Chapter 1

Cost-Benefit Analysis

1.1 What is cost-benefit analysis?

> "Assessing costs and benefits across all affected groups or places matters because even a proposal with a relatively low public sector cost such as new regulation, may have significant effects on specific groups in society, places or business"

- A cost-benefit analysis is the process used to measure the benefits of a decision or taking action relative to the associated costs
- If benefits > costs, the decision or action is a good one to take
- If costs > benefits, the proposed action or decision should be reconsidered
- Cost benefit analysis can also be used to compare altenate decisions or actions

Both costs and benefits are required to be expressed in monetary terms, accounting for the time value of money. Costs may be categorised as:

- Direct - e.g. labour costs, manufacturing costs, material costs
- Indirect - e.g. utilities, rent
- Intangible - e.g. reduced productivity because of a new process
- Opportunity - lost benefits (opportunities) when pursuing one stratey over another

Benefits may be categorised as:

- Direct - e.g. increased revenue and sales
- Indirect - e.g. increased consumer interest
- Intangible - e.g. improved employee morale
- Competitive - e.g. being an industry leader

1.2 The Benefit-Cost Ratio method

The Benefit-Cost Ratio (BCR) is defined as the ratio of the equivalent value of benefits to the equivalent value of costs. The equivalent-value measure can be:

- Annual value (AV)
- Present value (PV)
- Future value (FV)

The BCR method has been the accepted procedure for making decisions and comparing projects in the public sector for many decades.

if BCR ≥ 1, the project is acceptable

Several different formulations of the BCR method have been developed. We examine two formulations of the BCR method that are commonly used by government agencies:

- Conventional BCR method
- Modified BCR method

Both formulations will lead to identical project acceptability decisions (i.e. BCR ≥ 1 or BCR < 1).

1.2.1 Conventional BCR method

Present value (PV) formulation:

$$BCR_{PV} = \frac{PV_{benefits}}{PV_{costs}} \tag{1.1}$$

$$BCR_{PV} = \frac{PV_{benefits}}{I - PV_{MV} + PV_{O\&M}} \tag{1.2}$$

Annual value (AV) formulation:

$$BCR_{AV} = \frac{AV_{benefits}}{AV_{costs}} \tag{1.3}$$

$$BCR_{AV} = \frac{AV_{benefits}}{CR + AV_{O\&M}} \tag{1.4}$$

Both ratios lead to identical numerical results. Where:

- I is initial investment in the proposed project
- MV is market value at the end of useful life
- $O\&M$ is operating and maintenance costs
- CR is capital-recovery amount (i.e. equivalent cost of I, includance an allowance for market or salvage value)

1.2.2 Modified BCR method

Present value (PV) formulation:

$$BCR_{PV} = \frac{PV_{benefits}}{PV_{costs}} \tag{1.5}$$

$$BCR_{PV} = \frac{PV_{benefits} - PV_{O\&M}}{I - PV_{MV}} \tag{1.6}$$

Annual value (AV) formulation:

$$BCR_{AV} = \frac{AV_{benefits}}{AV_{costs}} \tag{1.7}$$

$$BCR_{AV} = \frac{AV_{benefits} - AV_{O\&M}}{CR} \tag{1.8}$$

Both ratios lead to identical numerical results.

1.2.3 Convential and modified BCRs

Remember the formula for PV:

$$PV = \frac{FV}{(1+i)^n} \tag{1.9}$$

Present value (PV) of a future value (FV) in n years, for an interest rate i. Remember the formula for AV:

$$AV = PV \frac{i(1+i)^n}{(1+i)^n - 1} \tag{1.10}$$

Value of a series of uniform (annual) receipts (AV) that occur at the end of periods (years) 1 to n, given their present value (PV) and an interest rate i.

1.2.4 What value of i to use?

There are three main considerations when it comnes to what interest rate to use for engineering economy studies of public-sector projects:

- the interest rate on borrowed capital
- The opportunity cost of capital to the government agency
- The opportunity cost of capital to the taxpayers

1.2.5 Why do conventional and modified BCRs lead to the same decision?

Convential BCR formulation:

$$BCR_V = \frac{V_{benefits}}{I - V_{MV} + V_{O\&M}} = \frac{B}{C} \tag{1.11}$$

Where subscript V denotes either PV or AV. Modified BCR formulation:

$$BCR_V = \frac{V_{benefits} - V_{O\&M}}{I - V_{MV} + V_{O\&M} - V_{O\&M}} = \frac{B-X}{C-X} \tag{1.12}$$

Both the numerator and denominator differ by the same constant.

$$\frac{B}{C>1} \to B > C \to B - X > C - X \to \frac{B-X}{C-X} > 1 \tag{1.13}$$

leading to the same decision.

1.2.6 Example 1

The Greater London Authority is considering extending the runways of Stansted Airport so that larger commercial airplanes can use the facility. The land necessary for the runway extension is currently a farmland that can be purchased for £350,000. Construction costs for the runway extension are projected to be £600,000, and the additional annual maintenance costs for the extension are estimated to be £22,500. If the runways are extended, a small terminal will be constructed at a cost of £250,000. The annual operating and maintenance costs for the terminal are estimated at £75,000. Finally, the projected increase in flights will require the addition of two air traffic controllers at an annual cost of £100,000. Annual benefits of the runway extension have been estimated as follows:

Description	**Annual benefit**
Leasing fee receipts from airlines	£325,000
Passenger airport tax receipts	£65,000
Convenience benefit for residents near Stansted	£50,000
Additional tourism money for London	£50,000
Total	**£490,000**

Table 1.1: Example 1.

Apply the BCR method with a study of 20 years and a MARR of 10% per year to determine whether the runways at Stansted airport should be extended.
Information provided:

$$i = 0.1 \tag{1.14}$$

$$n = 20\,\text{years} \tag{1.15}$$

$$I = 350000 + 600000 + 250000 = 1200000 \tag{1.16}$$

$$AV_{benefits} = 490000 \tag{1.17}$$

$$PV_{MV} = AV_{MV} = 0 \tag{1.18}$$

$$AV_{O\&M} = 22500 + 75000 + 100000 = 197500 \tag{1.19}$$

First, we need to determine PVs and AVs using:

$$PV = AV\frac{(1+i)^n - 1}{i\,(1+i)^n} \tag{1.20}$$

$$AV = PV\frac{i\,(1+i)^n}{(1+i)^n - 1} \tag{1.21}$$

$$PV_{benefits} = 4171646 \tag{1.22}$$
$$PV_{O\&M} = 1681429 \tag{1.23}$$
$$AV_I = CR = 140951 \tag{1.24}$$

Conventional BCRs:

$$BCR_{PV} = \frac{PV_{benefits}}{I - PV_{MV} + PV_{O\&M}} = 1.448 \tag{1.25}$$
$$BCR_{AV} = \frac{AV_{benefits}}{CR + AV_{O\&M}} = 1.448 \tag{1.26}$$

Modified BCRs:

$$BCR_{PV} = \frac{PV_{benefits} - PV_{O\&M}}{I - PV_{O\&M}} = 2.075 \tag{1.27}$$
$$BCR_{AV} = \frac{AV_{benefits} - AV_{O\&M}}{CR} = 2.075 \tag{1.28}$$

BCR ≥ 1 in all cases, so runway should be extended.

1.2.7 Issues of concern using BCRs

- The treatment of disbenefits
  - Negative consequences to the public resulting from the implementation of a public sector project
- The treatment of certain cash flows as additional benefits or reduced costs

1.2.8 Treatment of disbenefits

Disbenefits can be incorporated in BCR calculations by:

- Reducing benefits accordingly (traditional approach) or
- Increasing costs accordingly

How do these approaches affect the BCR? How do these approaches affect the final decision?