Evaluating and Choosing Preferred Projects

Richard de Neufville
Professor of Engineering Systems
MIT Institute for Data, Systems, and Society
THE THOUGHT

- Fundamental Question: To what extent is it meaningful to look for “the best”?
- What can we expect to do?
- Value Functions (simple form of Utility)

THE METHODS

- Target Curves
- Dominant Designs
- Tables
The Thought

To what extent is it meaningful to optimize, to look for “the best?”

What defines “best”?

- Extreme (high or low) of all other possibilities

This supposes what?

- Either (1): we have one metric of performance
- Or (2): metrics can be put on single scale

Is (1) realistic? Is (2)?

Under What Conditions?
Implied Need: “Value Function”

- Definition: \( V(X) \) is a means of
  - ranking the relative preference of
  - an individual for a
  - bundle on consequences, \( X \)

- A non-quantitative form of Utility Function
Let’s think of lunch

- How would you value helping of...
  - 1 serving?
  - 2?
  - 3?
  - 4, I made this especially for you?
Diminishing Marginal Utility
Does it always apply?

Can you think of exceptions?

Actually “exceptions” with “Decreasing Marginal Utility” are common:

- Critical Mass – only valuable if have enough
- Network – more connections, more valuable
- Threshold or Competition – only valuable if it
  - reaches required level (‘must have 70 to get driver’s license’) or
  - matches or beats competition
Conditions for a “Value Function”

Basic Axioms

1. Completeness or Complete Preorder
   People have preferences over all $X_i$

2. Transitivity
   If $X_1$ is preferred to $X_2$; and $X_2$ is preferred to $X_3$;
   Then $X_1$ is preferred to $X_3$

Caution: Assumed True for Individuals;
NOT Groups (discussion below)
3. Monotonicity or Archimedean Principle

For any $X_i$ ($X^* \geq X_i \geq X_*$) there is a weighting, $w$ ($0 < w < 1$) such that $V(X_i) = w V(X^*) + (1 - w) V(X_*)$

In short, value in middle is between value at ends

That is, More is Better (or Worse)

Reasonable?

No, not always true! Let’s look at a case…
for example, salt on food…
More may be better – until more is worse!
Consequence of V(X) Axioms

- Existence of V(X)
- Ranking Only
- "Strategic Equivalence" of Many V(X)
  Any Monotonic Transform of a V(X)
  .... is still an Equivalent V(X)

For example, ranking the same for both:
V(X_1, X_2) = X_1^2 X_2  \iff  2 \log (X_1) + \log (X_2)
Value Functions

Isovalue Contours

Demand Function (Maximize Value Given a Budget Constraint)
Does this apply to groups?

- Do all members in a group have same preferences?
- Possibly....
- In general, however:
  - Groups composed of stakeholders with different interests (builders, owners, users…)
  - Their interests almost certainly diverge

- Can we expect them to agree?
- NO!
Example Intransitivity for Groups

<table>
<thead>
<tr>
<th>Voter</th>
<th>Choice Order for Candidate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
</tr>
<tr>
<td>Tom</td>
<td>1</td>
</tr>
<tr>
<td>Diana</td>
<td>3</td>
</tr>
<tr>
<td>Harriet</td>
<td>2</td>
</tr>
</tbody>
</table>

- **WHO WINS ELECTION?**
- Left against Center: Left wins 2:1
- Center against Right: Center wins 2:1
- So: Left is preferred to Right? Wrong!!!
- Left against Right: Right wins 2:1 !!!
Where does this leave us?

- Under certain assumptions (conditions), individuals can rank alternatives (from least to most preferred).
- This does not apply to groups:
  - If they agree on a process (set of voting rules)
  - Then, they might be able to agree on a result
  - Arrow's Impossibility Theorem (or Paradox) [No “fair” voting system, without a dictator, satisfies everyone’s preferences…]

Concept of “best” not meaningful for design of complex systems => “preferred”
Take-Aways: Thoughts

- Evaluation is complex
  - Many metrics of performance
  - Plus Uncertainties

- Concept of “Best” is problematic
  - Individuals may have a value function
  - But groups are unlikely to do so
  - Especially stakeholders with different interests

- Preferred is more realistic concept

- Need to show dominating alternatives; Help Decision-Makers see trade-offs
Analysis of Outcomes

- What criteria?
- Target Curve, concept and construction
- Robustness?
- Tables of dimensions of preference
What can we expect to do?

- First, consider the nature of Problem for Evaluation and Choice
- Evaluation
  - Many dimensions, metrics of performance
  - Uncertainty about them, many states of metrics
  - Best is not defined
  - We can screen out dominated solutions
- Choice
  - Any single person, must see, make TRADEOFFS
  - Groups inevitably have to NEGOTIATE DEAL
Concept of “Dominance”

- Idea: One alternative better than others on all dimensions

If alternatives are dominated, they can be discarded
Is Expected Value best measure?

- "Expected Value" has been the index of choice for valuation...

- Is this appropriate? sufficient?
Conclusion about E(V)

- A useful single metric
- But Insufficient
- Cannot describe the range of effects

This is your A, B, C...
Other dimensions to explore

- The worst that could happen
  - People are “risk averse”, sensitive to loss
  - With some notion of probability of loss

- The best that might occur
  - Upside also important

- Capex (capital expenditure = investment)

- Some measure of Benefit-cost
P_5 , P_{10} or VAR

- P_5 , P_{10} are values for 5%, 10% lowest end of a distribution. The percentage = probability losses do not exceed a particular level.

- VAR is a standard concept in finance = "Value at Risk"
  - P_{10} = 10% VAR

- Motivated by lenders, who are mainly concerned about getting repaid
P_{90}, P_{95} or Value at Gain

- We have developed this “VAG” concept as counterpart of “VAR”
- It represents the upside potential of a project
- Motivated by investors, interested in amount they may gain (not especially interesting to bankers...)
Target curve

- Target curve is the cumulative distribution of outcomes
- Going from worst case at x% probability
- To best case with y% probability
- Combines VAR and “Value at Gain”
Target Curve: Oceanic oil platform

Staged deployment with reservoir (STOIOIP) uncertainty

About 30% Increase in Value from 2.7 to 3.5 Billion $
Dominance in Target Curves

- If Target Curve always to right of another…

- Does it dominate?

- Yes… but

- Does it mean that one alternative always performs better than the other?

- No! Frequency of occurrence does not translate that way!
  - Best case for one may be bad for another
Concept of “Robustness”

- Popular Basis for Design (“Taguchi method”)
- What is it?
  - Robust design ≡ “a product whose performance is minimally sensitive to factors causing variability…”
  - Robustness measured by standard deviation of distribution of outcomes
Illustration of Robustness

Probability

Outcome

More Robust
Smaller standard deviation
Do we want robustness?

- When might robustness be a good measure of performance?
- When we really want a particular result
  - Tuning into a signal
  - Fitting parts together, etc

- Is this what we want for maximizing value?
- No!! We want to limit downside but make upside as large as possible => higher $\sigma$
Robustness does not maximize expected value
# Table of Dimensions of Choice: Hassan Satellite Case

<table>
<thead>
<tr>
<th>Architectural Value Parameter ($ million)</th>
<th>Rigid Fleet</th>
<th>Flexible Fleet I</th>
<th>Flexible Fleet II</th>
<th>Flexible Fleet III</th>
</tr>
</thead>
<tbody>
<tr>
<td>E(NPV)</td>
<td>49.94</td>
<td>95.81</td>
<td>56.20</td>
<td>19.40</td>
</tr>
<tr>
<td>Std(NPV)</td>
<td>3.69</td>
<td>4.63</td>
<td>3.74</td>
<td>1.63</td>
</tr>
<tr>
<td>Flexibility Value</td>
<td>-</td>
<td>45.86</td>
<td>6.26</td>
<td>-30.55</td>
</tr>
<tr>
<td>Fixed cost, pay year 1</td>
<td>242</td>
<td>275</td>
<td>341</td>
<td>170</td>
</tr>
<tr>
<td>Fixed cost, pay year 6</td>
<td>242</td>
<td>-</td>
<td>-</td>
<td>170</td>
</tr>
<tr>
<td>PV(fixed cost) at year 1</td>
<td>392</td>
<td>275</td>
<td>341</td>
<td>276</td>
</tr>
<tr>
<td>Maximum possible gain</td>
<td>192</td>
<td>193</td>
<td>142</td>
<td>73</td>
</tr>
<tr>
<td>Maximum possible loss</td>
<td>162</td>
<td>68</td>
<td>131</td>
<td>86</td>
</tr>
</tbody>
</table>
Take-Aways: Method

- “Expected Value” not sufficient Measure
- Target Curve powerful visual image
  - Shows Maximum and Minimum
  - Compares alternatives

- Tables usefully show
  - Capex
  - Benefit-Cost of “Expected Value / Capex”
  - Value of Flexibility = Increase in Expected Project Value due to Flexibility