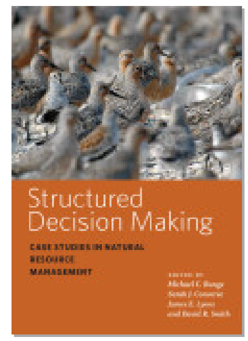
Structured Decision Making

Runge, Michael C., Converse, Sarah J., Lyons, James E., Smith, David R.



Published by Johns Hopkins University Press

Runge, Michael C., et al.
Structured Decision Making: Case Studies in Natural Resource Management.
Johns Hopkins University Press, 2020.
Project MUSE. doi:10.1353/book.74951.

PART I STRUCTURING DECISIONS

This page intentionally left blank

2 Introduction to Structuring Decisions

David R. Smith

Decision structuring, also known as decision framing, provides the foundation and roadmap for analyzing a decision. For decisions that warrant a systematic approach, structuring begins with identifying the problem for analysis. This sounds simple but can be deceptively difficult because decision problems are often ill-formed at the start. Many have worked on a problem, alone or with others, only to realize down the road that it's the wrong problem, something Ron Howard—a founder of the decision analysis discipline—calls an "error of the third kind." How a decision is framed can have a profound effect on subsequent analysis and solution. Tools and templates are available to get started, but perhaps no technique is more essential than simply taking the time to ponder what the problem is all about. All of the case studies in this book have gone through decision structuring, and most followed an iterative prototyping process. In particular, the case studies in part 1 highlight the value of decision structuring to uncover hidden assumptions hindering a good solution and identify the scientific information needed.

Introduction

Decision analysis, in the words of Ron Howard (1988), is a systematic process for "transforming opaque decision problems" into "transparent decision problems by a sequence of transparent steps." By opaque, he meant "hard to understand, solve, or explain; not simple, clear, or lucid." The key feature of this definition is that important decisions are often ill-formed as presented and that the initial and perhaps the central challenge is to clarify and identify the problem for analysis. This first-order challenge is so important that Howard Raiffa (2002), when reflecting over his extraordinarily productive career, mused that he "completely missed the boat" early on by ignoring "the nonmathematical underpinnings [of decision analysis]," namely, "how to identify a problem . . . to be analyzed." To meet this challenge, a decision analyst turns to decision framing (Keeney 2004a) or decision structuring (Gregory et al. 2012), which is the topic of this section. It is only through structuring the decision that an error of the "third kind; namely, working on the wrong problem" can be avoided (Howard 1988). It is not uncommon for a collaboration among decision makers and stakeholders to spend considerable time and effort working on the wrong problem, as Howard warned, or on decisions implicitly defined differently by the participants.

What is decision structuring? Simply speaking, decision structuring is identifying the problem to be analyzed, which von Winterfeldt and Edwards

(2007, 84) likened to "hunting for the decision." To structure a decision is to define the scope of and scale for its basic elements (table 2.1). The essence of decision analysis is decomposing a problem into its elemental parts, reflecting both value-based and technical aspects of a decision. Howard (1988) separates the generic problem into the 3-part "decision basis": the choice of alternatives, the information available to evaluate the choice, and the preferences in values, time, and risk to guide the choice—sort of a 3-legged stool. Hammond et al. (1999), in contrast, split the decision problem into 5 components: problem definition, objectives, alternatives, consequences, and trade-off analysis—the PrOACT process embedded into structured decision making (Gregory et al. 2012; Runge and Bean, chapter 1, this volume, fig. 1.1). In addition to those basic components, the decision structure identifies key actors (decision makers and stakeholders), uncertainties, and constraints. Structuring roughs out those decision parts before starting the analysis, as an artist might sketch the vision of a sculpture before starting to carve. While there is not a single "correct" structure (Gregory et al. 2012), a "good solution to a well-posed decision problem is almost always a smarter choice than an excellent solution to a poorly posed one" (Hammond et al. 1999).

The structuring of the decision problem influences both the range of possible solutions and how

Table 2.1. Basic elements of a decision structure

Elements
1. Identify the decision maker(s)
2. Identify other key actors
• Decision implementers and stakeholders
• Technical experts and facilitators
3. Consider the legal and regulatory context
4. Consider the decision structure
• Timing and frequency of the decision
• Temporal and spatial scope and scale
• Initial set of objectives
• Possible actions
• Constraints (perceived and real)
• Key uncertainties
5. Consider the type of analysis required
6. Revise as needed

decision makers and stakeholders feel about the solutions. While there is no single "correct" structure (Gregory et al. 2012), some framings will be more useful than others. Solving the decision problem is the end point, but all problems begin with decision framing. Insufficient time spent on framing often leads to wasted time at the analysis stage. Taking a shortcut by jumping over objectives and going straight to alternatives often results in a misplaced focus on the "means" rather than the "ends" (Keeney 1996). Depending on where the frame is placed to define the problem, the potential solutions will focus on strategic, fundamental, or means objectives (Keeney 1996, 44–47). For example, a focus on habitat improvement limits analysis to achieving a habitat goal; if instead species conservation is the target, factors other than habitat can determine viability. The framing effect can operate at a cognitive level, as in the well-known framing trap (Hammond et al. 1999; Tversky and Kahneman 1986), where whether a choice is framed in terms of gains or losses affects which alternative is preferred. In decision structuring, the framing effect can determine whether a problem is viewed narrowly or broadly.

To illustrate how framing can profoundly affect decision context, consider management of horseshoe crabs (*Limulus polyphemus*) and red knots (*Calidris canutus rufa*), which is the topic of chapter 24 (McGowan et al., this volume) and described by McGowan et al. (2015b). Two dramatically different scales can apply to this problem depending on whether we consider management at a single migratory stopover site or management across the range of a migratory species. Each spring, horseshoe crabs spawn on Delaware Bay beaches in densities so high that the crabs disturb each other's nests, bringing safely buried eggs up to the sandy surface where they are accessible to foraging shorebirds. At roughly the same time, red knots migrate from wintering areas to the breeding areas in the Arctic. Along the migratory route, the shorebird stops over at multiple places to refuel, including Delaware Bay with its abundance of fat-rich horseshoe crab eggs. Harvest of horseshoe crabs for bait and biomedical products sets up a trade-off between harvest of crabs and conservation of red knots. A horseshoe crab population decline due to overharvesting in the 1990s contributed significantly to a drop in the red knot population. The US Fish and Wildlife Service (USFWS) listed the red knot's status as threatened under the Endangered Species Act, citing that the primary future threats are "habitat loss and degradation due to sea level rise, shoreline hardening, and Arctic warming," which includes threats outside of Delaware Bay (USFWS 2014). The *broad frame* is how to recover the red knot so that it is no longer a threatened species. This broad framing would include actions throughout the red knot's wintering, stopover, and nesting habitats. The *narrow frame* is how best to manage the harvest of horseshoe crabs in Delaware Bay while providing forage for migratory shorebirds.

These framings are not mutually exclusive, and for management to be ultimately successful, both problems need to be solved. The 2 complementary frames provide insight into the nature of the trade-offs at each scale. The harvest management problem nests within the red knot recovery problem and is necessary to understand the importance of egg availability to overall recovery.

As it happened, harvest management proceeded first through the support of the Atlantic States Marine Fisheries Commission (ASMFC), which sets maximum harvest regulations for horseshoe crabs. The objective statement for the horseshoe crab harvest problem was qualitatively phrased as, "Manage harvest of horseshoe crabs in the Delaware Bay not only to maximize harvest but also to maintain ecosystem integrity and provide adequate stopover habitat for migrating shorebirds" (McGowan et al. 2015b). The USFWS is currently developing a red knot recovery plan, a product of the broad frame, with consideration for other narrowly framed conservation problems in wintering areas, additional stopover habitats, and the Arctic breeding grounds.

Who Makes the Decision?

Perhaps the most important question to ask when framing a decision is, "Who is the decision maker?" Although this seems like a simple question, the answer can be surprisingly complex or fiercely contested. Natural resource management agencies are often hierarchical; authority to make a decision is provisionally delegated, but that delegation can be rescinded if the decision garners enough attention. Natural resource management agencies also often pursue their aims through elaborate partnerships with other actors, each of which has its own authority to make decisions. Further, the authority for making a decision is often contested among independent agencies and stakeholders. Thus, identifying the decision maker may be the central impediment to decision making.

Classical decision analysis, which is the topic of this book, assumes there is a single decision maker with authority to act. Other related fields of study focus on situations where authority is shared, negotiated, or contested. *Game theory* analyzes strategies when multiple decision makers are competing and the outcomes of the decision made by one decision maker are affected by the decisions made by the other decision makers (von Neumann and Morgenstern 1944). Game theory's relevance to natural resource management has only begun to be explored (Colyvan et al. 2011). *Negotiation analysis* is a hybrid between decision analysis and game theory, in that it uses a decision-analytical understanding of the position of each actor to motivate and identify opportunities for collaboration (Sebenius 2007). Again, there is tremendous opportunity to use negotiation analysis in natural resource management, but there are so far few, if any, applications. Game theory and negotiation analysis are not explored further in this book; instead, the attention is on the fruitful use of decision analysis.

Although classical decision analysis implicitly assumes an individual decision maker acting with sole authority (Howard 1988), a full, open, and truthful exchange (FOTE) among collaborators can help them operate like a unitary decision maker and thoroughly apply the decision-analysis framework (PrOACT) promoted in this book (Gregory et al. 2012; Raiffa et al. 2002). At the start, collaborators might not possess the required level of trust, but the initial structured decision making (SDM) steps can help shift the level of trust toward a common understanding of the problem and open communication (Keeney 1996). When trust is insufficient for FOTE, then collaborators or decision-making groups can seek resolution through alternative processes (i.e., negotiation, mediation, or litigation), resulting in a potentially durable, but not necessarily optimal, solution.

Decision makers willing to find resolution collaboratively can use the decision analysis approaches described in this book. For example, the ASMFC was the decision maker for horseshoe crab harvest management with multispecies constraints (see above). The ASMFC, as a collaborative decision-making commission, receives advice from technical and stakeholder committees (McGowan et al. 2015b). When the ASMFC initiated the SDM process, significant conflict among stakeholder groups hindered efforts to reach a durable, let alone optimal, solution. However, the engagement of all stakeholders in decision structuring helped to break down barriers of communication and create the level of trust necessary to proceed with decision analysis and to implement an adaptive management framework (McGowan et al. 2015a, 2015b).

Tools for Structuring Decisions

Several useful tools and approaches are available to aid in structuring a decision. The essential technique is merely to take the time to deliberate on what the decision problem is all about (Gregory et al. 2012). Keeney (2004a) imagined that among the many decisions a person might face, the vast majority are either of small consequence or quickly resolved, but an important subset (say, 10% of all decisions) deserve careful thought, beginning with questions about problem framing. Among the questions to ponder, start with the following. What makes this particular decision challenging to resolve? Who are the key actors: who has the authority to make the decision, who can affect the decision, and who will be affected by the decision? Then move on to drafting a *decision statement*, which sums up the problem in a format that can serve as a ready reference or roadmap to follow as the decision analysis proceeds. This decision statement should be communicated to the key actors in order to ensure a shared vision and common understanding of the decision problem and the analytical approaches taken to find a solution. A shared vision of the decision problem is essential for collaborative and public policy decisions (Keeney 2004b; Raiffa et al. 2002, part V). Without a shared vision, collaboration is stymied, and conflict ensues.

A decision statement can appear in various formats. One format is a brief statement crafted from responses to a series of questions. A minimal set of topical questions includes

- Decision maker and stakeholders: Who will make the decision? Under what authority do they act? Who are the relevant stakeholders? What are their goals, aspirations, and concerns? What are they trying to achieve through the decision?
- Trigger: Why does a decision need to be made? Why does it matter?
- Alternatives: What type of options are available? What action could be taken?
- Constraints: What are the legal, financial, and political constraints? Are these constraints real or perceived?
- Frequency and timing: How often will the decision be made? Are other decisions linked to this one?
- Scope: How broad or complicated is the decision? Are there important bounds in space or time?
- Type of decision: What is the primary challenge inherent to the decision? Will decision structur-

ing illuminate the solution? Will the solution require addressing trade-offs or resource allocation? Is risk or uncertainty at the heart of the decision problem? How is the decision related to other decisions that have been or will be made? What are the likely technical analyses given the type of decision?

Regarding the last question in the list, the contents of this book are organized to match common decision types: (1) decomposing complex decisions into tractable pieces (which applies to all decisions worthy of systematic thought); (2) resolving trade-offs among competing objectives; (3) allocating limited resources; (4) coping with uncertainty and risk; (5) tying research to decisions; and (6) linking multiple decisions through time or space (Runge and Bean, chapter 1, this volume). Preliminary identification of a decision type, along with the other parts of the decision statement, provides insight into what challenges lie ahead on the way to solving the problem. In other words, forewarned is forearmed (Hammond et al. 1998).

In some situations, a template for decision statements can be convenient. For example, a template used in SDM courses offered at the USFWS National Conservation Training Center in Shepherdstown, West Virginia, results in a succinct decision statement (Romito et al. 2015):

> Decision Maker (*D*) is trying to do *X* to achieve *Y* over time *Z* and in place *W* considering *B* where *D* = the Decision maker(s), *X* = the type(s) of action that needs to be taken, *Y* = the ultimate goal(s) to be achieved by implementing *X*, *Z* = the temporal extent of the decision problem, *W* = the spatial extent of the decision problem, and *B* = potential constraints (legal, financial, and political) and important uncertainties (scientific or other).

Templates, while a bit constraining, can be highly useful for a quick distillation of the problem at hand. Also, when developing a common understanding of the problem in a group decision setting, the template's well-defined terms can be valuable.

In some collaborative efforts, a formal statement with an agreement between the decision makers and key stakeholders is useful. Gregory et al. (2012, 67) recommended a decision charter with the following components to formalize a decision statement:

1) The pending decision, its relationship to other decisions, and confirmed scope constraints (what's in and what's out)
2) The scope of alternatives under consideration (not their details, just the general scope)
3) Preliminary objectives and performance measures
4) Uncertainties and trade-offs that are expected to be central to the decision
5) The expected approach to analysis and consultation
6) Roles and responsibilities including who is/are the decision maker(s)
7) Milestones for decision maker input
8) An implementation plan, budget and timeline

While Gregory et al. (2012) suggested this list as a template for a formal decision charter, it is generally applicable for group decisions to help a collaborative effort move beyond the initial scoping phase. An initial deliberation guided by this template can help identify appropriate stakeholder involvement, types of expertise required, decision class, and likely analysis needed to solve the problem.

The critical nature of involving the decision maker, as Gregory et al. (2012) emphasize in the decision charter list, cannot be overstated. A decision analysis without decision-maker input from the start and throughout the process is unlikely to be successful. Recall Howard's 3-legged decision basis: what is to be achieved, what can be done to achieve that, and what is known about the outcome of possible actions. Decision makers have relevant input for all 3 legs of the stool, but they have the final say on what is to be achieved, which is the ultimate target of values-focused thinking (Keeney 1996). As Keeney (2007, 108) said, "Without knowing what you [the decision maker] want to achieve, there doesn't seem to be any reason to care or think about a decision." In practice, if the decision analysis is not based on the framing from the decision maker's perspective, then the solution will almost certainly miss the mark. This can happen, for example, when there is a mismatch in decision framing between a recommendation team and the ultimate decision maker. Differences can arise from any part of the frame, such as relevance and importance of the objectives, acceptability of alternatives, or level of trust and transparency among stakeholders.

A decision statement or structure will not be a finished product on the first try. Several revisions, with testing and learning between each revision, might be required before a decision structure is provisionally final (von Winterfeldt and Edwards 2007). The term "provisional" is used here because the decision analyst should view a decision structure as continually subject to revision until a decision is made, although after a few iterations, we would expect there to be less need for change. What we are describing here is the design and engineering practice of prototyping, which fits well to structured decision making (Blomquist et al. 2010; Garrard et al. 2017). An engineered product does not start off in final form. Rather, the design progresses in phases or prototypes with the initial phase merely a sketch of the product. Gregory et al. (2012) use the term "decision sketch" to refer to the initial prototype, which roughly describes the basic elements (table 2.1) resulting in the first draft of a decision structure.

Test, revise, and repeat is the prototyping mantra. By "test," we mean solve the prototype decision problem with what you have available at the time to gain insights into whether all the relevant perspectives or objectives were considered, whether the constraints were real or perceived, whether the alternatives were sufficient and comprehensive, and whether the decision choice appears to be sensitive to underlying assumptions or key uncertainties. The aim is to converge on a durable decision structure as quickly as possible. By definition, a prototype is a simplification, but much can be learned about the essential ingredients for solving a decision problem by starting simple and adding complexity only as needed. Prototyping is also a "fail fast" approach. The idea is to fail when the investment is low, learn from that failure, and revise the approach to address the shortcomings. A large investment into a polished product makes it very hard to acknowledge shortcomings and make needed revisions. Blomquist et al. (2010) provide an excellent example of a decision problem worked in the form of 2 prototypes with different frames (structures). Garrard et al. (2017) provide an excellent synopsis of rapid prototyping with sage advice on how to proceed.

Case Studies

Decision structuring is an iterative and clarifying process. Decision problems worthy of systematic thought are often complex and difficult to wrap one's arms around. Environmental decision problems are characterized by competing objectives, alternatives with multiple steps or multiple components, and an overlay of constraints (some real and some perceived), among other complexities. Environmental managers, when faced with such complexity, intuitively rely on the status quo option or other heuristics for solutions, which are often demonstrably inferior choices. Thinking systematically about the decision problem can help alleviate the frustration and confusion caused by overwhelming complexity. The 2 case studies in part 1 illustrate how decision structuring alone can clarify the problem and provide key insights leading to a solution or to critical next steps. The same process of structuring, often through iterative prototyping, is also evident in all the other case studies in this book.

In chapter 3, Michael Runge describes an analysis of how best to allocate funding under the National Fish Habitat Action Plan. The previous allocation approach had resulted in inequities and questionable effectiveness. The decision structure that resulted from a prototyping workshop identified fundamental, means, process, and strategic objectives, developed a set of alternative allocation approaches that span and contrast the range of possibilities, and built a simple but serviceable predictive model that could be used with available information. The prototype confirmed that the underlying structure for the decision was to choose an allocation strategy that balanced multiple objectives, articulated a comprehensive set of fundamental objectives, and exposed hidden assumptions regarding the roles of leverage and efficiency, which had been sources of past disagreements and once exposed allowed for transparent steps to reach a solution to the problem. The insights from the prototype allowed the agency to focus on the critical tasks needed to develop a final allocation approach, which was then implemented.

In chapter 4, Eben Paxton and Jim Kraus analyze options for conservation of Hawai'ian birds in the face of climate change and consequent environmental changes. Because climate change elevates the risk of mosquito-vectored disease, there is an urgent need to identify effective actions. The decision analysis started at a prototyping workshop where objectives and alternatives were structured. In this case study, the predictive model matters a great deal. The models that are needed to predict the effectiveness of actions, are not yet available, but the framing and prototyping identified the inputs and outputs for such a model. The inputs are related to the actions, and outputs are understood in terms of the objectives and measurable attributes. By prototyping and identifying objectives and alternatives, the model building can be much more definite and targeted to the requirements of the decision analysis.

LITERATURE CITED

Blomquist SM, Johnson TD, Smith DR, Call GP, Miller BN, Thurman WM, McFadden JE, Parkin MJ, Boomer GS. 2010. Structured decision-making and rapid prototyping to plan a management response to an invasive species. *Journal of Fish and Wildlife Management* 1:19–32.

Colyvan M, Justus J, Regan HM. 2011. The conservation game. *Biological Conservation* 144:1246–1253.

Garrard GE, Rumpff L, Runge MC, Converse SJ. 2017. Rapid prototyping for decision structuring: an efficient approach to conservation decision analysis. Pages 46–64 in Bunnefeld N, Nicholson E, Milner-Gulland EJ, eds. *Decision-Making in Conservation and Natural Resource Management: Models for Interdisciplinary Approaches*. Cambridge, UK: Cambridge University Press.

Gregory R, Failing L, Harstone M, Long G, McDaniels T, Olson D. 2012. *Structured Decision Making: A Practical Guide to Environmental Management Choices*. West Sussex, UK: Wiley-Blackwell.

Hammond JS, Keeney RL, Raiffa H. 1998. The hidden traps in decision making. *Harvard Business Review* 76(5):47–58.

———. 1999. *Smart Choices: A Practical Guide to Making Better Life Decisions.* New York: Broadway Books.

Howard RA. 1988. Decision analysis: practice and promise. *Management Science* 34:679–695.

Keeney RL. 1996. *Value-Focused Thinking*. Cambridge, MA: Harvard University Press.

———. 2004a. Making better decision makers. *Decision Analysis* 1:193–204.

———. 2004b. Framing public policy decisions. *International Journal of Technology, Policy and Management* 4(2):95–115.

———. 2007. Developing objectives and attributes. Pages 104–128 in Edwards W, Miles RFJ, von Winterfeldt D, eds. *Advances in Decision Analysis: From Foundations to Applications*. Cambridge, UK: Cambridge University Press.

McGowan CP, Lyons JE, and Smith DR. 2015a. Developing objectives with multiple stakeholders: adaptive management of horseshoe crabs and red knots in Delaware Bay. *Environmental Management* 55:972–982.

McGowan CP, Smith DR, Nichols JD, Lyons JE, Sweka JA, Kalasz K, Niles LJ, Wong R, Brust J, Davis M, Spear B. 2015b. Implementation of a framework for multi-species, multi-objective adaptive management in Delaware Bay. *Biological Conservation* 191:759–769.

Raiffa H. 2002. Decision analysis: a personal account of how it got started and evolved. *Operations Research* 50:179–185.

Raiffa H, Richardson J, Metcalfe D. 2002. *Negotiation Analysis: The Science and Art of Collaborative Decision Making*. Cambridge, MA: Harvard University Press.

Romito AM, Cochrane JF, Eaton MJ, Runge MC. 2015. Problem definition. Module 04 in Runge MC, Romito AM, Breese G, Cochrane JF, Converse SJ, Eaton MJ, Larson MA, Lyons JE, Smith DR, Isham AF, eds. *Introduction to Structured Decision Making*. Shepherdstown, WV: US Fish and Wildlife Service, National Conservation Training Center.

Sebenius JK. 2007. Negotiation analysis: between decisions and games. Pages 469–488 in Edwards W, Miles RFJ, von Winterfeldt D, eds. *Advances in Decision Analysis: From Foundations to Applications*. Cambridge, UK: Cambridge University Press.

Tversky A, Kahneman D. 1986. Rational choice and the framing of decisions. *The Journal of Business* 59: S251–S278.

US Fish and Wildlife Service. 2014. Endangered and threatened wildlife and plants; threatened species status for the rufa red knot. *Federal Register* 79:73705–73748.

von Neumann J, Morgenstern O. 1944. *Theory of Games and Economic Behavior*. Princeton, NJ: Princeton University Press.

von Winterfeldt D, Edwards W. 2007. Defining a decision analytic structure. Pages 81–103 in Edwards W, Miles RFJ, von Winterfeldt D, eds. *Advances in Decision Analysis: From Foundations to Applications*. Cambridge, UK: Cambridge University Press.