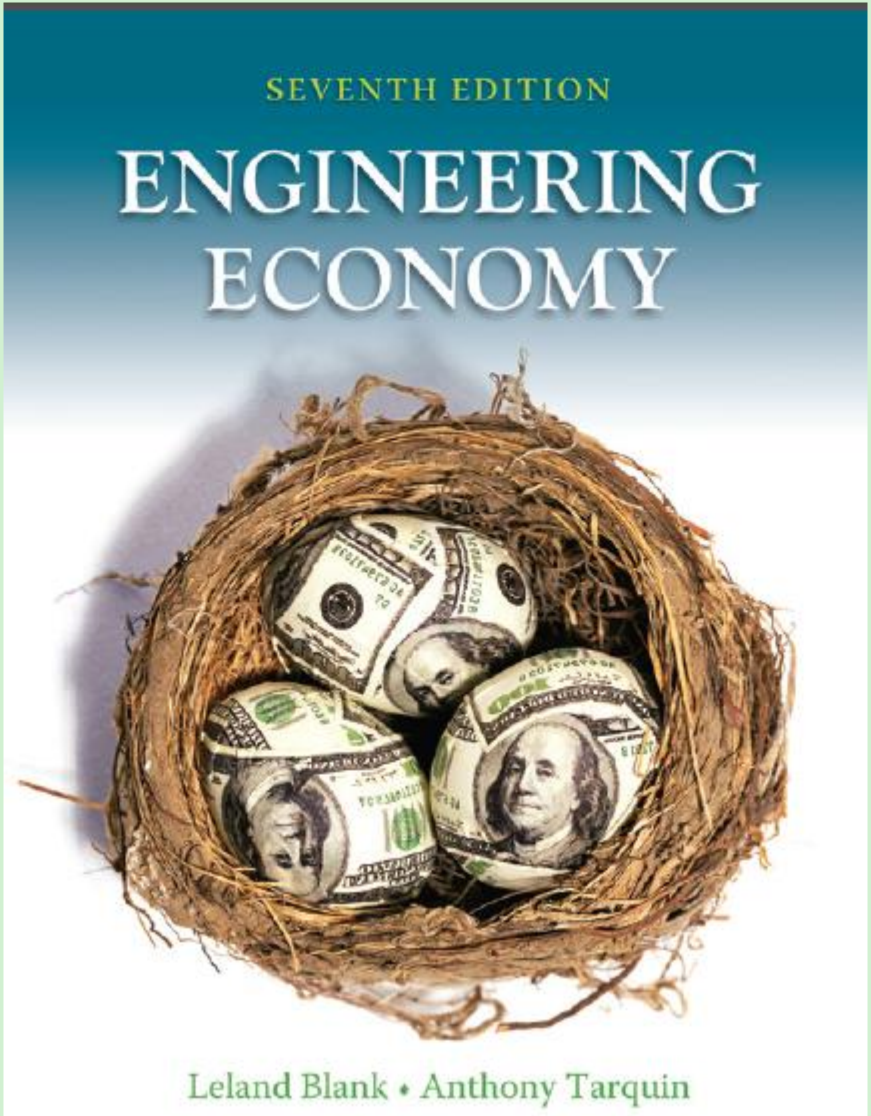

Chapter 9
Benefit/Cost Analysis

Lecture slides to accompany

Engineering Economy

7^{th} edition

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LEARNING OUTCOMES

1. Public Sector Projects
2. Difference in public vs. private sector projects
3. Calculate B/C ratio for single project
4. Alternative Selection Using Incremental B/C Analysis

Public Sector Projects

A public sector project is a product, service, or system used, financed, and owned by the citizens of any government level.

The primary purpose is to provide service to the citizenry for the public good at no profit. Areas such as public health, criminal justice, safety, transportation, welfare, and utilities are publically owned and require economic evaluation.

Public Sector Projects Examples

1. Hospitals and clinics
2. Parks and recreation
3. Utilities: water, electricity, gas,
4. sewer, sanitation
5. Schools: primary, secondary, community colleges, universities
6. Economic development projects
7. Convention centers
8. Sports arenas
9. Transportation: highways, bridges,
10. Waterways

12. Public housing
13. Emergency relief
14. Codes and standards
15. sewer, sanitation
16. Police and fire protection
17. Courts and prisons
18. Food stamp and rent relief programs
19. Job training

Differences: Public vs. Private Projects

Characteristic	Public sector	Private sector
Size of investment	Large	Some large; more medium to small

Often alternatives developed to serve public needs require large initial investments, possibly distributed over several years. Modern highways, public transportation systems, universities, airports, and flood control systems are examples.

Differences: Public vs. Private Projects

Characteristic	Public sector	Private sector
Life estimates	Longer (30–50 years)	Shorter (2–25 years)

The long lives of public projects often prompt the use of the capitalized cost method, where infinity is used for n and annual costs are calculated as A= P (i). As n gets larger, especially over 30 years, the differences in calculated A values become small. For example, at i =7%, there will be a very small difference in 30 and 50 years, because (A/P ,7%,30) =0.08059 and (A/P ,7%,50) =0.07246.

Differences: Public vs. Private Projects

Characteristic	Public sector	Private sector
Annual cash flow estimates	No profit; costs, benefits, and disbenefits are estimated	Revenues contribute to profits; costs are estimated

Costs—estimated expenditures *to the government entity for construction, operation, and maintenance* of the project, less any expected salvage value.

Benefits—advantages to be experienced *by the owners, the public.*

Disbenefits—expected undesirable or negative consequences *to the owners if the alternative is* implemented. Disbenefits may be indirect economic disadvantages of the alternative.

Differences: Public vs. Private Projects

Characteristic	Public sector	Private sector
Funding	Taxes, fees, bonds, private funds	Stocks, bonds, loans, individual owners

The capital used to finance public sector projects is commonly acquired from taxes, bonds, and fees. Taxes are collected from those who are the owners—the citizens (e.g., federal gasoline taxes for highways are paid by all gasoline users, and health care costs are covered by insurance premiums). This is also the case for fees, such as toll road fees for drivers.

Differences: Public vs. Private Projects

Characteristic	Public sector	Private sector
Interest rate	Lower	Higher, based on cost of capital

Because many of the financing methods for public sector projects are classified as *low-interest,* the interest rate is virtually always lower than for private sector alternatives. Government agencies are exempted from taxes. For example, municipal projects do not have to pay state taxes. Interest rates in the 4% to 8% range.

Differences: Public vs. Private Projects

Characteristic	Public sector	Private sector
Environment of the evaluation	Politically inclined	Primarily economic

There are often public meetings and debates associated with public sector projects to accommodate the various interests of citizens (owners). Elected officials commonly assist with the selection, especially when pressure is brought to bear by voters, developers, environmentalists, and others. The selection process is not as “clean” as in private sector evaluation.

Benefit /Cost Analysis of a Single Project

There are several variations of the B/C ratio; however, the fundamental approach is the same. All cost and benefit estimates must be converted to a common equivalent monetary unit (PW, AW, or FW) at the discount rate (interest rate). The B/C ratio is then calculated using one of these relations:

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

- Present worth and annual worth equivalencies are more used than future worth values. The sign convention for B/C analysis is positive signs, so *costs are preceded by a positive sign.*
- *Salvage values, when they are estimated, are subtracted from* costs.

Benefit /Cost Analysis of a Single Project

Most commonly, disbenefits are subtracted from benefits and placed in the numerator.

The *conventional B/C ratio, probably the most widely used, is calculated as* follows:

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

In above equation disbenefits are subtracted from benefits, not added to costs.
The B/C value could change considerably if disbenefits are regarded as costs.

Benefit /Cost Analysis of a Single Project

The *modified B/C ratio includes maintenance and operation (M&O) costs in* the numerator and treats them in a manner similar to disbenefits. The denominator includes only the initial investment. Salvage value is included in the denominator as a negative cost. Once all amounts are expressed in PW, AW, or FW terms, the modified B/C ratio is calculated as

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

The decision guideline is simple:

If B/C≥1.0, accept the project as economically acceptable for the estimates and discount rate applied.

If B/C ≤1.0, the project is not economically acceptable.

If the B/C value is exactly or very near 1.0, noneconomic factors will help make the decision for the “best” alternative.

Example 1: B/C Analysis – Single Project

A flood control project will have a first cost of \$1.4 million with an annual maintenance cost of \$40,000 and a 10 year life. Reduced flood damage is expected to amount to \$175,000 per year. Lost income to farmers is estimated to be \$25,000 per year. At an interest rate of 6% per year, should the project be undertaken?

Solution: Express all values in AW terms and find B/C ratio

B = \$175,000

D = \$25,000

C = 1,400,000(A/P,6%,10) + \$40,000 = \$230,218

B/C = (175,000 – 25,000)/230,218
= 0.65 < 1.0

Do not build project

EXAMPLE 2

The Bureau of Reclamation is doing an irrigation project at \$1.5 million and maintenance of \$25,000 per year. Agricultural revenue is expected to be \$175,000 per year. It's a 20 year project at 6% per annum. Find: Do a B/C analysis. Rework the problem doing a modified B/C analysis.

AW = C = 1,500,000(A/P,6%,20) + 25,000
= 1,500,000(.08718) + 25,000
= \$155,770

Annual revenue = B = \$175,000

B/C = 175,000/155,770
=1.12 >**1.0**

B/C>1.0 therefore it's go, the canals should be extended

For the modified B/C ratio

C = 1,500,000(A/P,6%,20)

= $130,770

B = 175,000- 25,000

= $150,000

Modified B/C = 150,000/130,770

Modified B/C = 1.15 **>1**

Since B/C>1 therefore it’s a go, the canals should be extended.

EXAMPLE 3

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. This grants program will share Foundation funding with ongoing activities, so 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.

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

Use Equation [9.2] for conventional B/C analysis, where M&O is placed in the denominator as an annual cost.

$$B/C = \frac{1{,}500{,}000 - 200{,}000}{2{,}038{,}050 + 500{,}000} = \frac{1{,}300{,}000}{2{,}538{,}050} = 0.51$$

The project is not justified, since $B/C < 1.0$.

By Equation [9.3] the modified B/C ratio treats the M&O cost as a reduction to benefits.

$$\text{Modified } B/C = \frac{1{,}500{,}000 - 200{,}000 - 500{,}000}{2{,}038{,}050} = 0.39$$

The project is also not justified by the modified B/C method, as expected.

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

$$B - C = (1{,}500{,}000 - 200{,}000) - (2{,}038{,}050 + 500{,}000) = \$-1.24 \text{ million}$$

Since $(B - C) < 0$, the program is not justified.

Alternative Selection Using Incremental B/C Analysis

The B/C analysis of two alternatives is as follows:

1. **Determine the equivalent total costs for both alternatives.**
2. **Order the alternatives by equivalent total cost: first smaller, then larger.**
3. **Calculate the incremental** cost (ΔC) *for the larger-cost alternative.*
4. **Calculate the equivalent total benefits and any disbenefits estimated for both alternatives.** Calculate the incremental benefits (ΔB) *for the larger-cost alternative. This is $\Delta(B-D)$ if* disbenefits are considered.
5. **Calculate the $\Delta B/\Delta C$ ratio using Equation $\Delta(B\text{-}D)/\Delta C$.**
6. **Use the selection guideline to select the higher-cost alternative if $\Delta B/\Delta C \geq 1.0$.**

The technique is used to compare two mutually exclusive alternatives with the following selection rule:

If $\Delta B/ \Delta C \geq 1.0$, choose the higher-cost alternative, because its extra cost is economically justified.

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

EXAMPPLE 4

Two routes are under construction. The route X is 25km and cost \$21 million. The route Y is 10km and cost \$45million. Maintenance is \$40,000/yr for route X and \$15,000 for the route Y. Additionally, resurfacing will be required every 10 years at a cost of 10% of the first cost for each route. The volume of traffic is 400,000 vehicles/year. The operating expense is assumed to be \$.35/km and time savings for the route Y is estimated to be \$900,000 per year. Take i=6% per year and an infinite life.

Annual cost of route X

=21,000,000(.06)+40,000+21,000,000(.10)(A/F,6%,10)

= 1,260,000+40,000+2,100,000(.07587) = $1,459,327

Annual cost of route Y

=45,000,000(.06)+15,000+45,000,000(.10)(A/F,6%,10)

=2,700,000+15,000+4,500,000(.07587) = $3,056,415

The route Y must be incrementally justified

Extra cost for route Y = $3,056,415-$1,459,327= $1,597,088

Incremental benefits of route Y= 400,000(.35)(25-10)+900,000

= $3,000,000

$\Delta B/\Delta C$= 3,000,000/ 1,597,088=**1.88** $\geq$ **1**

$\therefore$ **Build the route Y.**