Problem 09

Water Project

E213 – Engineering Cost Decisions

SCHOOL OF ENGINEERING

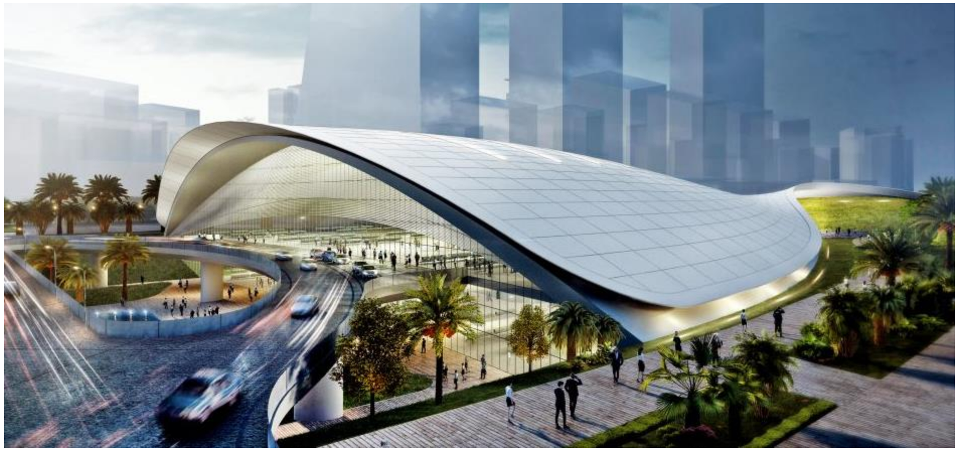
Module Coverage: Topic Tree

E213 – Engineering Cost Decisions

- Cost Allocation and Estimation
  - Activity Based Costing method
  - Cost Estimation techniques
- Concept of Equivalence
  - Single payment
  - Uniform series and uniform gradient
- Project Evaluation
  - Single Project Evaluation
    - MARR & EW Method
    - IRR& ERR
  - Multiple Projects Comparison
    - Project life = study period
      - Payback method
    - Project life ! = study period
      - Repeatability/Co-terminated Assumption
    - Public Project Evaluation
      - B/C Ratio Approach
- Depreciation and Tax
  - depreciation
  - Tax
- Replacement Analysis
- Sensitivity Analysis

Overview of Public Project

- Public projects are different from private projects, which are purely economically-driven
- Social impact of project is key consideration
- Costs – Sponsored by government (in part or full)
- Benefits – Advantages gained by the public
- Disbenefits – Expected undesirable consequences to the public



Differences between Public and Private Projects

	Public Projects	Private Projects
Purpose	Provide services, jobs; Protect lives and properties; Improve infrastructure and efficiency	Maximize profits or minimize costs
Funding	Taxation, bonds	Private investors, loans
Beneficiaries	Public	Company undertaking the project
Type of Cash flow	Benefits and disbenefits to public (difficult to quantify)	Revenue and expenses (monetary)
Selection Criteria	Can have multiple criteria	Mainly based on return rate
Project Life	Usually long (10 to 60 years)	Usually short (5 to 10 years)

Benefit-Cost (B/C) Analysis

- B/C analysis is the calculation of the ratio of benefits to costs.
- Normally PW and AW are used in B/C analysis
- Time value of money must be considered to account for timing of cash flow.
- B/C analysis is used in evaluating public projects because the aim is to ensure that the net benefit to the public is greater than the cost of funding the project.
- Objective is not to maximize returns, unlike in private projects (hence, lower interest rates of 3 to 5% are usually used).

Conventional Benefit-Cost (B/C) ratio using Present Worth (PW)

- Conventional B/C Ratio = $\dfrac{PW(B) - PW(D)}{PW(C) + PW(O)}$
  - PW : Present Worth
  - B : Benefits (favorable outcomes)
  - D : Disbenefits (unfavorable outcomes)
  - C: Initial capital investment
  - O : Operating / Maintenance Cost

- Project is economically feasible if B/C ratio >1

Modified B/C ratio using PW

Modified B/C Ratio = $$\frac{PW(B) - PW(D) - PW(O)}{PW(C)}$$

Project is economically feasible if B/C Ratio >1

Modified B/C ratio will be different from conventional B/C ratio, but the conclusion will still be the same.

Conventional B/C ratio feasibility criteria is

PW(B) – PW (D) > PW(C) + PW(O)

i.e. PW(B) – PW(D) – PW(O) > PW(C) which is also the Modified B/C ratio feasibility criteria

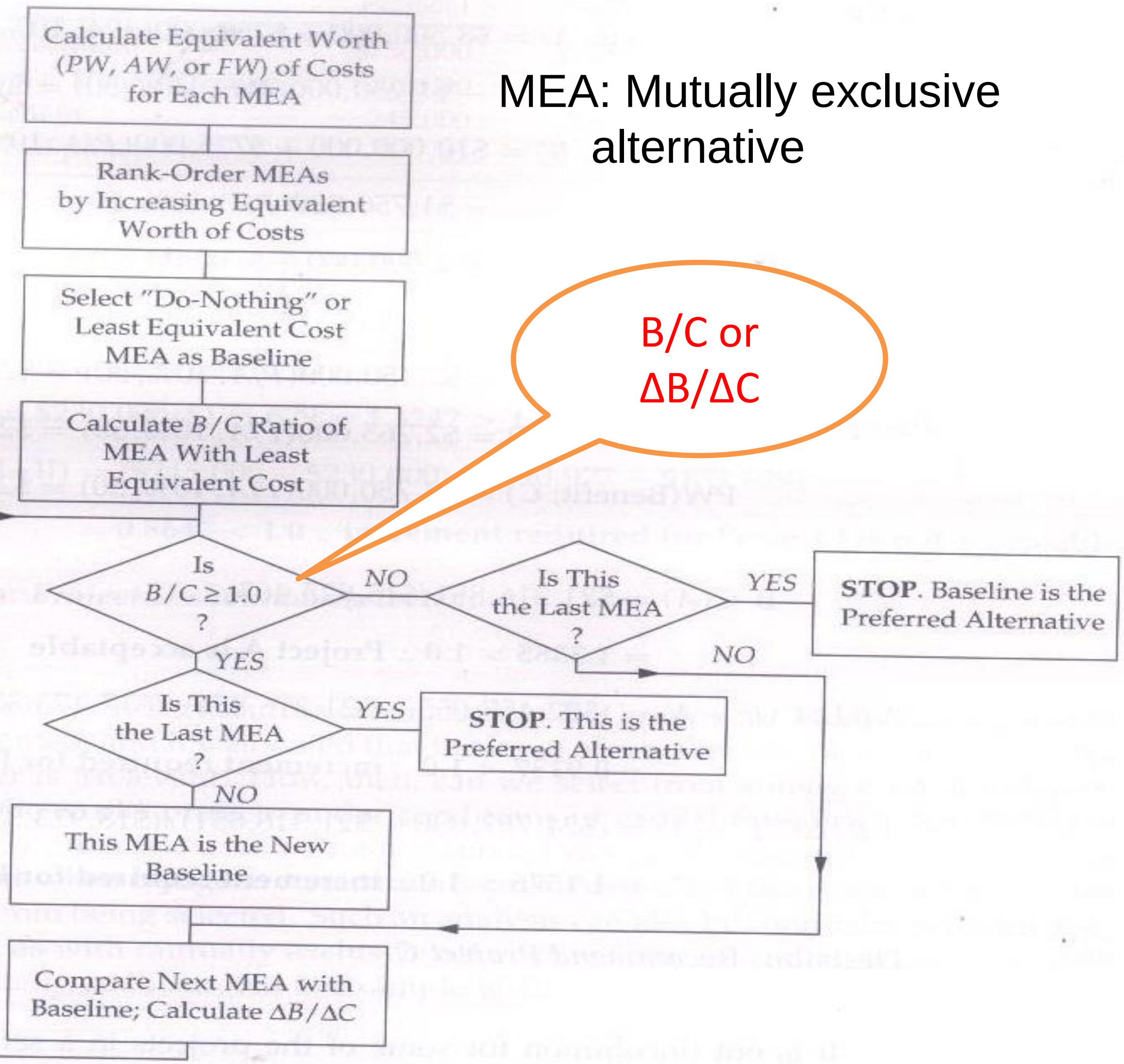
B/C Ratio

- B/C ratio estimates the value of projects to determine whether those projects are worth undertaking.
- It should not be used as criterion in multiple projects selection.
  - i.e. choosing a project with the highest B/C ratio out of several projects is incorrect
- Incremental B/C analysis has to be carried out to select the best project amongst the mutually exclusive alternatives

Incremental B/C procedure

MEA: Mutually exclusive alternative

Figure 11-3
The Incremental Benefit–Cost-Ratio Procedure



P09 Suggested Solution

Proposed Approach

- Look at Conventional or Modified B/C ratio, not Equivalent Worth approach.
- Study Period: Consider 60 years
- Interest Rate: 3.5% per annum

Benefits / Disbenefits

- Annual Worth (Benefits) potentially coming from:
  - ✓ Secure water supply for projected increase in water demand
  - ✓ Reduce/eliminate reliance on imported water;
  - ✓ Research and develop latest water desalination/recycling/management technology
  - ✓ Create more job/employment opportunities for the public.

- Potential Disbenefits from:
  - ✓ Heavier traffic, noise and dust around the neighborhood during construction;
  - ✓ Relocation of residents and/or businesses to make way for the public project;

B/C and Modified BC

- Consider Conventional B/C ratio: $$\frac{PW(B)-PW(D)}{PW(C)+PW(O)}$$
- Or Modified B/C ratio: $$\frac{PW(B)-PW(D)-PW(O)}{PW(C)}$$
- It is possible (but challenging) to obtain numerical estimates which could also be controversial (i.e. too high or too low) for B/C ratio computation for a project of such nature and scale
- Project feasibility criterion is B/C ratio > 1

Cash flow for Projects

Interest rate = 3.5%

Life: 60 years

Project	Initial building cost (million)	Annual benefit (million)	Annual operation and maintenance cost (million)
Project A	\$72.0	\$3.6	\$0.35
Project B	\$99.0	\$5.2	\$0.51
Project C	\$46.0	\$6.0	\$3.40
Project D	\$60.0	\$3.1	\$0.18

Calculations (Project A)

- Calculate B/C ratio and Modified B/C ratio for the "new water catchment area and treatment plant"

  PW(Benefit, Project A)=$3.6M (P/A,3.5%,60) = $89.8 million

  PW(Capital, Project A)=$72 million

  PW(Operation Cost, A)=$0.35M (P/A,3.5%,60) = $8.73 million

$$B/C\ ratio = \frac{PW(B) - PW(D)}{PW(C) + PW(O)} = \frac{\$89.8 - 0}{\$72 + \$8.73} = 1.112$$

$$\text{Modified } B/C \text{ ratio} = \frac{PW(B) - PW(D) - PW(O)}{PW(C)}$$

$$= \frac{\$89.8 - 0 - \$8.73}{\$72} = 1.126$$

- Project A is economically viable.

Calculations (Project B)

- Calculate B/C ratio and Modified B/C ratio for the “new hybrid desalination plant” Project

PW(Benefit, Project B)=$5.2M (P/A,3.5%,60) = $129.71 million

PW(Capital, Project B)=$99 million

PW(Operation Cost, Project B)=$0.51M (P/A,3.5%,60) = $12.72 million

$$B/C\ ratio = \frac{PW(B) - PW(D)}{PW(C) + PW(O)} = \frac{\$129.71 - 0}{\$99 + \$12.72} = 1.161$$

$$\text{Modified } B/C \text{ ratio} = \frac{PW(B) - PW(D) - PW(O)}{PW(C)}$$

$$= \frac{\$129.71 - 0 - \$12.72}{\$99} = 1.182$$

- Project B is economically viable.

Calculations (Project C)

- Calculate B/C ratio and Modified B/C ratio for the “new water reclamation plant” Project

PW(Benefit, Project C)=$6M (P/A,3.5%,60) = $149.67 million

PW(Capital, Project C)=$46 million

PW(Operation Cost, Project C)=$3.4M (P/A,3.5%,60) = $84.81 million

$$B/C\ ratio = \frac{PW(B) - PW(D)}{PW(C) + PW(O)} = \frac{\$149.67\ \text{-}\ 0}{\$46 + \$84.81} = 1.144$$

$$\text{Modified } B/C \text{ ratio} = \frac{PW(B) - PW(D) - PW(O)}{PW(C)}$$

$$= \frac{\$149.67 - 0 - \$84.81}{\$46} = 1.41$$

- Project C is economically viable.

Calculations (Project D)

- Calculate B/C ratio and Modified B/C ratio for the "extension of DTSS" Project

PW(Benefit, Project D)=\$3.1M (P/A,3.5%,60) = \$77.33 million

PW(Capital, Project D)=\$60 million

PW(Operation Cost, Project D)=\$0.18M (P/A,3.5%,60) = \$4.49 million

$$B/C\ ratio = \frac{PW(B) - PW(D)}{PW(C) + PW(O)} = \frac{\$77.33\ \text{-}\ 0}{\$60 + \$4.49} = 1.199$$

$$\text{Modified } B/C \text{ ratio} = \frac{PW(B) - PW(D) - PW(O)}{PW(C)}$$

$$= \frac{\$77.33 - 0 - \$4.49}{\$60} = 1.214$$

- Project D is economically viable.

B/C Ratio and Modified B/C Ratio

B/C and Modified B/C ratio for all Projects

Project	Conventional B/C ratio	Modified B/C ratio
Project A	1.112	1.126
Project B	1.161	1.182
Project C	1.144	1.410
Project D	1.199	1.214

All projects are economically viable since all the ratios are greater than 1.

Incremental B/C Ratio– Choose Baseline

- **Calculate costs (millions)**
  - PW(Costs, Project A) = \$72M + 0.35M(P/A,3.5%,60) = \$80.73M
  - PW(Costs, Project B) = \$99M + 0.51M(P/A,3.5%,60) = \$111.72M
  - PW(Costs, Project C) = \$46M + 3.4M(P/A,3.5%,60) = \$130.81M
  - PW(Costs, Project D) = \$60M + 0.18M(P/A,3.5%,60) = \$64.49M

  (Least cost project, choose it as baseline)
- **Calculate benefit (millions)**
  - PW(Benefit, Project A) = \$3.6M(P/A,3.5%,60) = \$89.8M
  - PW(Benefit, Project B) = \$5.2M(P/A,3.5%,60) = \$129.71M
  - PW(Benefit, Project C) = \$6.0M(P/A,3.5%,60) = \$149.67M
  - PW(Benefit, Project D) = \$3.1M(P/A,3.5%,60) = \$77.33M

- Rank the Alternatives by Increasing Equivalence Worth of Cost (PW)
  - Project D, Project A, Project B, Project C
- Choose **Project D** as the baseline (lowest PW)

Incremental B/C Ratio - Choose the best alternative

1. Project D as the baseline.

Calculate B/C

- B/C (Project D)= \$77.33/\$64.49 = **1.2 >1**.

2. Compare Project A with Project D

- ΔB/ΔC(Project A – Project D) = (\$89.80 – \$77.33)/(\$80.73 – \$64.49) = 0.77 **< 1**

→ Reject Project A, keep Project D as baseline.

3. Compare Project B with Project D

- ΔB/ΔC(Project B – Project D) = (\$129.71 - \$77.33)/(\$111.72 – \$64.49) = 1.11 **> 1**

→ Accept Project B as new baseline.

4. Compare Project C with Project B

- ΔB/ΔC(C(Project C – Project B) = (\$149.67 - \$129.71)/(\$130.81 – 111.72) = 1.05 **> 1**,

→ Accept Project C as new baseline

Project C (new water reclamation plant) is the best alternative.

Disadvantages of B/C Analysis

- Difficult to quantify the economic impact of benefits and disbenefits of public sector project alternatives, which can be very different in nature (e.g. protect environment, improve living conditions, create new jobs, security, …)

- Public sector projects normally last a long time, making accurate estimations of benefits and cost information difficult.

- Distributional inequities – One group benefits while another group pays for costs are typically not accounted for by the B/C analysis

Learning Objectives

- Describe the objectives of public projects
- Recognize the use of Conventional and Modified Benefits and Cost (B/C) ratio approach for public project evaluation
- Apply incremental B/C method to evaluate mutually exclusive public projects

E213 Engineering Cost Decisions (Topic Flow)

- Application of ABC costing method in cost management
- Application of different cost estimating techniques
- Comparison of alternatives using the concept of equivalence
- Alternatives evaluation using single, uniform series and uniform gradient cash flows
- Project evaluation using MARR and Equivalent Worth method
- Project evaluation based on Internal Rate of Return and External Rate of Return
- Evaluate alternatives of equal life spans using payback method
- Evaluate alternatives with different life spans
- Evaluate public projects through incremental B/C analysis
- Depreciation estimation and consideration in economic analysis
- Tax consideration in economic analysis
- Replacement analysis application
- Risk and uncertainties handling in economic analysis

Today's learning