Why Structured Decision Making?

Predicting the future

“...decision-making is a forward-looking process...And if decision making is the attempt to achieve a desired future, then any such attempt must include, implicitly or explicitly, a vision of what that future will look like.”

What makes decisions hard?

Structured Decision Making

1. Helps identify where the impediments to a decision are, which allows us to focus our efforts on the right parts of the problem
   • Provides tools for dealing with those impediments
Structured Decision Making

2. Integrates
   - Management objectives
   - Alternative management actions
   - Predictive models of system response

When is SDM appropriate?

- Deliberately obscured
- Obscured
- Clear

- Structured Decision Making
- Joint Fact Finding
- Conflict Resolution
- Adaptive Management

Well Understood
Uncertain
Disputed

SCIENCE
Problem

- Develop a plan of actions to manage the vegetation in Coconino National Forest
Objectives

- Fundamental
  - Maintain healthy populations of native vertebrates and invertebrates in understory of Ponderosa Pine forest

- Means
  - Maintain open canopy pine stand with appropriate understory vegetation

Actions

- Alternative actions
  - Prescribed understory fire
  - Mechanical thinning of understory

- Timing
  - How frequently?
  - Under what conditions?
Consequences

- Predict by ‘modeling’
  - How basal area and vegetation composition change as a function of time and treatment
  - How native animal communities change as a function of habitat conditions
- These models might be mental, conceptual, or quantitative
  - But they should explicitly link actions to objectives

Trade-offs or Optimal Solution

- Find by integrating
  - Objectives
  - Actions
  - Models
- Identify the action (and its timing) that best achieves the objectives
- For example, thinning whenever the basal area exceeds 85 ft$^2$/ac
Benefits of SDM

- Decision processes that are
  - Deliberative, thorough, robust to uncertainty
    - More likely to achieve objectives
  - Transparent, explicit, able to be documented, replicable
    - More likely to be accepted by others
Problem Statement

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3. Develop a decision statement

- **Trigger**: why this decision? Why now?
- **Action**: What is the decision?
- **Constraints**: legal, financial, political? Are they real or perceived?
- **Decision Maker(s)**
- **Frequency and timing**: Periodicity of the decision. Are there linked decisions?
- **Scope**: how broad or complicated is the decision?
Determining Objectives

“'If you don't know where you're going, Any road will get you there.’” --Lewis Carroll

Objectives are what you really care about
Recipe for Good Objectives

1. Articulate concerns and wishes
2. Convert concerns to objectives
3. Structure objectives
4. Create measurable attributes for each objective
5. Repeat as needed

Step 1. Articulate goals & concerns

Think about:

- Why is it hard to make this decision?
- What’s wrong with the current situation?
- What do you want to avoid?
- What are you ultimately trying to achieve?

*Ask “why”*
Step 2. Convert concerns into objectives

State objective as an object and a preferred direction of movement

<table>
<thead>
<tr>
<th>Concern</th>
<th>Potential Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>It’s hard to catch bluegills any more</td>
<td>Increase bluegill population</td>
</tr>
<tr>
<td>Many loons die ingesting lead tackle</td>
<td>Minimize lead in tackle</td>
</tr>
<tr>
<td>Ballast water brings invasive species</td>
<td>Minimize ballast dumping</td>
</tr>
<tr>
<td>Certain stakeholders feel excluded</td>
<td>Increase communication</td>
</tr>
<tr>
<td>I won’t have enough money for this</td>
<td>Reduce cost</td>
</tr>
</tbody>
</table>

Step 3. Structure Objectives

Types of objectives

- **Fundamental**: the basic reason for caring about the decision (essential)
- **Means**: influence the achievement of fundamental objectives (not necessarily essential)
- **Process**: concerns *how the decision is made* rather than *what* decision is made
Getting to Fundamental Objectives

Ask “Why?”

WITI – Why Is That Important?

When your answer is:

- “Just because (it is an essential area of concern)”
- “It's the law”
- “This is important”
- “Inherent value”

You have reached a fundamental objective.

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Fundamental and Means
Objectives are Decision-Specific

Fundamental objectives are the broadest objectives for that decision.

<table>
<thead>
<tr>
<th>Fundamental</th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context 1: Increase loon populations</td>
<td>Minimize lead in tackle</td>
</tr>
<tr>
<td>Context 2: Conserve NE biodiversity</td>
<td>Increase loon populations</td>
</tr>
</tbody>
</table>
Attributes provide the evaluation criteria for how well your alternatives serve your objectives.

\[ \text{Attribute} = \text{Performance Measure} = \text{Criteria} \]

**Step 4. Create Measurable Attributes**

**An attribute includes:**
*Content (what you’ll measure)*
*Preferred direction of the measured content*
*The aspiration:*
  -- maximize (or minimize)
  -- a threshold
  -- a particular level of change
Example:

Objective: Establish a reproducing plant population

Measurable attribute: 3-year mean flowering stems/m²

Preferred direction: Increase

Aspiration: Maximize

Three types of attributes

1. Natural attributes
   - Objective can be directly measured

2. Constructed attributes
   - Sliding or relative scale
   - Requires interpretation

3. Proxy attributes
   - Natural attribute that is highly correlated with the objective, but does not directly measure it
Natural attribute examples

Minimize number of employee sick days
→ # of sick days

Maintain reproductive success → # of fledglings

Constructed attribute example

Wetland development impacts scale:

0  No loss of riparian areas and ≥ 300 acres estuary restored
1  No loss of riparian areas and < 300 acres estuary restored
2  No loss of riparian areas and no loss of estuary
3  Loss of < 300 acres riparian area and < 300 acres of estuary
4  Loss of < 300 acres riparian area and ≥ 300 acres of estuary
5  Loss of ≥ 300 acres riparian area and ≥ 300 acres of estuary
Proxy attribute examples

Minimize student boredom $\rightarrow$ # of yawns

Maintain genetic diversity $\rightarrow$

% of natural range preserved

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I want to get a new pet. What kind should I get?

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Measurement Criteria</th>
<th>Desired direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize total cost</td>
<td>$/year</td>
<td>Low</td>
</tr>
<tr>
<td>Maximize friendliness</td>
<td>Scale (1=low, 5=high)</td>
<td>High</td>
</tr>
<tr>
<td>Maximize pet-sitters</td>
<td># possible pet-sitters</td>
<td>High</td>
</tr>
<tr>
<td>Minimize required care</td>
<td>Hours per week</td>
<td>Low</td>
</tr>
</tbody>
</table>
Objective: Maintain biodiversity

Objective: A fish management strategy that’s robust across a range of climate scenarios

Objective: Identify and protect resilient habitat

*Write at least one possible attribute (content, direction, aspiration) for each objective*

**Develop Alternatives**
I want to get a new pet. What kind should I get?

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</table>

Good alternatives require...

- **Imagination**
  - Don’t consider only ‘practical’ alternatives
  - Think outside the box

- **Creativity**
  - Expand range of possibilities
  - Identify assumptions and challenge constraints
Creativity & Imagination Exercise

Without lifting your pencil from the page, draw 4 or fewer straight lines that connect all 9 circles.


Did anyone try these?

If you had trouble, WHY?
You defined the scope of the problem narrowly and were not creative in alternative solutions (didn’t think outside the box)
Preconceived limitation?

Develop alternatives
(only after you’ve laid out your problem and objectives!)

- Focus on your values and fundamental objectives first
- You can never choose an alternative you haven’t considered
- No matter how many alternatives you have, the alternative that you choose can be no better than the best of the bunch
Assess Consequences

Make an Initial Framework

Consequence tables

- Geeky but very useful
- Puts a lot of information in a concise and orderly format
- Easy to compare alternatives, objective by objective
- Initial framework for assessing tradeoffs
I want to get a new pet. What kind should I get?

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Measurement Criteria</th>
<th>Desired direction</th>
<th>Dog</th>
<th>Cat</th>
<th>Fish</th>
<th>Hamster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize total cost</td>
<td>$/year</td>
<td>Low</td>
<td>$300</td>
<td>$250</td>
<td>$20</td>
<td>$50</td>
</tr>
<tr>
<td>Maximize friendliness</td>
<td>Scale (1=low, 5=high)</td>
<td>High</td>
<td>3-5</td>
<td>2-4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Maximize pet-sitters</td>
<td># possible pet-sitters</td>
<td>High</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Minimize required care</td>
<td>Hours per week</td>
<td>Low</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

Lake Management Example

Lake is filling with silt
- What are our concerns about managing the lake?
- How do we want to use the lake?
Concerns
Lake is filling with silt
- Boating and ice skating are getting difficult
- We like seeing birds and wildlife on the lake
- Expensive and time consuming to keep treating
- The river at lake outlet is sensitive to silt runoff
## Objectives & Attributes

<table>
<thead>
<tr>
<th>Concerns</th>
<th>Objectives</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boating/Skating</td>
<td>Maximize recreation</td>
<td>% Area open to use</td>
</tr>
<tr>
<td>Birds/Wildlife</td>
<td>Maximize wildlife values</td>
<td>Scale (1 - 5)</td>
</tr>
<tr>
<td>Expense</td>
<td>Minimize costs</td>
<td>$/10 yrs</td>
</tr>
<tr>
<td>Silt into River</td>
<td>Maximize filtration</td>
<td>Avg siltation at outlet</td>
</tr>
</tbody>
</table>

## Alternatives
- Annual mechanical weed cutting
- Bi-annual chemical treatments
- Dredging
- No treatment (status quo)
## Consequences

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Attributes</th>
<th>Desired level</th>
<th>Alternative Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mech</td>
</tr>
<tr>
<td>Recreation</td>
<td>% open</td>
<td>Max</td>
<td>15</td>
</tr>
<tr>
<td>Wildlife</td>
<td>1-5 scale</td>
<td>Max</td>
<td>4</td>
</tr>
<tr>
<td>Costs</td>
<td>$$/10 yr</td>
<td>Min</td>
<td>10k</td>
</tr>
<tr>
<td>Filtration</td>
<td>Avg silt</td>
<td>Min</td>
<td>0.6</td>
</tr>
</tbody>
</table>

## Tradeoffs and Optimization

PrOACT
### Classes of Analytical Methods

<table>
<thead>
<tr>
<th>Repeated</th>
<th>No Uncertainty</th>
<th>With Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>No Uncertainty</td>
<td>With Uncertainty</td>
</tr>
<tr>
<td>Single Objective</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple Objectives</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Before you get into all kinds of fancy tools…

Simplify the problem
Simplify the problem

A. Identify any dominated alternatives:
   - at least one alternative performs the same or better on all objectives

Simplifying an impoundment repair decision
Any dominated alternatives?

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Status quo</td>
</tr>
<tr>
<td>Cost ($M)</td>
<td>min</td>
</tr>
<tr>
<td>Environmental Benefit (0-10)</td>
<td>Max</td>
</tr>
<tr>
<td>Disturbance (0-10)</td>
<td>min</td>
</tr>
<tr>
<td>Silt runoff (k ft3)</td>
<td>min</td>
</tr>
<tr>
<td>Water Retention (MG)</td>
<td>Max</td>
</tr>
</tbody>
</table>
## Objectives

<table>
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<tr>
<td>Disturbance (0-10)</td>
<td>min</td>
</tr>
<tr>
<td>Silt runoff (k ft³)</td>
<td>min</td>
</tr>
<tr>
<td>Water Retention (MG)</td>
<td>Max</td>
</tr>
</tbody>
</table>

### Simplify the problem

A. Identify any dominated alternatives
B. Identify any irrelevant objectives
   - Performance measures do not vary across alternatives
   - This doesn’t mean the objective isn’t important to you, just that it doesn’t help discern among these alternatives
Simplifying an impoundment repair decision
Any irrelevant alternatives?

<table>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Status quo</td>
</tr>
<tr>
<td>Cost ($M) min</td>
<td>0</td>
</tr>
<tr>
<td>Environmental Benefit (0-10) Max</td>
<td>1</td>
</tr>
<tr>
<td>Disturbance (0-10) min</td>
<td>0</td>
</tr>
<tr>
<td>Silt runoff (k ft³) min</td>
<td>5</td>
</tr>
<tr>
<td>Water Retention (MG) Max</td>
<td>41</td>
</tr>
</tbody>
</table>
Simplify the problem
A. Identify any dominated alternatives
B. Identify any irrelevant objectives
C. Consider even swaps (merging one objective into another)
   • Express one objective in terms of another
   • Set the first objective to the same value for all alternatives by shifting the differences to the second objective

Convert silt runoff to cost @ $0.5M / Kft3

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Alternatives</th>
<th>Status quo</th>
<th>Minor repair</th>
<th>Major repair</th>
<th>Re-build</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost ($M)</td>
<td>min</td>
<td>0 + 2 = 2</td>
<td>2</td>
<td>12 + 1 = 13</td>
<td>20</td>
</tr>
<tr>
<td>Environmental Benefit (0-10)</td>
<td>Max</td>
<td>1</td>
<td>3</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Disturbance (0-10)</td>
<td>min</td>
<td>0</td>
<td>1</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Silt runoff (k ft3)</td>
<td>min</td>
<td>5-4=1</td>
<td>1</td>
<td>3-2=1</td>
<td>3</td>
</tr>
<tr>
<td>Water Retention (MG)</td>
<td>Max</td>
<td>41</td>
<td>41</td>
<td>41</td>
<td>39</td>
</tr>
</tbody>
</table>
Another approach to simplifying the problem: Turn some objectives into constraints Which ones?

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Alternatives</th>
<th>Status quo</th>
<th>Minor repair</th>
<th>Major repair</th>
<th>Re-build</th>
</tr>
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<tbody>
<tr>
<td>Cost ($M)</td>
<td>min</td>
<td>0</td>
<td>2</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>Environmental Benefit (0-10)</td>
<td>Max</td>
<td>1</td>
<td>3</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Disturbance (0-10)</td>
<td>min</td>
<td>0</td>
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<td>10</td>
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<td>3</td>
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<td>Max</td>
<td>41</td>
<td>41</td>
<td>41</td>
<td>39</td>
</tr>
</tbody>
</table>

You can also essentially turn a multiple-objective problem into a single-objective problem by:

- Assigning a weight to each objective
- Converting all the scores to normalized scales, then
- Calculating a summed, weighted score for each alternative
Before you get into all kinds of fancy tools...

1. Simplify the problem

2. Direct trade-off methods (quantitative)

3. Negotiated solution
   - Examine the trade-offs directly
   - Negotiate a palatable solution from among the “equally-best” solutions