Integrating Structured Decision Making with Scenario Planning

Graham Long
Compass Resource Management Ltd.

Introduction

• The case study I was going to present...

• Athabasca River water management framework
### Athabasca Water Mngt Framework

<table>
<thead>
<tr>
<th>Government / Regulators</th>
<th>Oil Sands Companies</th>
<th>Aboriginal Organizations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberta Environment (Water)</td>
<td>Canadian Natural Resources Limited</td>
<td>Fort McKay First Nation</td>
</tr>
<tr>
<td>Alberta Sustainable Resource Development (Fish &amp; Wildlife)</td>
<td>Imperial Oil Resources</td>
<td>Fort Chipewyan Métis</td>
</tr>
<tr>
<td>Energy Resources Conservation Board</td>
<td>Shell Canada Energy</td>
<td>Fort McMurray Métis 2020</td>
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<td>Fisheries and Oceans Canada</td>
<td>Suncor Energy</td>
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<tr>
<td>Parks Canada – Wood Buffalo National Park</td>
<td>Syncrude Canada</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total E&amp;P Canada</td>
<td></td>
</tr>
</tbody>
</table>

| Non-Governmental Organizations | | |
|------------------------------|--------------------------|
| World Wildlife Fund Canada   |                         |
| Alberta Wilderness Association|                         |
| South Peace Environmental Assoc. |              |

### Introduction

- **Integrated SDM & Scenario Planning**
  - Wide range of future possibilities (scenarios)
  - Unknown probabilities of scenarios coming true
  - But consequences of scenarios can be estimated to a plausible degree
Core steps of SDM

1. Clarify the Decision Context
2. Define Objectives & Performance Measures
3. Develop Alternatives
4. Estimate Consequences
5. Evaluate Trade-Offs and Select
6. Implement, Monitor and Review

Iterate as required

Core steps

1. Clarify the Decision Context
2. Define Objectives & Performance Measures
3. Develop Alternatives
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6. Implement, Monitor and Review

Iterate as required
Decision Context

• You are a manager of Dry Tortugas National Park tasked with managing cultural resources.
• Changes in hurricane frequency are unknown but frequency of major hurricanes (Category 3) are predicted to increase proportional to increased SLR.
• Fort maintained by masons.
Decision Context

- Decision is sensitive to climate scenarios:
  - **Scenario A:** low SLR – storm surge Cat 3+ hurricane severely crumbles Fort Walls, fort floods
  - **Scenario B:** medium SLR – walls seriously damaged with Cat 1-2 hurricane, sand around fort moves extensively, fort floods on high tides (6x/year)
  - **Scenario C:** high SLR – Fort flooded, walls crumble extensively on ongoing basis, winter storms -> large chunk of wall fall

Some features we recognize...

- Need to balance multiple objectives
- Multiple stakeholders and roles
- High stakes
- Complexity and uncertainty
- Intense government and public scrutiny
- High expectations: quality and transparency
- Limited resources: time, money, personnel
Decision Context

• What makes decisions hard?
  – “People”
  – “Living with the consequences of decisions”
    • Woulda
    • Coulda
    • Shoulda

Decision Context

• Multi-stakeholder SDM
  – Gets people truly engaged in today’s decisions
  – Helps them understand the pros and cons of management actions, with uncertainty
  – Helps them share the DM’s burden of responsibility
  – If there is an unwanted outcome, the DM can say, “we explored that but people thought the pros outweighed the cons”
Decision Context

• Stakeholders
  – Heritage lovers
    • Today
    • Future generations
  – Government ➔ Taxpayers
  – Campers / tourism industry
  – Building industry
  – Environmentalists??

• Other decision context
  • Planning horizon – 100 years? More?
  • Who is the decision maker?
  • Isolated project or one project among many?
  • Resources for the decision making process?
  • Timeline for meetings?
Core steps

1. Clarify the Decision Context
2. Define Objectives & Performance Measures
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Iterate as required

Introduction

- What do stakeholders think are important?
- Ask ‘em!

Protect the fort!
Generate revenues from tourism
Reduce my taxes!
Stop climate change!
Protect part of the fort
Increase maintenance
Move the artifacts to a museum

Protect the fort!
• Clarify objectives using influence diagrams...
  – May need technical subcommittees of stakeholders for this one

Dry Tortugas National Park

• Possible influence diagram for Heritage
Dry Tortugas National Park

• Possible influence diagram for Cost

Climate change scenarios → Sea Level Rise
    → High intensity storms freq → Prevention Activities
    → Avoidance Activities
    → Mitigation Activities
    → Costs → Fort Revenues

Management Actions → Condition of Fort & Artifacts

Minimize Costs to Government

Let’s assume these objectives
– Maximize condition of fort
– Maximize condition of artifacts
– Minimize net costs to government

In this case there are other objectives...we’ll neglect for now
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Performance measures for ‘condition of fort’?
- Natural units....no (simulated photos?)
- Proxies...e.g. quality weighted % intact areas(?)
- Constructed scales e.g.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>“Ruin....”</td>
<td>elaborate...</td>
<td>elaborate...</td>
<td>elaborate...</td>
<td>“As good as today or better”</td>
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Performance measures for ‘condition of artifacts’?
- Natural units....no (simulated photos?)
- Proxies...e.g. quality weighted % intact artifacts(?)
- Constructed scales e.g.

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</table>
Dry Tortugas National Park

- Performance measures for ‘cost’?
  - Natural units....
    - sure, just use expected $ per year?
  - BUT: Do we care about cost risk tolerance?

Core steps

1. Clarify the Decision Context
2. Define Objectives & Performance Measures
3. Develop Alternatives
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Iterate as required
In this case, might help to make use of a strategy table...

In this case, it seems to make sense to:

– Define a trigger point
– Things to do up to a trigger point
– Things to do after a trigger point

<table>
<thead>
<tr>
<th>Dry Tortugas National Park</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Before trigger point</th>
<th>Trigger</th>
<th>After trigger point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid</td>
<td>Prevent</td>
<td>Mitigate - Maintenance</td>
</tr>
<tr>
<td>Do Nothing</td>
<td>Do Nothing</td>
<td>Do Nothing</td>
</tr>
<tr>
<td>Move artifacts</td>
<td>Build sea wall</td>
<td>Maintain up to $1m yr</td>
</tr>
<tr>
<td>Build floating island</td>
<td>Maintain up to $5m yr</td>
<td>Repair damage up to $50m yr</td>
</tr>
<tr>
<td>Jack-up</td>
<td>Maintain all</td>
<td>Repair Full</td>
</tr>
</tbody>
</table>
### Dry Tortugas National Park

#### ALTERNATIVE 1

**“Abandon ship”**

<table>
<thead>
<tr>
<th>Before trigger point</th>
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</thead>
<tbody>
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<td>Maintain up to $1m yr</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Build floating island</td>
<td>Maintain up to $5m yr</td>
<td>Repair damage up to $50m yr</td>
</tr>
</tbody>
</table>

#### ALTERNATIVE 2

**“Whatever it takes”**

<table>
<thead>
<tr>
<th>Before trigger point</th>
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<th>After trigger point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid</td>
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<td>Mitigate - Maintenance</td>
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<tr>
<td>Do Nothing</td>
<td>Do Nothing</td>
<td>Do Nothing</td>
</tr>
<tr>
<td>Move artifacts</td>
<td>Build seawall</td>
<td>Maintain up to $1m yr</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Build floating island</td>
<td>Maintain up to $5m yr</td>
<td>Repair damage up to $50m yr</td>
</tr>
</tbody>
</table>

| Jack-up               | Maintain all | Repair Full |

---

**ALTERNATIVE 1**

**“Abandon ship”**

**ALTERNATIVE 2:**

**“Whatever it takes”**
### Dry Tortugas National Park

<table>
<thead>
<tr>
<th></th>
<th>Before trigger point</th>
<th>Trigger</th>
<th>After trigger point</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Avoid</strong></td>
<td>Do Nothing</td>
<td>Do Nothing</td>
<td>Do Nothing</td>
</tr>
<tr>
<td><strong>Prevent</strong></td>
<td>Do Nothing</td>
<td>Do Nothing</td>
<td>Do Nothing</td>
</tr>
<tr>
<td><strong>Mitigate - Maintenance</strong></td>
<td>Do Nothing</td>
<td>Do Nothing</td>
<td>Do Nothing</td>
</tr>
<tr>
<td><strong>Mitigate - Repair</strong></td>
<td>None</td>
<td>Do Nothing</td>
<td>Do Nothing</td>
</tr>
<tr>
<td><strong>Do Nothing</strong></td>
<td>Move artifacts</td>
<td>Build sea wall</td>
<td>Maintain up to $1m yr</td>
</tr>
<tr>
<td><strong>Repair damage up to $10m</strong></td>
<td>Repair damage up to $5m/yr</td>
<td>Move artifacts</td>
<td>Repair $20m</td>
</tr>
<tr>
<td><strong>Repair $20m</strong></td>
<td>Jack-up</td>
<td>Maintain all</td>
<td>Repair Full</td>
</tr>
</tbody>
</table>

**ALTERNATIVE 3:**
“When the going gets tough, the tough...er, take their stuff and get going”

<table>
<thead>
<tr>
<th></th>
<th>Before trigger point</th>
<th>Trigger</th>
<th>After trigger point</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Avoid</strong></td>
<td>Do Nothing</td>
<td>Do Nothing</td>
<td>Do Nothing</td>
</tr>
<tr>
<td><strong>Prevent</strong></td>
<td>Do Nothing</td>
<td>Do Nothing</td>
<td>Do Nothing</td>
</tr>
<tr>
<td><strong>Mitigate - Maintenance</strong></td>
<td>Do Nothing</td>
<td>Do Nothing</td>
<td>Do Nothing</td>
</tr>
<tr>
<td><strong>Mitigate - Repair</strong></td>
<td>None</td>
<td>Do Nothing</td>
<td>Do Nothing</td>
</tr>
<tr>
<td><strong>Do Nothing</strong></td>
<td>Move artifacts</td>
<td>Build sea wall</td>
<td>Maintain up to $1m yr</td>
</tr>
<tr>
<td><strong>Repair damage up to $10m</strong></td>
<td>Repair damage up to $5m/yr</td>
<td>Move artifacts</td>
<td>Repair $20m</td>
</tr>
<tr>
<td><strong>Repair $20m</strong></td>
<td>Jack-up</td>
<td>Maintain all</td>
<td>Repair Full</td>
</tr>
</tbody>
</table>

**ALTERNATIVE 4:**
“Solid commitment – but There comes a point...”
### Dry Tortugas National Park

#### Before trigger point
<table>
<thead>
<tr>
<th>Avoid</th>
<th>Prevent</th>
<th>Mitigate - Maintenance</th>
<th>Mitigate - Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do Nothing</td>
<td>Do Nothing</td>
<td>Do Nothing</td>
<td>Do Nothing</td>
</tr>
<tr>
<td>Move artifacts</td>
<td>Build sea wall</td>
<td>Maintain up to $20m yr</td>
<td>Repair damage up to $50m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trigger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do Nothing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>After trigger point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid</td>
</tr>
<tr>
<td>Do Nothing</td>
</tr>
<tr>
<td>Damage greater than $50m/yr</td>
</tr>
</tbody>
</table>

#### Dry Tortugas National Park

- So we’ll move forward with 4 management alternatives for now – iterate later:
  - 1: Abandon ship
  - 2: Whatever it takes
  - 3: When the going gets tough
  - 4: Solid to a point
Core steps

1. Clarify the Decision Context
2. Define Objectives & Performance Measures
3. Develop Alternatives
4. Estimate Consequences
5. Evaluate Trade-Offs and Select
6. Implement, Monitor and Review

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- If we weren’t considering climate change
- Could simply use various tools to estimate consequences of alternatives on objectives:
  - E.g. storm damage stochastic modelling
    - Expert judgment panels on damage assessment ranges?
  - Cost estimations for management options
  - Multiply consequences by probability of storms etc over, say 100 years to get expected values
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- But...this is a **scenario planning workshop**
- We don’t know the probabilities of those scenarios...remember the scenarios?

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**Scenarios – a reminder**

- **Decision is sensitive to climate scenarios:**
  - **Scenario A:** low SLR – storm surge Cat 3+ hurricane severely crumbles Fort Walls, fort floods
  - **Scenario B:** medium SLR – walls seriously damaged with Cat 1-2 hurricane, sand around fort moves extensively, fort floods on high tides (6x/year)
  - **Scenario C:** high SLR – Fort flooded, walls crumble extensively on ongoing basis, winter storms -> large chunk of wall fall
We don’t know how likely each scenario is.
But we can make reasonable assumptions about their effects if we characterize them specifically enough.
We know climate change:
- Increases frequency of high intensity storms
- Increases sea level

So for each of our scenarios, we need to define:
- Precisely what change in frequency of storms of each intensity category
- Precisely what change in sea level rise

So let’s ask a climatologist to do that...
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Climatologist looks into it and says...

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Frequency of Cat 1 Storms</th>
<th>Frequency of Cat 2 Storms</th>
<th>Frequency of Cat 3 Storms</th>
<th>Average Sea Level Rise over 50 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario A</td>
<td>1 in 20</td>
<td>1 in 30</td>
<td>1 in 50</td>
<td>50 cm</td>
</tr>
<tr>
<td>Scenario B</td>
<td>1 in 12</td>
<td>1 in 18</td>
<td>1 in 30</td>
<td>100 cm</td>
</tr>
<tr>
<td>Scenario C</td>
<td>1 in 8</td>
<td>1 in 12</td>
<td>1 in 16</td>
<td>150 cm</td>
</tr>
</tbody>
</table>
Remember the beauty of scenarios is that they don’t need to be ‘correct’
They don’t need to be collectively exhaustive
They’re just scenarios...

More about where those numbers in the consequence table are coming from...

Could be some modelling, expert judgment panels or you might need to...
1. Counting Cobbler

How many cobbler are there in the United States?

One excuse for including this problem in a book about the environment is that getting your shoes repaired consumes less resources than buying a new pair. It is here mainly, however, to illustrate the ease with which a few plausible guesses can be combined to answera question that at first glance seems resistant to guesswork. Can you estimate the order of magnitude of the answer?

To do so, you could find out if there are cobbler licensing boards and, if so, write to them for their statistics. Or you could walk to the library and check the yellow pages of telephone directories for representative U. S. cities. However, why not be lazy and let your mind do the walking? Start by assuming that cobbler are generally busy most of the work week. As a rough estimate, they spend about 10 minutes on a heel job and perhaps 30 minutes on full heels and soles. More complicated repairs are rare, so ignore them. If time out for cleaning shop and dealing with customers is included, an average of 30 minutes per job is a reasonable guess. (Remember, the answer is an order of magnitude.)
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By this reasoning, a cobbler can finish perhaps 15 jobs in a workday, or about 4000 a year. All you need to know now is how many repair jobs are done each year in the United States. I get a pair of shoes or boots repaired about every four years. Assuming I am typical, the $2.3 \times 10^6$ people in the United States (1983) have about $2.3 \times 10^9/4$ or $5.75 \times 10^7$ repair jobs carried out each year. Since one cobbler can repair 4000 shoes in a year, we need $5.75 \times 10^7/4000$ or 14,375 cobblers to do all the repair work in the United States.

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• For the damage to the condition of the fort...

Management Actions

- Climate change scenarios
- Sea Level Rise
- High intensity storms freq

Prevent

- Building erosion rate
- Flooding freq
- Structural damage freq

Mitigate

- Condition of Fort
- Condition of Artifacts

Maximize Condition of Fort & Artifacts

Avoid
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• In our case, we would work with a technical panel through each step
  – E.g. how much damage would the fort suffer during a Category 1 storm if a solidly constructed seawall of x dimensions existed...etc

• The more specific we are in terms of defining our objectives, performance measures, alternatives and scenarios, the more plausible the numbers generated are
• Remember it’s more important to get the relative difference across alternatives right

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• For the damage to the condition of the fort...

  Management Actions
  - Climate change scenarios
    - Sea Level Rise
      - Building erosion rate
    - High intensity storms freq
      - Flooding freq
      - Structural damage freq
  - Mitigate
    - Condition of Fort
    - Condition of Artifacts
  - Avoid
    - Maximize Condition of Fort & Artifacts
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• For costs...

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• For consequences, let’s assume we have:

<table>
<thead>
<tr>
<th>Objective</th>
<th>Units</th>
<th>Dir</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario A</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximize condition of fort (a)</td>
<td>%</td>
<td>H</td>
<td>30</td>
<td>98</td>
<td>55</td>
<td>91</td>
</tr>
<tr>
<td>Maximize condition of artifacts (a)</td>
<td>%</td>
<td>H</td>
<td>25</td>
<td>95</td>
<td>85</td>
<td>89</td>
</tr>
<tr>
<td>Minimize costs (a)</td>
<td>$m / yr</td>
<td>L</td>
<td>0.2</td>
<td>15.0</td>
<td>3.0</td>
<td>8.0</td>
</tr>
<tr>
<td><strong>Scenario B</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximize condition of fort (b)</td>
<td>%</td>
<td>H</td>
<td>15</td>
<td>72</td>
<td>39</td>
<td>65</td>
</tr>
<tr>
<td>Maximize condition of artifacts (b)</td>
<td>%</td>
<td>H</td>
<td>8</td>
<td>65</td>
<td>98</td>
<td>50</td>
</tr>
<tr>
<td>Minimize costs (b)</td>
<td>$m / yr</td>
<td>L</td>
<td>0.2</td>
<td>18.0</td>
<td>5.0</td>
<td>10.0</td>
</tr>
<tr>
<td><strong>Scenario C</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximize condition of fort (c)</td>
<td>%</td>
<td>H</td>
<td>10</td>
<td>85</td>
<td>28</td>
<td>55</td>
</tr>
<tr>
<td>Maximize condition of artifacts (c)</td>
<td>%</td>
<td>H</td>
<td>8</td>
<td>56</td>
<td>29</td>
<td>53</td>
</tr>
<tr>
<td>Minimize costs (c)</td>
<td>$m / yr</td>
<td>L</td>
<td>0.2</td>
<td>26.0</td>
<td>7.3</td>
<td>15.0</td>
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Dry Tortugas National Park

- For trade-offs, we’ll explore two methods:
  - Non-weighted dominance
  - Multi-method weighting
Core steps

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Iterate as required

Summary

- Final decisions made by the DM of course
- But rationale is well documented
- If a ‘trigger event’ occurs, plan is already agreed.
- Shared responsibility
- No woulda, coulda, shoulda
Summary

• Integrated SDM & Scenario Planning
• Works where...
  – Wide range of future possibilities (scenarios)
  – Unknown probabilities of scenarios coming true
  – But consequences of scenarios can be estimated to a plausible degree

THANKS!

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