Engineering Economy

[9]
Benefit Cost Analysis

General Definitions

- Benefits: the advantages to the public [*favorable consequences of the project to the public*]
- Costs: construction, operations, and maintenance [*monetary disbursement required from the government*]
- Disbenefits: expected undesirable (negative) consequences to the public [*loss in funding*, *decline in service*,..]

Benefit/Cost Analysis

- The benefit/cost ratio (B/C) is relied upon as a fundamental analysis method for public engineering projects

- All cost and benefit estimates must be converted to a common monetary unit (PW, AW, FW)

$$\text{B/C} = \frac{\text{PW of benefits}}{\text{PW of costs}} = \frac{\text{AW of benefits}}{\text{AW of costs}} = \frac{\text{FW of benefits}}{\text{FW of costs}}$$

- The sign of B/C is positive so the *costs are considered positive amounts*

B/C Decision Guidelines

- If B/C ≥ 1.0, *accept* the project

- If B/C < 1.0, *reject* the project

The Conventional B/C Ratio

- The conventional B/C ratio is calculated as follows (most widely used):

$$\frac{B}{C} = \frac{benefits - disbenefits}{costs}$$

- In this equation, *disbenefits* are subtracted from benefits not added to costs

- *Net benefits = benefits – disbenefits*

The Modified B/C Ratio

- The modified B/C ratio includes *maintenance and operation* (M&O) costs and treat them in a manner similar to disbenefits

- *Salvage value is included as a negative cost*

- The modified B/C ratio is:

$$Modified\ \frac{B}{C} = \frac{benefits - disbenefits - M\&O\ costs}{initial\ investment}$$

The Benefit and Cost Difference Measure

- This measure (formula) is based on the difference between PW, AW, FW of benefits and costs
- That is, B – C
- If (B – C) ≥ 0, the project is acceptable

Example [1]

- The Ford Foundation expects to award *$15 million* in grants to public high schools to develop new ways to teach the fundamentals of engineering that prepare students for university-level material

- The grants will extend over a 10-year period and will create an estimated savings of *$1.5 million per year* in faculty salaries and student-related expenses. The Foundation uses a rate of return of 6% per year on all grant awards

- An estimated *$200,000 per year* will be removed from other program funding. To make this program successful, a *$500,000 per year* operating cost will be incurred from the regular M&O budget. Use the B/C method to determine if the grants program is economically justified

Example [1]

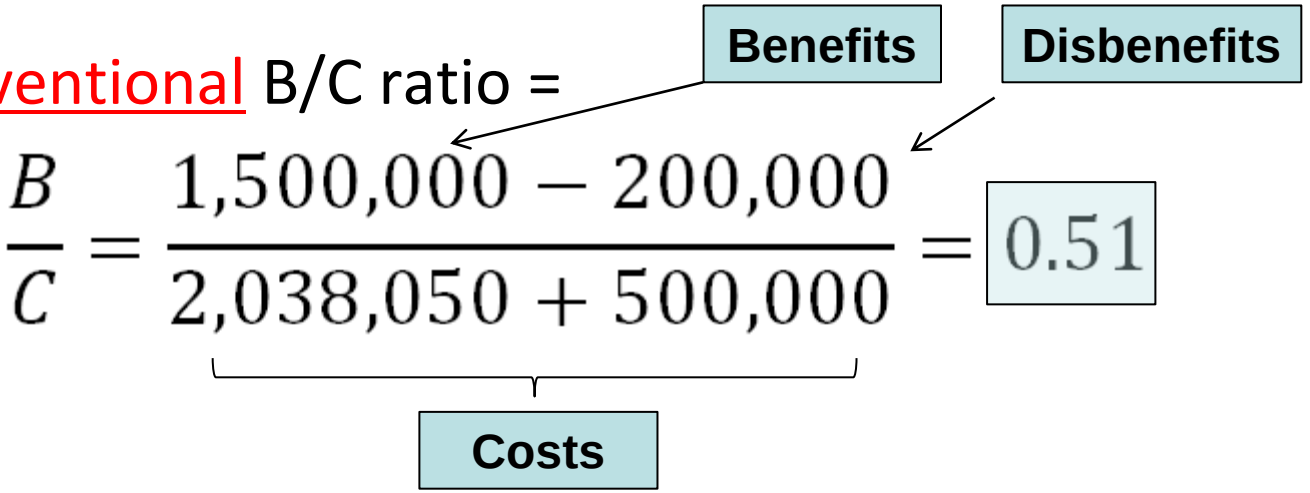
- The first step is to convert all the cash flows into annual worth flows (AW)

- Thus, you need to find AW for the investment cost, benefit, disbenefit, and M&O cost

- AW of investment cost = 15,000,000(A/P,6%,10) = $2,038,050 per year
- AW of benefit = $1,500,000 per year
- AW of disbenefit = $200,000 per year
- AW of M&O cost = $500,000 per year

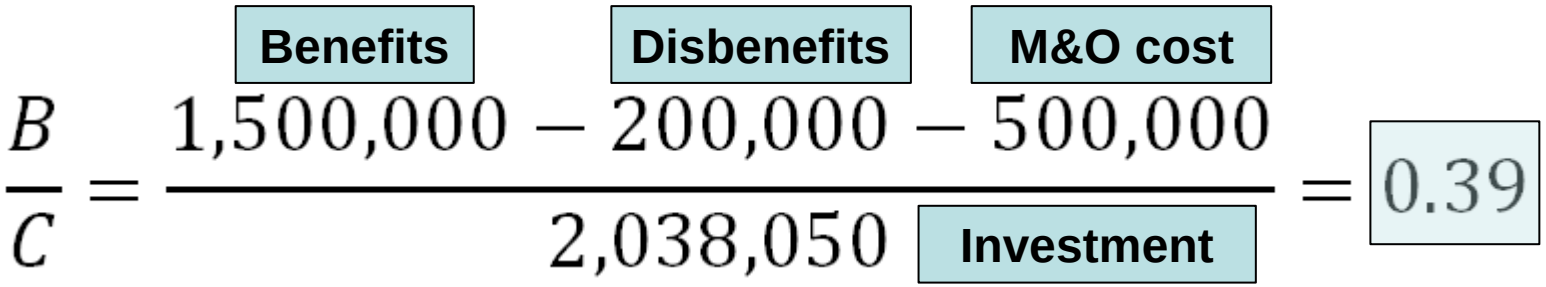
Example [1]

- The conventional B/C ratio =



The project is not justified since B/C < 1.0

- The modified B/C ratio =



The project is not economically justified since B/C < 1.0

Example [1]

- For the (B – C) model, B is the net benefit, and the annual M&O cost is included with costs

- B – C = (1,500,000 – 200,000) – (2,038,050 + 500,000) = $ -1.24 million

- Since (B – C) < 0, the project is not economically justified

Alternative Selection

- The technique to compare two mutually exclusive alternatives using B/C analysis is to use $\Delta B/\Delta C$ for the *larger-cost alternative*

- If $\Delta B/\Delta C \geq 1.0$, choose the higher-cost alternative

  If $\Delta B/\Delta C < 1.0$, choose the lower cost alternative

Example [2]

- There are *two* designs and one of them must be accepted
- The *three* estimates in the table should be considered to determine which design to recommend
- The interest rate is 5% and the life is 30 years

	Design A	Design B
Construction cost, $	10,000,000	15,000,000
Maintenance cost, $/year	35,000	55,000
Usage cost, $/year	450,000	200,000

Example [2]

- The AW of **total** *costs* is the sum of construction and maintenance costs:

Construction **Maintenance**

$AW_A = 10{,}000{,}000(A/P,5\%,30) + 35{,}000 = \$685{,}500$

$AW_B = 15{,}000{,}000(A/P,5\%,30) + 55{,}000 = \$1{,}030{,}750$

- Design B has the larger AW costs, so the incremental cost value is:

$\Delta C = AW_B - AW_A = 1{,}030{,}750 - 685{,}500 = \$345{,}250/\text{ year}$

- Although design A has less investment cost compared to design B, yet design B can yield benefits in terms of *reducing the usage cost at a value of $250,000/year*

Example [2]

- The incremental (**net**) *benefit* is the difference in usage cost:

  $\Delta B = 450{,}000 - 200{,}000 = \$250{,}000$ per year

- The incremental B/C ratio is:

  $\Delta B/\Delta C = 250{,}000 / 345{,}250 = 0.72$

- The $\Delta B/\Delta C$ ratio is less than 1.0 indicating that *design A is selected*

Example [3]

- There are four proposals for a *rehabilitation of a park* and you need to find out the best one using the B/C analysis if the interest rate is 7%

- The cash flows are provided in the table below:

	1	2	3	4
Initial cost, $	$ 250,000	$ 350,000	$ 500,000	$ 800,000
Maintenance cost, $/year	$ 25,000	$ 35,000	$ 50,000	$ 80,000
Entrance fees, $/year	$ 500,000	$ 450,000	$ 425,000	$ 250,000
Extra sales, $/year	$ 310,000	$ 320,000	$ 320,000	$ 340,000
Life, years	8	8	8	8

Example [3]

- Find the annual cost for each proposal. For instance, proposal #1 has the following annual cost:

  Initial investment + maintenance cost =
  $250,000(A/P,7%,8) + 25,000 = $66,867

	Proposal 1	Proposal 2	Proposal 3	Proposal 4
AW C	$ 66,867	$ 93,614	$ 133,734	$ 213,974

- For #1 and #2, compute $\Delta C = 93,614 - 66,867 = \$26,747$
- Compute $\Delta B = (500,000 - 450,000) + (320,000 - 310,000) = \$60,000$ (when proposal #2 is compared to proposal #1, the entrance fees decrease by $50,000 per year and the sales increase by $10,000)
- $\Delta B/\Delta C = 60,000/26,747 = 2.24$
- Choose #2 over #1

Example [3]

	2-to-1	3-to-2	4-to-2
ΔC	$ 26,747	$ 40,120	$ 120,360
ΔB	$ 60,000	$ 25,000	$ 220,000
ΔB/ΔC	2.24	0.62	1.83
	2 is better	2 is better	4 is the best

Example [4]

- Compare three flood-control options all with 50 year life time under the assumption of i = 6%

- Option C causes environmental damage (e.g., damage to salmon fisheries)

	A	B	C
Investment cost	$ 0	$ 2,900,000	$ 5,300,000
Annual maintenance cost	$ 0	$ 35,000	$ 40,000
Expected annual flood damage	$ 480,000	$ 105,000	$ 55,000
Annual damage caused by dam	$ 0	$ 0	$ 38,000
Life, years		50	50

Example [4]

- First of all, convert to annual worth the estimates of investment costs

- Thereafter, find out the total annual cost
  (*investment* + *maintenance*)

- Then, find the total **annual damage**
  (*caused* by dam + *flood*)

- Choose any two alternatives and compute ΔB/ΔC

Example [4]

2,900,000(A/P,6%,50)+ 35,000

2,900,000(A/P,6%,50)

	A	B	C
Annual dam investment cost	$ 0	$ 183,988	$ 336,255
Total annual dam cost	$ 0	$ 218,988	$ 376,255
Total annual damage	*$ 480,000*	*$ 105,000*	*$ 93,000*

	A vs. B	B vs. C
Δ costs	$ 218,988	$ 157,266
Δ benefits	$ 375,000	$ 12,000
ΔB/ΔC	1.712	0.076

480,000 – 105,000

- Since ΔB/ΔC ratio (1.7) > 1, *then choose B*
- Since ΔB/ΔC ratio (0.07) < 1, *then choose B*

Example [5]

- Two engineers, Bob and Judy, made the estimates shown below for two optional methods by which new construction technology would be implemented at a site for public housing

- Either one of the two options may be selected. Determine if option 1 or option 2 is selected by each engineer

- Use a life time of 5 years and an interest rate of 10% per year for all analyses

Example [5]

	Engineer Bob		Engineer Judy	
	Option 1	Option 2	Option 1	Option 2
Initital cost, $	$50,000	$90,000	$75,000	$90,000
Cost, $/year	$3,000	$4,000	$3,800	$3,000
Benefits, $/year	$20,000	$29,000	$30,000	$35,000
Disbenefits, $/year	$500	$1,500	$1,000	$0
Life, years	5	5	5	5

You need to find the *net benefits* (*benefits* - *disbenefits*) and *total costs* (*initial* + *running*) for each option

Net Benefits, $/year	$19,500	$27,500	$29,000	$35,000
Net cost, $/year	$16,190	$27,742	$23,585	$26,742

Example [5]

- Find the incremental B/C ratio and do the selection of alternatives

- Select option 1 according to the estimates of the first engineer
- Select option 2 according to the estimates of the second engineer

	2-1		2-1
ΔB	$8,000		$6,000
ΔC	$11,552		$3,157
ΔB/ΔC	0.69		1.90

Example [6]

- A public project has the following cash flows (in millions):

Year	Inflow ($)	Outflow ($)
0	0	10
1	0	10
2	20	5
3	30	5
4	30	8
5	20	8

- Compute the benefit cost ratio for this project

Example [6]

- Assume that the benefits (B) are the inflows and compute the present worth:

  B = 20(P/F,10%,2) + 30(P/F,10%,3) + 30(P/F,10%,4) + 20(P/F,10%,5) = $71.98

- Assume that the cost values (C) are the outflows and compute the present worth:

  C = 10 + 10(P/F,10%,1) + 5(P/F,10%,2) + 5(P/F,10%,3) + 8(P/F,10%,4) + 8(P/F,10%,5) = $37.41

- B/C = 71.98/37.41 = 1.92 and the project is economically feasible