Lecture 9

Benefit/Cost Ratios
Judging proposed investments

- Benefit/cost ratios are frequently used for government decisions
- Costs accrue to government, but:
  - Benefits frequently accrue to others!
  - Benefits may take on non-monetary forms
  - Some benefits may not be counted!
    - E.g., profits by hospitals due to pollution
  - For some programs, costs exceed benefits!
Judging proposed investments

- For now, we will avoid some of these problems
- In particular, we will assume that:
  - All relevant costs and benefits have been put in dollar terms
Example

Consider three choices of new highway:
- Lifetime = 20 years for all three
- $i^* = 7\%$
Example

Option A:
- Invest $110,000, no salvage value
- Annual maintenance cost = $35,000/year
- User “costs” (travel time) are:
  - $210,000/year in year 1
  - Increasing by $10,000/year until year 10
    - (due to increasing congestion)
  - Constant at $300,000/year until year 20
Example

Option B:
- Invest $700,000, salvage value = $300K
- Annual maintenance cost = $21,000/year
- User “costs” (travel time) are:
  - $157,500/year in year 1
  - Increasing by $7,500/year until year 10
    - (due to increasing congestion)
  - Constant at $225,000/year until year 20
Example

Option C:
- Invest $1,300,000, salvage value = $550K
- Annual maintenance cost = $17,000/year
- User “costs” (travel time) are:
  - $136,500/year in year 1
  - Increasing by $6,500/year until year 10
    - (due to increasing congestion)
  - Constant at $195,000/year until year 20
Example

To government, option C is more costly:
- Savings go to *someone else*!
Example

<table>
<thead>
<tr>
<th></th>
<th>Option A</th>
<th>Option B</th>
<th>Option C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Present worth ($ million)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3.304</td>
<td>2.962</td>
<td>3.173</td>
</tr>
<tr>
<td>Government</td>
<td>0.481</td>
<td>0.845</td>
<td>1.338</td>
</tr>
<tr>
<td>User</td>
<td>2.823</td>
<td>2.117</td>
<td>1.835</td>
</tr>
<tr>
<td><strong>Equivalent annual cost ($ thousand)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>311.9</td>
<td>279.7</td>
<td>299.5</td>
</tr>
<tr>
<td><strong>Incremental rate of return</strong></td>
<td>12.8% (B-A)</td>
<td>3% (C-B)</td>
<td></td>
</tr>
</tbody>
</table>

- Note that present worth and equivalent annual cost have same ratios:
- E.g., \( \frac{3.304}{2.962} = \frac{311.9}{279.7} = 1.115 \)
Note

Benefits minus costs:

- What is a benefit?
  - Reduction in user costs
- Both must be in equivalent terms
  - (Either present worth or annual equivalent)
Example

- Benefits minus costs

  - A - B:
    - Benefit (reduction in user costs)
      - $2.823 million_A - $2.117 million_B = $706,000
    - Cost (increase in government costs)
      - $0.845 million_B - $0.481 million_A = $364,000
    - **Net** benefit = $706,000 - $364,000
      - = $342,000
Example

 Benefits minus costs

 B - C:

 Benefit
  = $2.117 million_B - $1.835 million_C = $282,000

 Cost
  = $1.338 million_C - $0.845 million_B = $493,000

 Net benefit = $282,000 - $493,000
  = -$211,000
Note

- If we take *differences*,
  - It doesn’t matter whether we count savings as:
    - A positive benefit
  or
    - A reduction in cost
- If the Corps of Engineers builds a dam,
  - This reduces FEMA costs (cost or benefit?)
Note

- If we take *ratios* of benefit to cost,
- It *does* matter how we count savings:
  - A positive benefit?
  - or
  - A reduction in cost?
Example

A vs. B:
- Benefit = $706,000
- Cost = $364,000
- Ratio = $706,000/$364,000 = 1.94 > 1

B vs. C:
- Benefit = $282,000
- Cost = $493,000
- Ratio = $282,000/$493,000 = 0.57 < 1
Example

- What if we consider maintenance cost reductions a benefit instead of a cost?
- In present worth terms, maintenance is:
  - $371,000 for option A
  - $223,000 for option B
  - $180,000 for option C
Example

A vs. B:
- Benefit = $706,000 + ($371,000 - $223,000)
- Cost = $364,000 + ($371,000 - $223,000)
- Ratio = $854,000 / $512,000 = 1.67 vs. 1.94

B vs. C:
- Benefit = $282,000 + ($223,000 - $180,000)
- Cost = $493,000 + ($223,000 - $180,000)
- Ratio = $324,000 / $536,000 = 0.61 vs. 0.57
Note

- Adding/subtracting a constant amount to the numerator and denominator:
  - Cannot change whether ratio is > 1 or < 1
    - If a/b < 1, then (a+c)/(b+c) < 1
  - But *can* change which ratio is bigger!
    - Problem unless definition of benefits is clear!!!

This is not a problem with *differences*,
- But benefit/cost *ratios* are more popular!
Another example

- **A vs. B**: Increased capital cost = $150
  - User benefit = $150
  - Reduced maintenance = $100

- **A vs. C**: Increased capital cost = $125
  - User benefit = $200
  - Reduced maintenance = $25
Another example

- **Ratio = Benefit/(Capital-Maintenance)**
  - A vs. B: \( \frac{\$150}{\$150-\$100} = 3 \)
  - A vs. C: \( \frac{\$200}{\$125-\$25} = 2 \)
    - Option B looks better than option C

- **Ratio = (Benefit+Maintenance)/Capital**
  - A vs. B: \( \frac{\$150+\$100}{\$150} = 1.67 \)
  - A vs. C: \( \frac{\$200+\$25}{\$125} = 1.8 \)
    - Option C looks better than option B!!!
Another example

- What is wrong?
  - As with IRR, need to evaluate each incremental investment!
- A vs. C: Increased capital cost = $125
  - User benefit = $200
  - Reduced maintenance = $25
  - Benefit/cost ratio of 2 or 1.8 is > 1
    - So option C is better than option A
Another example

- Now consider the more costly option, B
- C vs. B: Increased capital cost = $25
  - *Decreased* user benefit = -$50
  - Reduced maintenance cost = $75
  - Benefit/cost ratio of ($75-$50)/($25) = 1
- So options B and C are equally desirable
  - But comparing against A can be misleading
More realistic example

- Compare three flood-control options:
  - All with 50 year lifetime
    - (under the assumption of $i^* = 6\%$)
  - Option C causes environmental damage
    - E.g., damage to salmon fisheries
  - Is this a cost of the dam?
    - Or a reduction in its benefit???
More realistic example

<table>
<thead>
<tr>
<th></th>
<th>Option A</th>
<th>Option B</th>
<th>Option C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected annual flood damage</td>
<td>$480,000</td>
<td>$105,000</td>
<td>$55,000</td>
</tr>
<tr>
<td>Annual maintenance cost</td>
<td>$0</td>
<td>$35,000</td>
<td>$40,000</td>
</tr>
<tr>
<td>Investment</td>
<td>$0</td>
<td>$2.9 million</td>
<td>$5.3 million</td>
</tr>
<tr>
<td>Annual damage caused by dam</td>
<td>$0</td>
<td>$0</td>
<td>$38,000</td>
</tr>
<tr>
<td>Expected annual total damage</td>
<td>$480,000</td>
<td>$105,000</td>
<td>$55,000 + $38,000 = $93,000</td>
</tr>
<tr>
<td>Equivalent annual dam cost</td>
<td>$0</td>
<td>$219,000</td>
<td>$376,000</td>
</tr>
</tbody>
</table>
More realistic example

- **A vs. B:**
  - Benefit = $480,000 - $105,000 = $375,000
  - Cost = $219,000
  - Net benefit = $375,000 - $219,000 = $156,000

- **B vs. C:**
  - Benefit = $105,000 - $93,000 = $12,000
  - Cost = $376,000 - $219,000 = $157,000
  - Net benefit = $12,000 - $157,000 = -$145,000
More realistic example

A vs. B:
- Benefit = $480,000 - $105,000 = $375,000
- Cost = $219,000
- Ratio = $375,000/$219,000 = 1.71 > 1

B vs. C:
- Benefit = $105,000 - $93,000 = $12,000
- Cost = $376,000 - $219,000 = $157,000
- Ratio = $12,000/$157,000 = 0.08 < 1
More realistic example

- What if damage to salmon fisheries is treated as a cost of the dam?
  - Instead of reduction in flood control benefit

B vs. C:

- Benefit = $12,000 + $38,000 = $50,000
- Cost = $157,000 + $38,000 = $195,000
  - Ratio = $50,000/$195,000 = 0.26, *not 0.08!*
  - Still less than 1, so don’t choose option C
Review

- What is the single most important pitfall to avoid when using **present worth** to compare projects?
- What is the single most important pitfall to avoid when using **internal rate of return** to compare projects?
- What is the single most important pitfall to avoid when using **benefit/cost ratio** to compare projects?