on new information that might help to resolve some of the uncertainty. This decision-making framework takes into account the option values associated with waiting for more information about uncertainty when working out the optimal timing of an action. While ROADS is adaptive in the sense that it is all about...
maintaining the opportunity to revise plans in light of new information, its attention to expected values reveals its roots in the cost-benefit analysis meta-framework.

### 4.4 Resilience Analysis and Management (RAM)

RAM is a decision-making framework that puts the ideas described by Brian Walker and David Salt in their books *Resilience Thinking* and *Resilience Practice* into practice. An organization called the Resilience Alliance champions this approach to the management of ‘social-ecological systems’ and has produced online workbooks to help researchers and practitioners apply these ideas. It is important to point out that whilst these workbooks provide practical guidance, and a step-by-step guide, there is a great deal of flexibility in the application of this system of ideas as a decision framework.

The idea that social-ecological systems may contain thresholds and may exhibit hysteretic and irreversible changes into alternative regimes is central to RAM. This decision-making framework seeks to identify and understand the processes that produce these thresholds.

### 4.5 Strategic Adaptive Management (SAM)

SAM is a particular approach to adaptive management developed through lessons learned from the management of Kruger National Park in South Africa. This decision-making framework focuses on managing the interface between science, policy, and stakeholders by connecting a strategic vision of ecological and societal values with the ecological endpoints that can be monitored as part of the management process.

A hierarchy of objectives is formulated starting with a value-based statement of strategic intent suitable for upper levels of management and for communicating with the general public. At lower levels of management, goals are defined using specific ecological endpoints referred to as ‘thresholds of potential concern’ that are described using ranges of values bounded spatially and temporally. These thresholds of potential concern are used as indicators of a systems response to potential drivers of change.

### 4.6 Further reading

If you would like further information about the use of these particular decision-making frameworks, here are some suggestions for further reading:

- **CBA**  

- **INFFER**  
  http://www.inffer.org/

- **ROADs**  

- **RAM**  
5. COMPARE ALTERNATIVES: WHAT ARE THE ADVANTAGES AND DISADVANTAGES OF DIFFERENT DECISION-MAKING FRAMEWORKS?

We have examined a selected set of decision-making frameworks and broken them up into their conceptual framework and their procedural framework (their step-by-step guide). This section of the Handbook demonstrates some of the key differences among the decision frameworks in terms of the kinds of uncertainty they address and the way they deal with uncertainty in decision-making.

5.1 Cost-Benefit Analysis (CBA)

The simplest forms of CBA treat risky and uncertain prospects as certainty-equivalent, by valuing benefits and costs at their expected values. Certainty-equivalence is appropriate for a risk-neutral decision maker (one whose preferences are attentive to mean values but not to variability). Applications of CBA based on this principle invest a good deal of effort in assessing possible outcomes and calculating their expected values. Where data are inadequate to calculate probabilities, simplified CBA often proceeds with subjective (i.e. best guess) probabilities and the expected values calculated are treated as certainty-equivalent.

The broader cost-benefit analysis meta-framework has incorporated risk and uncertainty in a variety of ways since the 1950s.

- With risk-aversion (a degree of preference for sure outcomes over variable outcomes), attention turns to the expected utility (rather than expected value) of benefit and cost streams. Willingness-to-pay is now explicitly for uncertain prospects, rather than for certainty-equivalent prospects as immediately above, and concepts of options price and option value come into play.
- A different perspective on option value was provided by Arrow and Fisher (1974) and Henry (1974), who defined quasi-option value as the value of the opportunity to defer a decision given that new information resolving (some of) the uncertainty may emerge in the interim.
- Real options theory generalised the value of keeping options open – the value of waiting, including the value of any learning that may occur while we wait. The
value of an uncertain stream of benefits and costs is now conceptualised as the value of the relevant real option.

The bottom line is that the whole apparatus of utilitarian analysis of risk and uncertainty is available to applications of the cost-benefit analysis meta-framework and is implemented in the most sophisticated applications thereof. However, simplified CBA takes refuge in certainty-equivalence, which is attentive to the mean of the relevant distribution but not its variability.

### 5.2 Investment Framework for Environmental Resources (INFFER)

INFFER approaches uncertainty by using probabilities to represent the risks of project failure. These are the risk of technical failure, socio-political risks, and risks associated with the continuity of funding for a project. Whereas a similar approach for incorporating uncertainty into CBA would elicit a joint probability distribution for possible outcomes, INFFER simplifies its treatment of uncertainty by allowing only two possible outcomes for each type of risk above, which assumes that the project will either succeed or fail completely.

### 5.3 Real Options for Adaptive Decisions (ROADs)

Real options analysis is a modern analytical method for flexible decisions under uncertainty, including deciding when to act. We use the abbreviation ROADS here to refer to the specific framework developed by Hertzler (2007) to examine questions of the optimal timing of decisions, specifically, in applications to agricultural and resource decisions in climate change adaptation. Real options approaches examine the trade-off between responding now, based on available information, and retaining the option to respond later, based on new information that might help to resolve some of the uncertainty. This decision-making framework takes into account the option values associated with waiting for more information about uncertainty when working out the optimal timing of an action.

While ROADS is adaptive in the sense that it is all about maintaining the opportunity to revise plans in light of new information, its attention to expected values reveals its roots in the cost-benefit analysis meta-framework.

### 5.4 Resilience Analysis and Management (RAM)

The conceptual framework behind this decision-making framework is the basis of its approach to dealing with uncertainty. A number of concepts are used to describe the dynamics of complex adaptive social-ecological systems, including resilience, thresholds, adaptive cycles, panarchy, functional diversity, response diversity, adaptive capacity and transformability. RAM promotes the idea that the most pragmatic way to manage ecosystems that are faced by increasing environmental change and uncertainty is to build the resilience of the desired states of the social-ecological system.

One of the assumptions of the resilience approach is that probability distributions for key decision variables are highly uncertain and that both the functional form and the parameters of probability distributions may be unknown. A consequence of this assumption is that extreme forms of uncertainty need to be taken into account. These
include the possibility of unknown unknowns and the possibility that key parameters might change faster than we can update information.

5.5 **Strategic Adaptive Management (SAM)**

SAM uses a process of active adaptive management to deal with uncertainty. The thresholds of potential concern serve as hypothesis about the limits of acceptable change in terms of ecosystem structure, function and composition. By integrating monitoring, research and modelling to track indicators relative to the defined thresholds of potential concern, managers can better determine what actions are needed, or whether thresholds of potential concern should be revised to better fit the overall strategy. The effect of uncertainty on the decision-making process in application of adaptive management extends to uncertainty about the goals of management, and therefore the adaptive management framework seeks to revise objectives over time.

The following table summarises some other advantages and disadvantages of the decision-making frameworks in turn.
<table>
<thead>
<tr>
<th>Decision-making framework</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBA</td>
<td>Simplified CBA identifies a clearly preferred option using a method that has credibility with many government agencies and that has been widely validated. Social welfare and equity concerns can be considered within the CBA framework.</td>
<td>The economic valuations required for a CBA, particularly non-market valuation, can be difficult. Choosing a discount rate for net present value calculations can be contentious. Incorporating sophisticated treatments of risk and uncertainty into CBA is not easy. CBA assumes we know enough to map streams of benefits and costs over many years into the future. Long time frames and uncertainty about climate change mean that it is difficult to quantify the costs and benefits of adaptation options.</td>
</tr>
<tr>
<td>INFFER</td>
<td>INFFER provides a step-by-step version of CBA specifically for environmental management. As a proprietary process, INFFER enables environmental managers to draw upon the expertise of its developers, specifically David Pannell’s group based at the University of Western Australia. INFFER draws upon a “public-private benefits” framework that is useful for communicating the appropriateness of alternative policies.</td>
<td>As a simplified version of cost-benefit analysis, INFFER can be subject to many of the criticisms that apply generally to simplified cost-benefit analysis. The practical application of INFFER assumes a discount rate fixed at five percent. This assumption is problematic for the assessment of benefits and costs over very long time horizons. The INFFER framework addresses uncertainty using simple proxies for complex sources of uncertainty.</td>
</tr>
<tr>
<td>ROADs</td>
<td>Real Options explicitly takes account of the uncertainty and places a value on the irreversibility of a decision, both common features of climate adaptation decisions. Real Options values at every stage the costs and benefit of making a decision, even where there are uncertainties about future outcomes. Basic incarnations of Real Options are accessible to users who come from non-technical backgrounds. Hertzler (2007) uses diagrams which allow users to represent the stages and options associated with their decision problems. Further, these decision diagrams have the benefit of facilitating communication between decision makers and researchers by clearly identifying where greater information is required to inform</td>
<td>The real options framework is mostly about organizing information and making assumptions explicit as a preliminary step before a mathematical analysis. The framework doesn’t resolve the issues in characterizing alternative futures and valuing them (including the nonmarket valuation of outputs, quantifying risk aversion, etc.). In this context, the main disadvantages of real options are its demand for quantitative data and its reliance on the existence of a portfolio capable of replicating the cash flows associated with a given strategic decision, which can be very difficult to compute.</td>
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### Table: Decision-making framework

<table>
<thead>
<tr>
<th>Framework</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tr>
<td><strong>RAM</strong></td>
<td>The advantages of RAM arise from its underlying conceptual model. This model presents stakeholders with a new perspective on environmental and resource dilemmas. The ideas of adaptive cycles, resilience, and the possible existence of thresholds, all help RAM practitioners to engage with stakeholders to describe key elements of dilemmas in environmental management. The attention paid to slowly changing key driving variables encourages a long term perspective to managing uncertainty. RAM emphasizes the importance of stakeholder involvement in a process of active adaptive management.</td>
<td>RAM aims to help stakeholders develop a shared vision and understanding of the resilience and desired states of the social-ecological system. Whilst this is an advantage, if this is not achieved RAM does not have much to say about the rest of the decision process, i.e. making decisions whilst managing irresolvable conflicting interests amongst different stakeholders. RAM is an approach for framing decision problems in terms of complex system theory, and aside from arguing that building and enhancing resilience is the most pragmatic way to manage complex social-ecological systems, it does not specify rigorous decision criteria for balancing the value of resilience with other stakeholder values. At this stage of its development, the implementation of RAM relies heavily on the enthusiasm of its proponents.</td>
</tr>
<tr>
<td><strong>SAM</strong></td>
<td>One of the advantages emphasized by advocates of SAM is the use of different formulations of the vision and objectives for communication purposes, with more general statements to help upper levels of management communicate with the broader public, and specific statements of management objectives formulated for environmental managers in a specific and measurable manner. Adaptive management approaches seem better adapted to complex human and natural systems with the property of increasing unpredictability.</td>
<td>SAM was developed specifically for the management of National Parks and its application to a broader range of climate change adaptation decision problems is relatively untested.</td>
</tr>
</tbody>
</table>
6. APPLY DECISION CRITERIA: HOW CAN YOU CHOOSE A DECISION-MAKING FRAMEWORK THAT SUITS YOUR NEEDS?

To choose a decision-making framework that suits your needs you will need to consider a number of factors in addition to their different approaches to dealing with uncertainty. In this section we outline a few broad criteria you might use to help you select a decision-making framework.

One way to choose a framework is evaluate alternative decision frameworks against normative ideals. For example, Adger et al. (2005) suggest that an ideal decision support tool for climate change adaptation is effective, efficient, equitable, and legitimate.

An **effective** tool achieves specific objectives, but also avoids unintended consequences or perverse outcomes, and therefore assessing effectiveness needs to take the uncertainties in links between actions and outcomes into account.

An **efficient** decision support tool leads to decisions with greater benefits than costs and requires consideration of market and non-market values, the values associated with the timing of adaptation actions and the distribution of costs and benefits.

An **equitable** decision support tool pays attention to public and private interests, and particularly vulnerable groups. Here, decisions may be weighted or constrained by ethical considerations, such as concern for future generations and the responsibility for decisions and impacts (see also Fischlin 2007, p. 248).

A **legitimate** tool in political terms has the approval of those people who are affected by the decision. Any decision requires trade-offs and the legitimacy of a decision support tool will help manage potential conflicts over the resulting distribution of costs and benefits.

### 6.1 Taking the types of uncertainty into account in choosing a decision-making framework

The decision frameworks vary in the kinds of risk and uncertainty they can handle. In the end, the practitioners’ choice of decision framework is not so much influenced by the real-world situation regarding risk and uncertainty as by the practitioners’ willingness to abide simplifying assumptions about that risk and uncertainty.

<table>
<thead>
<tr>
<th>Source of uncertainty (three kinds of chance)</th>
<th>Simplified CBA</th>
<th>INFFER</th>
<th>ROADS</th>
<th>RAM</th>
<th>SAM</th>
</tr>
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<tbody>
<tr>
<td>Outcomes are generated by a random process</td>
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</table>

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For example, practitioners willing to make best guesses about outcomes generated by systems they suspect are in fact changing can evaluate options with simplified CBA, but the future may surprise them with outcomes they had not considered.

We recommend careful consideration of your decision-making context as you work out the potential costs of assuming simpler forms of chance when the second or third kinds of chance might be in play. In general, with simplified CBA the appropriate decision contexts are best characterized as deciding between known solutions to known problems – the more you think you know, the more likely you will be to use simplified CBA. In the meta-framework of adaptive management, decision-making contexts may be characterized by the expectation that adaptation will involve discovering new solutions to new problems as part of an ongoing decision-making process.
7. IMPLEMENT: HOW DO YOU USE A DECISION-MAKING FRAMEWORK?

This section of the Handbook outlines the basic procedures followed by the different decision-making frameworks. However, first it can be useful to consider whether you want to use a framework formally and prescriptively, or whether it would be sufficient to use a framework as an informal guide to structure your decision-making process.

We should point out that, as you examine frameworks that incorporate elements of adaptive management, these frameworks encourage decision-makers to adapt procedures for their own specific purposes and not to rely as heavily upon prescriptive step-by-step guides.

Over the next several pages we provide outlines of the decision-making procedures followed by each decision-making framework, with a particular focus on their approaches to uncertainty. Of course, if you choose to use one of these frameworks to guide your decision-making process, we recommend consulting the references listed under Further Reading in section two of this Handbook.

7.1 The procedures of simplified Cost-Benefit Analysis (CBA)

CBA aims to compare the costs and benefits associated with alternative policies or public projects with the costs and benefits of the business-as-usual scenario. Costs and benefits are estimated using market prices and non-market valuation. Costs and benefits are based upon individual’s preferences, measured as their willingness-to-pay, and aggregated to obtain a value for society as a whole. To take into account people’s preferences for consumption now rather than later and the opportunity costs of alternative uses of capital, future costs and benefits are adjusted into present values using a discount rate.

The basic stages in a simplified CBA are:

1. Identify appropriate policy actions based on the drivers of the system.
2. Model the scenarios that result from each alternative policy action to compare with the business-as-usual scenario.
3. Quantify the costs and benefits associated with these scenarios.
4. Select the alternative with the highest net present value.

Present values (PV) are calculated using the formula $PV = F/(1 + r)^t$, where $F$ stands for future value of the estimated benefits or costs and $r$ is the selected discount rate and $t$ is the year in the life of the project.

For a more extensive discussion on CBA methods see Layard and Glaister (2003), Boardman et al. (2006), or Mishan and Quah (2007).

7.2 The procedures of the Investment Framework for Environmental Resources (INFFER)

The approach taken by INFFER to project development, prioritisation and assessment process involves a simple filtering to choose alternatives before a more detailed
assessments, based on a subset of criteria, a process of project development and assessment that is similar to CBA, and a feasibility assessment.

The initial filtering aims to identify good projects based on asset value and threat, involving a pre-consultation checklist and then community consultation and input. INFFER starts by identifying assets and then environmental threats, to keep the focus on outcomes.

**INFFER has seven stages:**

1. Develop a list of significant natural assets in the relevant region(s)
2. Apply an initial filter to the asset list, using a simplified set of criteria
3. Define projects and conduct detailed assessments of them
4. Select priority projects
5. Develop investment plans or funding proposals
6. Implement funded projects
7. Monitor, evaluate and adaptively manage projects

INFFER seeks to manage uncertainty by incorporating probability estimates of various risks associated with technical feasibility, the private adoption of actions, project failure, and socio-political risks into the calculation of a benefit ratio or index.

For further information see:

[http://ageconsearch.umn.edu/bitstream/59148/2/Pannell%2c%20David.pdf](http://ageconsearch.umn.edu/bitstream/59148/2/Pannell%2c%20David.pdf)

### 7.3 The procedures of Real Options for Adaptive Decisions (ROADs)

To examine questions of optimal timing, the ROADs approach represents sequences of transition between ‘regimes’ that is used to describe how people might change their activities over time in order to adapt. This approach calculates the value of remaining in a current regime, whilst retaining the option to switch to another regime later if needed. With uncertainty, there is always a trade-off between responding immediately by changing to an alternative regime based on less information versus the choice to remain in the current regime whilst retaining the option to respond later when new information that reduces the level of uncertainty might become available. The timing of these switches depends on the risks and uncertainties associated with the alternative regimes.

The basic steps in the ROADs approach to real options analysis are:

1. Identify the characteristics of your current regime in terms of its associated expenditures and revenues, or more generally in public decision-making, the streams of costs and benefits that you experience in your current regime.
2. Identify the characteristics of your current regime that produces the uncertainties. For example, is the stream of benefits uncertain? Can it be described as a stochastic process?
3. Repeat step 1 and step 2 for each of the other regimes (your decision alternatives) that you have the option to switch to.
10. For each of the regimes, current regime and alternative regimes, approximate the identified source of uncertainty (e.g. an uncertain stream of revenues) using a stochastic differential process (a mathematical description of the stochastic process).

11. Using the ROADs modelling approach, construct the relevant options equations using information gathered in steps 1 to 4.

12. Run the computational model, to identify measures of willingness to pay to exit your current regime and enter an alternative regime. This provides you with the threshold option values of exiting the current regime and entering an alternative regime.

Pindyck (2000) provides an example of how irreversibility and the timing of climate change policy can be taken into account in a real options analysis. When option values are taken into account, uncertainty means that it becomes more valuable to wait until some of the uncertainty is resolved before a decision is made.

A real options framework allows decision makers to model the timing of decisions by calculating the values associated with various aspects of climate adaptation decision problems. These include option values but also the costs of switching back after a mistaken decision to switch, and the costs and benefits associated with the timing of adaptation decisions, such as the implications for new investments or alternative policy strategies. This type of analysis can help end users better understand the value of investments into new technologies and the impact of alternative policies. However, it should be noted that the information requirements of a formal real options analysis can be high, and can involve the practitioner in substituting best guesses for firm estimates of outcomes and their probabilities.

7.4 The procedures of Resilience Analysis and Management (RAM)

There are four basic stages of RAM with stakeholders involved in every stage of the process. The resilience thinking perspective argues that it is important to for the managers of the system to be seen as part of the social-ecological system that is being managed.

1. Resilience of what? Resilience is considered in a specific context. This first step of RAM describes a conceptual model of the social-ecological system under consideration, including its spatial boundaries, its key ecosystem goods and services and their values. This stage of the process aims to identify important controlling variables that drive key ecosystem goods and services, with a view to identifying the factors that can be managed, e.g. land use policy, and those that cannot, e.g. the climate.

2. Resilience to what? The second stage of the process develops scenarios and visions to examine the external disturbances, policy drivers, and stakeholder actions to which a desirable regime is expected to be resilient. Around three to five future scenarios are developed to describe the possible outcomes of uncontrollable external drivers. The aim is to describe scenarios that cover the most important uncertainties and visions for the future. Visions describe the
preferred directions for the system, and are likely to differ between different stakeholder groups. The scenarios provide the basis for developing possible responses to previously unanticipated events, i.e. confronting stakeholder with possible surprises. They are developed by considering external shocks and disturbances, visions, hopes and fears and possible policies.

3. **Resilience analysis.** The third stage explores the interactions between the future states of the system that stakeholders care about and the major uncertainties about how the system will respond to the drivers of change. The aim is to identify the driving variables and processes that govern the dynamics of the ecosystem goods and services, with a particular focus on possible threshold effects and other non-linear dynamics. The resilience of the system is analysed beginning with discussions amongst stakeholders, policy makers, other local experts, and scientists, to examine how the system will respond and change under the various scenarios. This stage seeks to identify whether there are known or suspected alternative regimes, how a shift into an alternative regime might affect social wellbeing, and the probability of crossing a threshold into an alternative regime.

4. **Resilience management.** The final stage examines the implications of the resilience analysis conducted in the first three steps for policy and management actions. The first three stages identify the processes that determine critical levels of the system’s controlling variables and the fourth stage identifies a corresponding set of actions that can enhance or reduce resilience and form the basis of management and policy. The intended outcome is a set of targets for policy and management that will achieve sustainability in the form of continued well-being for the social-ecological system.

### 7.5 The procedures of Strategic Adaptive Management (SAM)

To better integrate science and management as part of a process of active adaptive management, SAM involves stakeholders in the management process, seeks to define acceptable goals and endpoints in operational terms, and integrates hypothesis generation and testing into a partnership between scientists and managers for auditing goal attainment.

**SAM has four stages:**

1. Establishing the strategy by describing the desired future through a vision statement that takes the form of value-based statements of strategic intent
2. Managing options by developing a model of the system
3. Operationalization through implementing management options
4. Evaluation and learning

**The management process of SAM consists of three types of activity:**
1. An operational framework sets and evaluates attainable and acceptable goals that reflect the desired future state of the system and selects and implements appropriate management actions.

2. A predictive modelling framework aims to predict the consequences of management actions and other changes to the system in order to help evaluate whether the consequences of management actions are acceptable.

3. A system response framework monitors the response of the system to management action and natural disturbance and change as well as auditing the attainment of goals.

SAM is process of active adaptive management where thresholds of potential concern serve as hypotheses about the limits of acceptable change in terms of ecosystem structure, function and composition. The predictive modelling framework is used to evaluate whether management actions have the intended consequences; however, rather than relying upon predictive models for management, emphasis is placed on the importance of monitoring the system with respect to thresholds of potential concern. This approach takes into account the limits of predictive modelling when seeking to manage a complex or non-stationary system. By integrating monitoring, research and modelling to track indicators relative to the defined thresholds of potential concern, managers can better determine whether actions are needed or whether thresholds of potential concern should be revised.
8. EVALUATE: DID I CHOOSE A USEFUL DECISION-MAKING FRAMEWORK?

If decision-making takes place as part of an adaptive and ongoing process then it is useful to evaluate the decision-making process itself so that the practitioner can learn lessons to improve future decision-making processes and provide guidance to others.

To help you evaluate the decision-making process you have chosen to follow, we list here a few key questions you can ask yourself, based on the approaches to each stage of the decision-making process taken by the various decision-making frameworks examined in this Handbook.

- Who are your stakeholders and how much have you managed to involve them in the decision-making process?

All modern decision-making frameworks can be adapted to include an element of stakeholder engagement. Those that that incorporate the iterative processes common to adaptive management are more likely to involve stakeholders directly in managing uncertainty, including uncertainty about the nature of the system and the costs and benefits associated with alternative policies.

- What kinds of uncertainty are involved in my decision context?

Did you take into account the possibility of non-stationarity, thresholds, or non-linear feedbacks? If so, were you able to reach the decisive conclusions you perhaps were seeking? If more definitive answers are a goal, you may be willing to resort more to best guesses about the uncertainties in your problem situation. If not, are you comfortable with the kind of answers you are got, or do you worry that important uncertainties might have been overlooked?

Has enough time passed to get a sense of whether the decisions actually made have turned-out well? For example, if the decisions made have led to unforeseen consequences, it could be that you have not taken all sources of uncertainty into account in the decision-making process.

- Have I considered policy actions that might help me learn about the system that generates outcomes?

Decision-making frameworks that incorporate the idea of active adaptive management seek to reduce uncertainty by learning about some aspects of the decision context as a component of their policy approach.

- Was my decision-making framework effective, efficient, equitable, and legitimate?

Some of the same criteria used to compare decision-making frameworks are useful also as criteria to evaluate your decision-making process. If your decision framework drew mostly on the cost-benefit analysis meta-framework, are you comfortable that it was sufficiently equitable and legitimate? If it drew mostly on the adaptive management
meta-framework are you convinced that it was sufficiently effective and efficient? If you worry about the second and third kinds of chance (we don’t understand the system, and the system itself may be changing), are you confident you have a clear idea of what constitutes effective and efficient decision making?

9. DISCUSSION AND CONCLUSIONS

This Handbook is intended to provide advice to decisions-makers about selecting a decision-making framework to help them manage uncertainty in climate adaptation decision-making. We address these decision frameworks by identifying two meta-frameworks, cost-benefit analysis and adaptive management, that provide general structure for decision making and serve as platforms for continuing development and improvement, and springboards for specialized versions address particular decision problems in particular ways. Cost-benefit analysis approaches are essentially reductive, and are best suited to comparing two or more alternative paths of action mapped-out from beginning to the far time horizon. Adaptive management approaches are more attuned to complex systems theory, and emphasizes learning by doing, and revision of plans in light of what is learned about system response and what is revealed by nature as the future unfolds.

Alternative decision frameworks take different approaches to uncertainty. Those rooted in the cost-benefit analysis meta-framework are inclined to calculate expectations, e.g. outcome sets and often expected values, sometimes substituting best guesses for better information. But this practice moves the process along toward decision making that is likely to be effective and efficient.

Some adaptive management approaches emphasize the importance of continually learn from implementation in order to improve future decisions. Resilience Analysis and Management pays particular attention to problem formulation – bringing stakeholders together to develop a shared understanding of a complex social-ecological system. Strategic Adaptive Management places a greater emphasis on implementation through an ongoing process of monitoring and re-evaluation of thresholds of potential concern.
10. REFERENCES


Choosing a decision-making framework to manage uncertainty in climate adaptation decision-making


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1 Selten (1978) describes these three levels of decision-making.

2 If you need to think more about the role of uncertainty in the climate debate, you might find Smithson’s (1989) Taxonomy of Ignorance to be a useful reference. Smithson (1989) provides a taxonomy that helps identify the various ways uncertainty can be manipulated in a debate.

3 See Randall (2012) for a discussion of risk and uncertainty at the level of public policy and decision-making.

4 Mearns (2010) summarizes this debate and noted that the scientific literature indicates that “physical climate scientists tend to consider reducing uncertainty on regional scales to be essential” for climate change adaptation (pp. 81-82).

5 Uncertainty can provide opportunities for innovation and creativity. See Bammer and Smithson (2008).

6 Using the example of the collapse of a price bubble, Lawson (1985) discusses when it might be better to seek a deeper understanding of underlying processes, rather than basing empirical models on historical regularities. The second approach sees deviations from the expected value of an observed variable as a form of disequilibrium, but when it is possible that fundamental changes to the systems that generate outcomes are occurring, a non-equilibrium perspective is more appropriate.

See Milly et al. (2008) for a discussion of non-stationarity in the context of water management.

See Dixit and Pindyck (1994); Copeland and Antikarov (2001); Heal and Kriström (2002); Hertzler (2007).


See Rogers and Biggs (1999).

See Dixit and Pindyck (1994); Pindyck (2007).

See Holling and Meffe (1996); Carpenter et al. (2001); Scheffer et al. (2001); Capon et al. (2009).

See the draft report from the Productivity Commission about barriers to climate change adaptation for a discussion of this point.

See Balmford et al. (2008) for an example of an application to biodiversity management.

Anda et al. (2009) and Yohe et al. (2004) both concluded that accounting for uncertainty in climate sensitivity justifies more drastic near-term emission reductions than a conventional CBA.

The descriptions of RAM and SAM here are based on a more complete summary presented in Capon et al. (2009). See Walker and Salt (2006) and Walker and Salt (2012) for a more thorough description and examples of applications of RAM. See Kingsford and Biggs (2012) for a more thorough description and application of SAM.

See Rogers and Biggs (1999).