Engineering Economics
ECO 1192
Topic 6: Public Sector Decision-Making

Claude Théoret
University of Ottawa

Recommended Readings

- Fraser et al.* chapter 10
  - Newnan et al. chapter 16

Lecture Content

- Financial analysis
- Economic Analysis (Cost-Benefit Analysis i.e., CBA)
  - Major Steps of CBA
  - Benefits and costs included?
  - Decision Rules
    - CBA and Independent Projects
    - CBA and Mutually Exclusive Projects

Summary

- CBA leads to the same conclusion on the acceptability of a project as
  - NPW, NFW, AEW, IRR and ERR methods
- However, it will likely lead to a different conclusion than payback methods
    - simple, discounted
- B/C criterion decision rule for independent projects
  - > 1➔ valid project; < 1 ➔ invalid project;
  - = 1➔ indifferent between the Bank (MARR) and the project.

Summary (2)

- Decision Rule for Mutually Exclusive projects
  - Rank projects from smallest first cost to largest first cost
  - Ensure that at least one of the projects has a valid B/C ratio (>1)
  - Perform an incremental B/C ratio (ΔB/C) analysis between the two smallest projects.
  - If ΔB/C
    - >1, select the larger project
    - < 1, select the smaller project
    - = 1, select either project.
  - Continue and complete all pairwise comparisons.
  - The last project standing (selected) is the best mutually exclusive project.

Private and Public CBA: Major Differences

- Private sector (Financial analysis)
  - Single objective: maximise profits.
  - Firms rely exclusively on market prices to evaluate inputs and outputs.
- Public Projects (Economic analysis)
  - can have multiple objectives
    - social, economic, cultural, ecological
    - usually intended to increase a target population's economic well-being
  - cannot rely exclusively on market prices because
    - prices may not exist
      - clean air, lives saved, time saved
    - prices may be distorted
      - Markets do not capture the true value of a good and its production cost.

Financial Analysis (Private Projects)

1. List the set of possible projects to be considered.
2. Identify the inputs and outputs of each alternative.
3. Assign a monetary value to each input and output.
4. Sum all revenues and costs to estimate the total profitability of each alternative.
5. Select the best (**profit maximizing**) alternative.

Example: Financial Analysis of a Ferry

1. **Privately owned**
2. **$5 fare per passenger**
3. **Average operating cost per fare: $3**
4. **Income tax rate: 20%.**
5. **500,000 passengers annually**
6. ~~**Non operating costs per passenger**~~
   - ~~**Carbon monoxide fumes = $0.10**~~
   - ~~**Water pollution = $0.05**~~
   - ~~**Noise pollution = $0.02**~~
   - ~~**Sea sickness = $0.05**~~
7. ~~**Average crossing time = 60 minutes**~~
8. ~~**Major accidents per year**~~
   - ~~**Accidental deaths = 3**~~
   - ~~**Lost workdays due to injuries = 100.**~~

Items Excluded

Example: Financial Analysis of a Ferry

1. Annual revenue = 500,000($5)=$2.5M
2. Annual operating cost = 500,000($3)=$1.5M
3. Profit before taxes = 2.5M-1.5M = $1M
4. Income Taxes = 20%($1M)= $0.2M
5. Profit after taxes = $0.8M

Please note:

The ferry's annual operating cost includes depreciation charges which are discussed in the next lecture.

The Treasury Board of Canada Guidelines for the Analysis of Public Projects

1. Formulate objectives and targets, and state the point of view from which costs and benefits will be assessed.
2. Define options.
3. Analyze **incremental** effects and gather data about costs and benefits.
4. Express the cost and benefit data in **nominal dollars** or c**onstant dollars.**
5. Run the **deterministic model** (using single-value costs and benefits as though the values were certain).
6. Conduct a sensitivity analysis to determine which variables appear to have the most influence on the NPV.
7. Analyse risk by using what is known about the ranges and probabilities of the costs and benefits values and by simulating expected outcomes of the investment.
8. Identify the best option based on the objective in step 1.
9. Make a reasoned recommendation.

Economic Analysis of Government Projects

- Determine a project's target population
  - For whom is the project?
- Identify all the cash and non-cash impacts of the project on the economic well-being of the target population.
- Quantify all project impacts on the economic well-being of the target population.
- Determine whether or not the project has a net positive impact the target population's economic well-being.

Example: Economic Analysis of a Ferry

Determine the $ value of all project impacts on the well-being of a target population.

1. **Privately owned**
2. **$5 per passenger**
3. **Average operating cost: $3**
4. **Income tax rate: 20%.**
5. **500,000 passengers annually**
6. **Non operating costs per passenger**
   - **Carbon monoxide fumes = $0.10**
   - **Water pollution = $0.05**
   - **Noise pollution = $0.02**
   - **Sea sickness = $0.05**
7. **Average crossing time = 60 minutes**
8. **Major accidents per year**
   - **Accidental deaths = 3**
   - **Lost workdays due to injuries = 100.**

Financial vs Economic Analysis

Example: Financial Analysis of a Ferry

1. Privately owned
2. $5 fare per passenger
3. Average operating cost per fare: $3
4. Income tax rate: 20%.
5. 500,000 passengers annually
6. ~~Non-operating costs per passenger~~
   - ~~Carbon monoxide fumes = $0.10~~
   - ~~Water pollution = $0.05~~
   - ~~Noise pollution = $0.02~~
   - ~~Sea sickness = $0.05~~
7. ~~Average crossing time = 60 minutes~~
8. ~~Major accidents per year~~
   - ~~Accidental deaths = 3~~
   - ~~Lost workdays due to injuries = 100.~~

Items Excluded

5

Example: Economic Analysis of a Ferry

1. Privately owned
2. $5 per passenger
3. Average operating cost: $3
4. Income tax rate: 20%.
5. 500,000 passengers annually
6. Non operating costs per passenger
   - Carbon monoxide fumes = $0.10
   - Water pollution = $0.05
   - Noise pollution = $0.02
   - Sea sickness = $0.05
7. Average crossing time = 60 minutes
8. Major accidents per year
   - Accidental deaths = 3
   - Lost workdays due to injuries = 100.

Monetise all project impacts

10

Conventional Benefit-Cost Ratio (CBR)

1. **Present Worth (PW) Criterion**

   PW (Project Benefits) ÷ [PW of Project Costs[1] - PW of Salvage value[2]]

2. **Future Worth (FW) Criterion**

   = FW (Project Benefits) ÷ [FW of Project Costs[1] - Salvage value[2]]

3. **Annual Equivalent (AE) Criterion**

   AE (Project Benefits) ÷ [AE of Project Costs[1] - AEW of Salvage value[2]]

Notes:
1. Projects costs include both the initial and the annual operating cost.
2. A project's positive salvage value (SV) offsets operating costs (and is added to operating costs if < $0).

Modified Benefit-Cost Ratio (MCBR)

For information ONLY: Excluded from this course

1. **Present Worth (PW) Criterion**

   PW (Benefits - O+M Expenses) ÷ [PW of Initial Cost - PW of Salvage value]

   O+M = Operating and maintenance

2. **Future Worth (FW) Criterion**

   FW (Benefits – O+M Expenses) ÷ [FW of Initial Cost – FW of Salvage value]

3. **Annual Equivalent (AE) Criterion**

   AE (Benefits – O+M Expenses) ÷ [AE of Initial Cost - AE of Salvage value]

Summary Table: Conventional B/C Ratio

	Project categories	
	Mutually exclusive	**Independent**
Method	**Incremental B/C Ratio = $\Delta B \div \Delta C$ (Must be applied only after determining that at least one project has a valid B÷C ratio)**	**Select all projects (no capital rationing) with acceptable B÷C ratios.**
Decision Threshold : (B÷C) or ($\Delta B \div \Delta C$) ≥ 1		
Decision criteria	**Select the better (best) project after exhausting all pair-wise project comparisons.**	**(B ÷ C) ≥ 1**

Example 1: Comparing B/C Ratios

- Given
  - X = Annual equivalent Revenues = $100
  - Y = Annual equivalent first cost = $20
  - Z = Annual equivalent operating cost = $50
  - W = Annual equivalent salvage value = $10
- Conventional B/C Ratio = (100÷(20+50+10) = 1.25
- Modified B/C Ratio = (100-50)÷(20+10) = 1.67

Decision:

- Both ratios lead to the same conclusion (Valid project).
- The modified B/C ratio > conventional B/C ratio when the B/C ratio > 1.

Example 2: Comparing B/C Ratios

- Given
  - X = Annual equivalent Revenues = $100
  - Y = Annual equivalent first cost = $20
  - Z = Annual equivalent operating cost = $80
  - W = Annual equivalent salvage value = $10
- Conventional B/C Ratio = (100÷(20+80+10) = 0.909
- Modified B/C Ratio = (100-80)÷(20+10) = 0.667

Decision:

- Both ratios lead to the same conclusion.
- The modified B/C ratio < conventional B/C ratio when the B/C ratio < 1.

Incremental B/C ratios: Warning !!!!

- The PW, FW and annuity criteria can be used to calculate
  - individual B/C ratios (independent projects); and
  - incremental B/C ratios (mutually exclusive projects).
- If the projects are mutually exclusive and have different lives ($N_A \neq N_B$), you will be required to repeat projects of unequal durations when using the PW and FW criteria.
- Repeating projects will require the adjustment of their respective initial investment.
- To avoid this problem, always use the annuity criterion (AEW) to calculate the incremental B/C ratios of projects with different lives.

CBA Steps for Mutually Exclusive Projects

1. Rank projects in ascending order of first or initial costs
2. Ensure that at least one project (any one) has an individual B/C ratio at least equal to one
3. Using the incremental B/C method, compare the two smallest projects
4. Use the following rule to decide on the better of two projects: assuming that the B/C ratio exceeds one, take the larger (the one with larger initial cost) project; if smaller than one, take the smaller project.
5. Exhaust all pair-wise comparisons using the incremental B/C method.
6. The last project to be retained is the best project among mutually exclusive projects.

CBA and Other Decision Criteria

- CBA focuses on the profitability of independent or mutually exclusive projects.
- Project decisions based on the CBA method
  - MUST coincide with the project decisions with all other decision criteria
    - NPW, NFW, AEW, IRR and ERR methods.
  - NEED NOT coincide with decisions based on payback methods (simple or discounted) as these methods are based on liquidity (not profitability).

Private and Social MARRs

- Social MARR (social discount rate)
  - rate used for public (government) projects
  - subject to significant debate and controversy.
- Diverging points of view on the social discount rate: it should equal
  1. the interest rate on financial capital borrowed by governments; or
  2. the weighted average of the funds borrowed from individuals, corporations and the foreign sector; or
  3. The before-tax MARR applicable to taxpaying individuals and corporations
     - Income taxes paid by individuals and corporations could have been used to fund private (instead of public) projects
- Discount rates recommended by the Treasury Board of Canada
  - 8 to 12% for projects with a life less than 30 years
  - 3 to 7% for projects with a life more than 30 years

Example
Mutually Exclusive Projects

Creek County is examining three alternative plans for a new road into a marsh. These mutually exclusive plans have different costs and benefits as indicated in the following table ($K).

Project	First Cost	Annual Benefits	Power Sales	Annual Operating Costs
A	$25,000	$1,700	$1,500	$200
B	35,000	2,000	1,800	250
C	50,000	2,450	3,600	350

Each road has an economic life of 50 years. MARR = 10%.

Independent Projects and the Conventional B/C Ratio

Project	First Cost	Annual Benefits	Power Sales	Annual Operating Costs
A	25,000	1,700	1,500	200
B	35,000	2,000	1,800	250
C	50,000	2,450	3,600	350

Conclusion: Without capital rationing (i.e., the potential investor has sufficient funds to develop the three projects), select all projects (A, B and C).

Project A

(B/C) = [1700+1,500] ÷ [25,000(A/P,10%,50)+200]

= (3,200 ÷ 2,721.5) = 1.18 > 1: **valid project**

Project B

(B/C) = [2,000+1,800] ÷ [35,000(A/P,10%,50)+250]

= (3,800 ÷ 3,780.1) = 1.005 > 1: **valid project**

Project C

(B/C) = [3,600+2,450] ÷ [50,000(A/P,10%,50)+350]

= (6,050 ÷ 5,393) = 1.12 > 1: **valid project**

Mutually Exclusive Projects and the Conventional B/C Ratio

Project	First Cost	Annual Benefits	Power Sales	Annual Operating Costs
A	25,000	1,700	1,500	200
B	35,000	2,000	1,800	250
C	50,000	2,450	3,600	350

Compare Projects A & B

The incremental B/C ratio ($\Delta B/\Delta C$)

= (3800 – 3200) ÷ (3780.1 – 2721.5)

= 2850 ÷ 2671.5 = 0.57 < 1

Decision: Since the incremental B/C ratio < 1, select project A (i.e., the smaller project.

Compare Projects A & C

The incremental B/C ratio ($\Delta B/\Delta C$) is

= (6050 – 3200) ÷ (5393 – 2721.5)

= 2850 ÷ 2671.5 = 1.07 > 1

Decision: Select project C (i.e., the larger project) even though Project A has the largest individual B/C ratio.

B/C Ratio and Private Projects

Machine X

- P=$180; AR=135; AC=50; N=6 years; SV=80

Machine Y

- P=$420; AR=190; AC=70; N=12 years; SV=100

1. Find individual B/C ratios.
2. Find incremental B/C i.e., Δ(B/C) ratio to determine the better machine (X and Y are mutually exclusive).

Individual B/C Ratios

Machine X

- P=180; AR=135; AC=50; N=6 years; SV=80

Machine Y

- P=420; AR=190; AC=70; N=12 years; SV=100

Machine X: AEW Method

(Benefits)/{AE(O+M)+AE(P)-AE(SV)

=135/(50+41.33-10.37) = 1.54

Machine Y: AEW Method

(Benefits)/{AE(O+M)+AE(P)-AE(SV)

=190/(70+61.64-4.68) = 1.50

Conclusion: X and Y are valid.

Incremental B/C Ratios

Machine X

- P=180; AR=135; AC=50; N=6 years; SV=80

Machine Y

- P=420; AR=190; AC=70; N=12 years; SV=100

Cash Flows (Machine Y - Machine X)

=(190-135)/ {(70+61.64-4.68) - (50+41.33-10.37)} = 1.20

Conclusion: Machine Y is better than Machine X.

Check

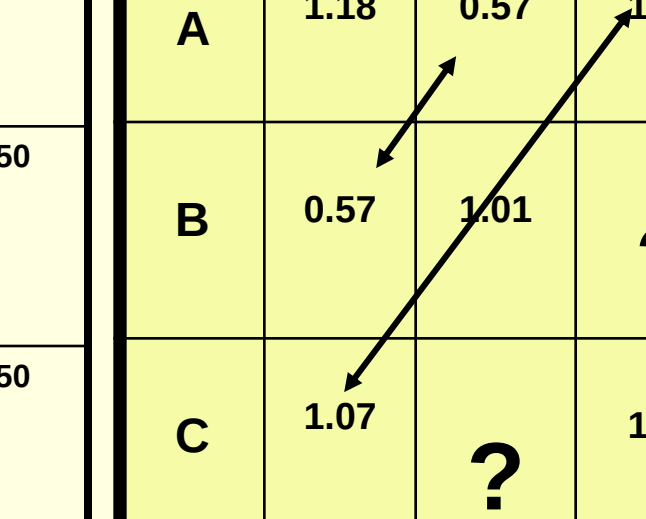
- AEW(X)=$54; AEW(Y)=$142
- ΔIRR(Y-X) = 15.3%

Summary Information

Project	First Cost	Annual Benefit	Power Sales	Annual Costs
A	25,000	1,700	1,500	200
B	35,000	2,000	1,800	250
C	50,000	2,450	3,600	350

B/C RATIOS

	A	B	C
A	1.18	0.57	1.07
B	0.57	1.01	?
C	1.07	?	1.12



Based on the incremental B/C method, project C is best.

Example: B/C Ratios

Project	FIRST COST (M$)	Individual B/C Ratio	INCREMENTAL B/C RATIOS A	B	C	D
A	10	1.6				
B	15	2.7	1.5 (B)			
C	20	1.7	0.9	1.2 (C)		
D	29	1.3	1.1	0.9	1.3 (D)	
E	35	1.1	0.8	0.5	0.8	0.9

- All projects (A,B,C,D and E) are valid.
- If the projects are
  - independent (without capital rationing), select all projects (B/C ratios > 1).
  - mutually exclusive, select project D.

Decision Criteria: A Comparison

- Single sums (PW and FW), annual equivalent (AEW) and ERR methods require fewer calculations than IRR methods
- In some cases,
  - Decision-makers may be more familiar with annual equivalent analysis ➔ easier to explain
  - A rate of return method may be easier to explain to people unfamiliar with economic analysis
- Generally, businesses favour one method over others for a variety of reasons
  - History (been done this way by the corporation for years)
  - Background (training …)
  - Familiarity with competing techniques

Decision Criteria: A Comparison (2)

Single Sum (Present & Future Worth)

1. Gives explicit measure of a project's profit contribution
2. Makes it difficult to compare projects of different sizes and durations

Annual Worth (AEW)

1. Familiarity with cash flow concepts makes interpretation of results easier
2. Underlying assumption makes the comparison of projects of different sizes more tenuous/questionable

Decision Criteria: A Comparison (3)

IRR

- Makes it easier to compare projects of different sizes
- Can be difficult to calculate
  - indirect method
  - multiple IRRs (some negative)

Decision Criteria: A Comparison (4)

Payback Period

- Easy to calculate; widespread use
- Focus on liquidity; other methods focus on profitability
- Discriminates against long-term projects
  - Ignores a project's expected service life
- Ignores time-value mechanics (simple payback)

Engineering Economics
ECO 1192
Topic 6: Public Sector Decision-Making

Claude Théoret
University of Ottawa