

Engineering Economy

Chapter 10: Evaluating Projects with the Benefit-Cost Ratio Method

How are public projects different than private projects?

- Capital Source - Taxpayers pay the bill
- Decisions are politically influenced
- Benefits can be non-monetary – difficult to measure

These elements make engineering economy studies more challenging.

- ❖ The Flood Control Act of 1936 requires that benefits must exceed costs to justify federally funded projects, this is a criterion now used in most public projects.
- ❖ There can be difficulty defining benefits, and even in establishing costs.
- ❖ *Disbenefits* represent negative consequences of a project to the public (owners).

Self-liquidating projects are expected to repay their costs.

- ❖ These projects generally provide utility services (power, water, toll roads, etc.).
- ❖ They earn direct revenue that offset their costs, but they are not expected to earn profits or pay taxes.

Cost allocations in multiple-purpose, public-sector projects tend to be arbitrary.

- ❖ Some projects naturally have multiple purposes
- ❖ Some of the costs incurred cannot properly be assigned to only one purpose.
- ❖ Purposes may be in conflict.
- ❖ Often support for a public project, and its many purposes, is politically sensitive.

Difficulties inherent in engineering economy studies in the public sector.

- ❖ Profit $\neq$ effectiveness
- ❖ Monetary effect of many benefits is difficult to quantify
- ❖ Often strong political influence whenever public funds are used, with little consideration to long-term consequences.

Difficulties inherent in engineering economy studies in the public sector.

- ❖ Public projects are more subject to legal restrictions than private projects
- ❖ The ability of governmental bodies to obtain capital is more restricted than that of private enterprise
- ❖ The appropriate interest rate for discounting benefits and costs is often controversially and politically sensitive.

Selecting the interest rate to use in public projects is challenging.

- ❖ Main considerations are
 - ❖ the rate on borrowed capital,
 - ❖ the opportunity cost of capital to the governmental agency,
 - ❖ the opportunity cost of capital to the taxpayers.
- ❖ If money is borrowed specifically for a project, the interest rate on the borrowed capital is appropriate to use as the rate.

More interest rate considerations...

- ❖ The 1997 Office of Management and Budget directive states that a 7% rate should be used, as an approximation of the return tax payers could earn from private investments.
- ❖ Bottom line: there is no simple formula, and it is an important policy decision at the discretion of the governmental agency.

Applying the benefit-cost ratio method

The benefits must outweigh the costs



Two B-C ratios

Conventional B-C ratio with PW

$$\begin{aligned} B - C &= \frac{PW(\text{benefits of the proposed project})}{PW(\text{total costs of the proposed project})} \\ &= \frac{PW(B)}{I - PW(MV) + PW(O\&M)} \end{aligned}$$

Modified B-C ratio with PW

$$B - C = \frac{PW(B) - PW(O\&M)}{I - PW(MV)}$$

A project is acceptable when the B-C ratio is greater than or equal to one.

B-C ratios for annual worth.

Conventional B-C ratio with AW

$$\begin{aligned} B - C &= \frac{AW(\text{benefits of the proposed project})}{AW(\text{total costs of the proposed project})} \\ &= \frac{AW(B)}{CR + AW(O\&M)} \end{aligned}$$

Modified B-C ratio with AW

$$B - C = \frac{AW(B) - AW(O\&M)}{CR}$$

Example #1

- A retrofitted space-heating system is being considered for a small office building.
- The system can be purchased and installed for \$120,000, and it will save an estimated 300,000 kilowatt-hours (kWh) of electric power each year over a six-year period.
- A kilowatt-hour of electricity costs \$0.10, and the company uses a MARR of 15% per year in its economic evaluations of refurbished systems.
- The market value of the system will be \$8,000 at the end of six years, and additional annual operating and maintenance expenses are negligible.
- Using the conventional benefit-cost method, find the value of the B-C ratio.

Helpful info

$$\begin{aligned} B - C &= \frac{PW(\text{benefits of the proposed project})}{PW(\text{total costs of the proposed project})} \\ &= \frac{PW(B)}{I - PW(MV) + PW(O\&M)} \end{aligned}$$

$$(P/A, 15\%, 6) = 3.7845$$

$$(P/F, 15\%, 6) = 0.43232$$

Solution

$$\begin{aligned} B - C &= \frac{(\$300,000) (\$0.10) (P/A, 15\%, 6)}{\$120,000 - (\$8,000) (P/F, 15\%, 6)} \\ &= \frac{\$113,535}{\$116,542} = 0.97 < 1 \end{aligned}$$

Since this value is 0.97,
this is not a good system to consider

Disbenefits (D) can be included in the B-C ratio in either the numerator or denominator, as shown with AW below.

$$\begin{aligned} B - C &= \frac{AW(\text{benefits}) - AW(\text{disbenefits})}{AW(\text{costs})} \\ &= \frac{AW(B) - AW(D)}{CR + AW(O\&M)} \end{aligned}$$

*HW has in numerator

or

$$\begin{aligned} B - C &= \frac{AW(\text{benefits})}{AW(\text{costs}) + AW(\text{disbenefits})} \\ &= \frac{AW(B)}{CR + AW(O\&M) + AW(D)} \end{aligned}$$

Selecting projects

- ❖ If projects are independent, all projects that have a B-C greater than or equal to one (≥ 1) may be selected.
- ❖ For projects that are mutually exclusive, a B-C greater than one is required, but selecting the project that maximizes the B-C ratio does not guarantee that the best project is selected.

Incremental B-C analysis for mutually exclusive projects.

- ❖ Incremental analysis must be used in the case of B-C and mutually exclusive projects.
- ❖ Rank alternatives in order of increasing total *equivalent worth* of costs.
- ❖ With “do nothing” as a baseline, begin with the lowest equivalent cost alternative and determine the incremental B-C ratio ($\Delta B/\Delta C$), selecting the alternative with the higher equivalent cost if the ratio is greater than one.

Which, if any, of the MEA projects below should be selected using B-C analysis? Assume a 20 year study period and $MARR=10\%$.

	A	B	C
Investment	\$125,000	\$160,000	\$180,000
Annual O&M	10,000	10,000	9,500
MV (20 yrs.)	40,000	50,000	50,000
Benefit/yr.	35,000	42,000	44,000
PW(10%)-costs	204,190	237,703	253,447
PW(10%)-benefits	297,975	357,570	374,597
B-C ratio	1.46	1.50	1.47

Each alternative is attractive.

Incremental analysis

	A	B	C
Investment	\$125,000	\$160,000	\$180,000
Annual O&M	10,000	10,000	9,500
MV (20 yrs.)	40,000	50,000	50,000
Benefit/yr.	35,000	42,000	44,000
PW(10%)-costs	204,190	237,703	253,447
PW(10%)-benefits	297,975	357,570	374,597
B-C ratio	1.46	1.50	1.47

	$\Delta(B-A)$	$\Delta(C-B)$
Investment	\$35,000	\$20,000
Annual O&M	0	-500
MV (20 yrs.)	10,000	0
Benefits/yr.	7,000	2,000
PW(10%)-costs	33,514	15,743
PW(10%)-benefits	59,595	17,027
B-C ratio	1.78	1.08
Conclusion	B is better	C is better

Choose alternative C.

Example #2

A state-sponsored Forest Management Bureau is evaluating alternative routes (one must be chosen) for a new road into a formerly inaccessible region. Three mutually exclusive plans for routing the road provide different benefits, as indicated in the table.

Route	Construction Costs	Annual Maint. Cost	Annual Savings Fire Dam.	Annual Recreation Benefit	Annual Timber Benefit
A	\$185,000	\$2,000	\$5,000	\$3,000	\$500
B	220,000	3,000	7,000	6,500	1,500
C	290,000	4,000	12,000	6,000	2,800

The roads are assumed to have an economic life of 50 years, and MARR is 8% per year. Which route should be selected according to the B-C ratio method?

Helpful info

1. Order the alternates in terms of increasing equivalent worth of costs
2. Determine the B-C Ratio to qualify each alternative
3. Calculate the ΔB and ΔC of PW to determine the B-C Ratio
4. Prefer more expensive alternative if B-C Ratio is > 1
5. Repeat for next alternative

MARR = 8%
Econ Life = 50yrs

Route	Construction Costs	Annual Maint. Cost	Total Annual Benefits	Total PW Costs	Total PW Benefits
A	\$185,000	\$2,000	\$8,500	\$209,497	\$103,985
B	220,000	3,000	15,000	256,701	183,503
C	290,000	4,000	20,800	338,934	245,457

Solution

Comparison of routes	$\Delta B/\Delta C$	Decision
$\Delta(B - A)$	1.68	Select Alternative B
$\Delta(C - B)$	0.86	Keep Alternative B

From an incremental analysis, route B is the “least objectionable” alternative. If B is chosen, it simply means that the state will be receiving less than an 8% return on its capital. If another alternative could be identified that had a B/C ratio greater than or equal to one, it should be recommended.