Decision Analysis

Urban Water Systems
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Developing decisions is a difficult task to achieve due to the errors and uncertainty in information. This results in projects failure to achieve their goals and objectives (Ewusi-Mensah, 2003). There is an increased awareness of the importance of dealing with both risk and uncertainty (Schutze et al., 2004).

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Decision Analysis

- Translates the stakeholders’ objectives into their relative worth to the decision maker or other interested parties (Pitt, 2007)

Uncertainty & Risk

- Uncertainty: A state of having limited knowledge about an action or state of future outcome
- Risk: A state of uncertainty where desired outcomes may have an undesired effect and impact

(Douglas Hubbard, 2007)
Utility Theory

- It is a successful method in assisting decision makers to deal with uncertainty and risk in information during decision analysis.
- Using the utility theory leads to high levels of confidence when deciding on systems.
- Utility theory is used to quantify the values of decision makers for consequences.

Example

- Best way to understand decision analysis and utility theory is through examples
- Going back to the E.coli example

Example

- Identify attributes of concern
  - Public health
  - Economic
  - Environmental
  - Resources
  - Cultural...etc
- Identify alternatives for implementation
- Each one of these attributes has a range of values from best to worst for each attribute

Alternatives

- Incineration
- Composting
- Filter Strip
Attributes’ Values for Alternatives

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Public Health</th>
<th>Environment &amp; Ecology</th>
<th>Economic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incineration</td>
<td>Reducing E.coli</td>
<td>P 100% 100% 100%</td>
<td>Cost 10.0</td>
</tr>
<tr>
<td>Composting</td>
<td>2 100% 90% 80% 60%</td>
<td>N -24.0</td>
<td>Sediment -24.0</td>
</tr>
<tr>
<td>Filter Strip</td>
<td>3 55% 85% NA 60%</td>
<td>P 37.5</td>
<td>Cost 55% 37.5</td>
</tr>
</tbody>
</table>

Attributes’ Values

<table>
<thead>
<tr>
<th>Units</th>
<th>Best</th>
<th>Worst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Health</td>
<td>%</td>
<td>100</td>
</tr>
<tr>
<td>Environment &amp; Ecology</td>
<td>P</td>
<td>%</td>
</tr>
<tr>
<td>Sed</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Economic</td>
<td>Cost $/ton</td>
<td>-24</td>
</tr>
</tbody>
</table>

Utility Curves
Tradeoff Analysis

- **Tradeoff:** Exchange that occurs as a compromise

  **Example:** Workout 3 times a week and reduce your health insurance by $5 a month or do not work out and increase your insurance by $5 a month

Attributes Ranking

- After utility curves are developed, the attributes are ranked.

  **In our example:**
  1. Public Health
  2. Cost
  3. Environment and Ecology

Tradeoff Analysis

- There are two possible situations for a pair of attributes "worst, best" compared to "?, worst"
- Assume that you are indifferent to both situations
- The common unit of comparison between the attributes is $
Using Utility Function

\[ U(x_1, x_2, x_3, x_4, x_5) = \sum K_i V_i(x_i) \]

Where: \( x_1: \text{PH}, x_2: \text{P}, x_3: \text{N}, x_4: \text{N}, x_5: \$ \)
\( k_1: \text{PH}, k_2: \text{P}, k_3: \text{N}, k_4: \text{Sed}, k_5: \$ \)

Solving for \( k \) values
\( \frac{k_5}{k_1} = U_1(75\%) = 0.48 \)
\( \frac{k_2}{k_5} = U_5(\$6.75) = 0.5 \)
\( \frac{k_3}{k_5} = U_5(\$6.75) = 0.5\ldots \text{etc} \)

Alternatives’ Utility Values

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Public Health</th>
<th>Cost</th>
<th>P</th>
<th>N</th>
<th>Sed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incineration</td>
<td>1.00</td>
<td>0.48</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Composting</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.49</td>
<td>0.00</td>
</tr>
<tr>
<td>Filter Strip</td>
<td>0.00</td>
<td>0.00</td>
<td>0.55</td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>

- Each attribute’s utility score is multiplied by its relevant \( k \) value. For example:
The relevant utility value for public health for incineration is 1.0 and its \( k \) value is 0.44 then the value is \((1 \times 0.44 = 0.44)\)
All of these values for each alternative are added together and will have a score for that alternative.
### Alternatives and Scores

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Score</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incineration</td>
<td>0.86</td>
<td>1</td>
</tr>
<tr>
<td>Composting</td>
<td>0.80</td>
<td>2</td>
</tr>
<tr>
<td>Filter Strip</td>
<td>0.06</td>
<td>3</td>
</tr>
</tbody>
</table>

For further information about decision making see Pitt and Voorhees, 2007 (Using Decision Analyses to Select an Urban Runoff Control Program).

Also Keeney and Raiffa, 1976 (Decisions with Multiple Objectives).