3: Cost Benefit Analysis (CBA)
INTRODUCTION

How can we use value measures in determining environmental policy?
Measures of project worth

• Are measures that tell us whether a project is *worth undertaking* from a particular viewpoint or not

• All such measures are concerned with the question as to *whether the benefits are greater than the costs*
• Since projects usually have a time dimension and costs are usually greater than benefits in the initial stages of the project, any measure of project worth must find a way of dealing with the valuation of costs and benefits at different moments of time.

• There are different ways of measuring project worth, some of which use discounting techniques and some of which do not.
Non-discounted measures of project worth: The payback period

• The **simplest** of all measures of project worth and, because of its simplicity, it is used extensively for the analysis of small investments by the private sector.

• It is simply defined as the **period** (i.e. the number of years) **required to recover the original investment cost**.

• The idea is that the **shorter** the period taken to repay the investment the **better** so that **low values** of the **payback period** are looked for.
• The payback period is a **very crude measure** of project worth because it completely **ignores benefits** after the period when the initial investment has been repaid.

• It would therefore be a very **unreliable** means for comparing two different investments with different time profiles and it discriminates heavily against projects with a long gestation period - particularly infrastructure projects, other large capital investment projects and forestry.

• Businessmen like to use it because it **focuses on early returns** which are regarded as less uncertain than returns in the medium to long term future.
Simple or annual rate of return

• For commercial projects with conventional financial accounts, a simple estimate of the value of a project is obtained by expressing the projected net profit after depreciation, interest and taxes as a proportion of the total share (equity) capital invested in the project.

• This measure would usually be taken for a 'typical' year - usually the year when the project reaches full capacity operation.
Simple or annual rate of return …

• The measure is sometimes called the return on equity capital and is defined as the percentage for year t by:

\[ \text{RE}_t = \frac{NP_t}{K_t} \times 100 \]

Where RE is the return on equity capital; NP is net profit and K is the value of equity capital.
Simple or annual rate of return …

- A **similar measure** can be defined for the **total capital** (including loan capital) invested in the project by excluding interest from the net profit and including **loan capital in the total capital invested**. The return on total capital invested is defined by:

\[
RE_t = \frac{NP_t + It}{Kt} \times 100
\]

Where \( R \) is the return on total capital, \( I \) is the interest paid and \( K \) is the value of total capital invested.
• These accounting measures take account of the fact that *investment takes place over a number of years* by including *depreciation* as a measure of the *annual value of investment costs* when calculating the value of net profit.
Disadvantages of use of accounting measures of profit

• The measures are *only applicable to commercial projects* for which *conventional accounts* are available.

• The measures *presuppose* that the *structure to be adopted for financing* the project is already *known*. This is often not the case at the pre-feasibility stage.

• The measures only *apply to one particular year* and so they may not be very representative for the project as a whole.
Disadvantages ....

• They use depreciation as an estimate of the capital invested. Depreciation as a measure simply divides total expenditure on capital assets over a period of years. It does not allow for the possibility that a unit of cost in Year zero may not be equivalent to a unit of benefit in a subsequent year. Measures of depreciation can also be heavily distorted by inflation.
• Accountant’s measures of profitability were designed for assessing the position of an existing enterprise during operation.

• They are not particularly well suited for ex ante project appraisal, especially for non-commercial projects.

• In general, non-discounted measures of project worth can be regarded as simplified short cuts that can be used for rough approximations and making decisions on small investments.

• They should not be used for comparing projects or making major investment decisions.
Discounted measure: The CBA

- Is a basic **project** or **policy analysis tool** often used in environmental analysis

- Developed in the **US** in the 1940s (first focused on **water resource development**)

- Asked the simple question “Do the expected benefits of an investment justify the costs?” (Flood Control Act of 1936)

- The idea is to **maximise** - Present Value of **Net Benefits** (PVB)
Decision Rules

Net Present Value (NPV)  \[ NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1 + r)^t} \]

Economic Internal Rate of Return (EIRR)  \[ \sum_{t=0}^{n} \frac{B_t - C_t}{(1 + r)^t} = 0 \]

Benefit-Cost Ratio (B/CR)  \[ \text{B/C ratio} = \frac{\sum_{t=0}^{n} \frac{B_t}{(1 + r)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1 + r)^t}} \]
Each evaluation criteria yields a different answer to the decision question
  – The answer to a NPV analysis is a monetary amount

  – The EIRR determines the discount rate where the PV of benefits is just equal to the PV of costs (and the EIRR is then compared to the discount rate)

  – The answer to a B/CR calculation is a ratio (a pure number, often just less than or just more than 1.0)
• All three criteria use the same input data on benefits and costs over a defined time period (the “time horizon”), and with a pre-determined discount rate for NPV and B/CR.

• The EIRR solves for the discount rate where PV benefits is equal to PV of costs.
The EIRR

• May be defined as that *rate of discount which equates the present worth* (or present values) of the costs and benefits streams

• It is calculated using the *same methodology* as the NPV and B/C ratios

• The *discount rate can be adjusted until the NPV becomes zero - or at least as close to zero* as possible without splitting the discount rate into less than discrete units of one percentage point each

• Thus *the rate is derived by trial and error* or *interpolation*
a) Arithmetic interpolation of EIRR …

- The arithmetic rule for interpolation using two discount rates, one which gives a positive NPV and the other which gives a negative NPV, is as follows:

\[
EIRR = r_1 + \left[ (r_2 - r_1) \times \left( \frac{NPV_1}{NPV_1 - NPV_2} \right) \right]
\]

where
- \( r_1 \) = the lower discount rate
- \( r_2 \) = the higher discount rate
- \( NPV_1 \) = NPV at the lower discount rate
- \( NPV_2 \) = NPV at the higher discount rate
b) Graphic interpolation of EIRR ...

- The graphical method calls for interpolation between points plotted on a graph with NPV measured on the vertical axis and the discount rate on the horizontal axis. If
  - EIRR > test discount rate ... accept
  - EIRR < test discount rate ... reject
b) Graphic interpolation of EIRR …

• The graphical method calls for interpolation between points plotted on a graph with NPV measured on the vertical axis and the discount rate on the horizontal axis. If
  – EIRR > test discount rate ... accept
  – EIRR < test discount rate ... reject
Worked examples - CBA
**Example 1**: From the following project information, calculate the NPV with an 8% discount rate

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>10 000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Cost</td>
<td></td>
<td>4 000</td>
<td>4 000</td>
<td>4 000</td>
</tr>
<tr>
<td>Revenue</td>
<td>8 000</td>
<td>8 000</td>
<td>8 000</td>
<td>8 000</td>
</tr>
</tbody>
</table>
**Method 1: Cost and revenue streams discounted separately:**

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Costs</td>
<td>10 000</td>
<td>4 000</td>
<td>4 000</td>
<td>4 000</td>
</tr>
<tr>
<td>Discount Factor</td>
<td>1.0000</td>
<td>0.9259</td>
<td>0.8573</td>
<td>0.7938</td>
</tr>
<tr>
<td>Present Value</td>
<td>10 000.0</td>
<td>3703.6</td>
<td>3429.2</td>
<td>3175.2</td>
</tr>
</tbody>
</table>

That is, \( \text{NPV} = \text{PV}(B) - \text{PV}(C) \)

\[
\text{NPV of project} = (\text{PV of benefits } 20 616 \text{ less PV of costs } 20 308) = 308
\]
**Method 2: Net benefit stream discounted (NPV = PV(B-C)):**

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefits</td>
<td>8 000</td>
<td>8 000</td>
<td>8 000</td>
<td></td>
</tr>
<tr>
<td>Capital Costs</td>
<td>10 000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Costs</td>
<td>4 000</td>
<td>4 000</td>
<td>4 000</td>
<td>4 000</td>
</tr>
<tr>
<td>Net Revenue</td>
<td>-10 000</td>
<td>4 000</td>
<td>4 000</td>
<td>4 000</td>
</tr>
<tr>
<td>Discount Factor</td>
<td>1.0000</td>
<td>0.9259</td>
<td>0.8573</td>
<td>0.7938</td>
</tr>
<tr>
<td>Present Value</td>
<td>-10000.0</td>
<td>3703.6</td>
<td>3429.2</td>
<td>3175.2</td>
</tr>
</tbody>
</table>

Net Present Value = 308.0

NPV of project = 308
Example 2: Using the same project data as before, the benefit/cost ratio can be calculated. A discount rate of 8% is again used.

Gross benefits divided by gross costs: The data required for this method is given by method 1 of the NPV calculation, i.e. taking the present values of the cost and benefit streams separately.

\[
\frac{\text{Gross Benefits}}{\text{Gross Costs}} = \frac{\text{PV of Benefits}}{\text{PV of Capital Costs} + \text{PV of Operating Costs}}
\]

\[
= \frac{20616}{10000 + 10308}
\]

\[
= \frac{20616}{20308} = 1.015
\]
**Example 3:** Using the same project data as in the NPV worked example 1, calculate the EIRR

**Method 1: Arithmetic method -** It was found that the NPV at 8% was 308. Adopting a second trial rate of discount at 10%, the NPV is found to be -52.8.

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Revenue</td>
<td>-10000</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
</tr>
<tr>
<td>Discount Factor (10%)</td>
<td>1.0000</td>
<td>0.9091</td>
<td>0.8264</td>
<td>0.7513</td>
</tr>
</tbody>
</table>
| Present Value (10%) | -10000.0 | 3636.4 | 3305.6 | 3005.2 | Net Present Value = -52.8
The EIRR therefore lies between 8 and 10%. Using the formula above, the calculation proceeds

\[
\text{IRR} = 8\% + \left[ (10 - 8) \times \left( \frac{308.0}{308.0 - (-52.8)} \right) \right]
\]

= 9.7 per cent
Method 2: Graphical Method - Using the same data, two points may be plotted on the graph (see the Figure in the next slide) and joined by a straight line:

The point at which this line cuts the horizontal axis (i.e. where the NPV is zero) gives the EIRR

It is conventional to report the EIRR obtained by either the arithmetic or graphical methods to the nearest whole percentage point below

The EIRR in this example is therefore 9%