Engineering Economy

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

The objective of Chapter 10 is to demonstrate the use of the benefit-cost ratio for the evaluation of public projects.

Public projects are unique in many ways.

- Frequently much larger than private ventures
- They may have multiple, varied purposes that sometimes conflict
- Often very long project lives
- Capital source is ultimately tax payers
- Decisions made are often politically influenced
- Benefits are often nonmonetary and are difficult to measure
- more...

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.

For any project, the proper perspective is to consider the *net* benefits to the *owners* of the enterprise.

- For government projects, the *owners* are ultimately the taxpayers.
- *Benefits* are favorable consequences of the project to the public (owners).
- *Costs* represent monetary disbursements required of the government.
- *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.
- In some cases *in-lieu* payments are made to governments in place of taxes and fees that would have been paid had it been under private ownership.

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

- Some projects naturally have multiple purposes—e.g., construction of a dam.
- 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 standard not used to measure effectiveness
- Monetary effect of many benefits is difficult to quantify
- May be little or no connection between the project and the public (owners).
- 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, and
  - 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.
- Another idea is to use a market-determined *risk-free* rate, about 3-4% per year.
- 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 consideration of the time value of money means this is really a ratio of *discounted benefits* to *discounted costs*.
- Recommendations using the B-C ratio method will result in identical recommendations to those methods previously presented.
- B-C ratio is the ratio of the equivalent worth of benefits to the equivalent worth of costs.

Two B-C ratios

Conventional B-C ratio with PW

$$B - C = \frac{PW(\text{benefits of the proposed project})}{PW(\text{total costs of the proposed project})}$$

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

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

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

Modified B-C ratio with AW

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

Pause and solve

Stillwater has initiated discussions on attracting rail service. A depot would need to be constructed, which would require $500,000 in land and $5.2 million in construction costs. Annual operating and maintenance costs for the facility would be $150,000, and personnel costs would be an additional $120,000. Other assorted costs would be born by the railroad and federal authorities. Annual benefits of the rail service are estimated as listed below.

$1,300,000	Railroad annual payments
$200,000	Rail tax charged to passengers
$180,000	Convenience benefits to local residents
$120,000	Additional tourism dollars for Stillwater

Apply the B-C ratio method, with a MARR of 8% per year and 20 year study period, to determine if the rail service should be established.

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

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

or

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

Added benefits vs. reduced cost

- As with the different types of ratios, the question arises if classifying certain cash flows as either added benefits or reduced costs.
- As before, while the numerical value of the ratio may change, there is no impact on project acceptability regardless of how the cash flows are handled.

Selecting projects

- If projects are independent, all projects that have a B-C great than or equal to one 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

	Δ(B-A)	Δ(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.

Pause and solve

Tempe is considering four mutually exclusive public-works projects. Their costs and benefits are presented in the table below. Each project has a useful life of 50 years and the MARR is 12% per year. Which of the projects, if any, should be selected?

	A	B	C	D
Capital investment	$23,000,000	$18,000,000	$31,000,000	$26,000,000
Annual op. and maint. cost	1,800,000	1,200,000	2,100,000	2,000,000
Market value	2,400,000	2,200,000	4,000,000	3,100,000
Annual benefit	5,000,000	4,500,000	6,500,000	5,800,000

Some criticisms of B-C analysis.

- B-C is often used as an “after-the-fact” justification tool.
- Distributional inequities (one group benefits, another pays the cost) may not be accounted for.
- Qualitative information is often ignored.
- Bottom line: these are largely reflective of the inherent difficulties in evaluating public projects rather than the B-C method itself.

Assignment on B-C analysis.

- Discuss history of Tista project
- Loss so far because dam made upstream at PW($)
- B-C analysis for the project under going/proposed