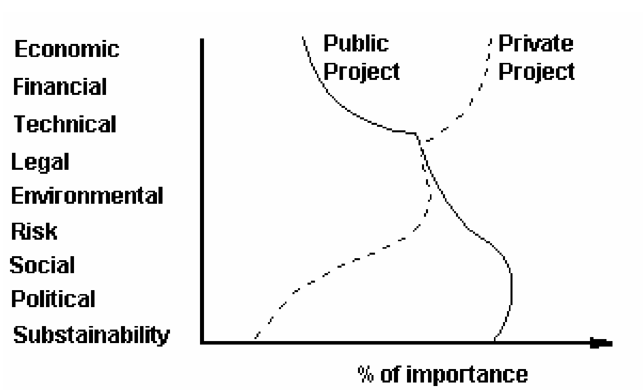
Project Evaluation

Selection of the right projects is crucial for long-term survival of the company. Choosing the wrong project does not just mean that the project will be doomed, but it may have a detrimental effect on the immediate future of the company. The development of the “RB111 carbon fibre turbine blade” project by Rolls Royce is one of the well-known cases. The aim of project evaluation is to facilitate choice amongst alternative projects under consideration. Data, which is relevant to projects, is organized and aggregated into a summary that reflects the relative strengths and weaknesses of each project. The projects are then ranked according to the pre-determined criteria and the one which best satisfies the objectives of the company is selected.

Selection Criteria

The criteria by which the merits of the alternatives are assessed depend on the project and the company’s objectives. Some of the most commonly used criteria and its relative importance are shown in the diagram below.



As shown in the above diagram, public projects and private projects are often evaluated using a different set of priorities. Different industries may also assign different priorities to the same set of criteria. Even within a project evaluation team, different members can assign different priorities to the same set of criteria. This explains why project evaluation team members often come to different conclusions on the selected alternative even though they are all using the same data. Team members may have different values and sometimes different objectives. It is therefore important for the project team to realize that conflict management is an important part of project evaluation.

Project evaluation analytical tools

Many tools are available to assist us in project evaluation. Most of these tools are quantitative. The most widely used quantitative tools are economic analysis tools. They aim at maximization of the usage of resources (in monetary terms). Most of the literature recommends the use of quantitative analysis, as it is easy to use and understand. It provides a powerful means of converting raw data into a few indices to facilitate choice. However, it has limitations. Most of the quantitative analysis tools assume that all factors can be somehow transformable into their monetary values. This is not always possible, as not all factors (such as intangibles) have market value. Shadow prices are often used to attach prices to intangibles. However, the process is somewhat arbitrary.

Time value of money

One of the most commonly used economic analysis tools is the Cost and Benefit Analysis. Its aim is to aggregate all costs and benefits of a project, and to use the result to gauge the worthiness of each project. When the life of a project spans over several periods (for example, years), costs incurred in one period may generate benefits for many periods to come. Money, however, has a time value. A dollar in a period may not be the same dollar in the next period to come. A dollar now may not have the same usefulness or purchasing power later. Evaluation of the worthiness of a project must therefore compare benefits and costs that occur at different time periods. This requires a conversion facility to translate all cash flows into comparable quantities. In practice, the conversion is carried out by a handful of formulas which depend on only two parameters; the "life" of the project and the discount rate. As these two parameters are rarely known with certainty, the results of the Cost and Benefit Analysis are often somewhat arbitrary and the results must therefore be interpreted with care. Evaluation of projects is both an art and a science.

Discount rate, interest rate and inflation

Money increases its value in future if it is put to productive use (such as "putting it in the bank") between now and then. Furthermore, inflation can erode the purchasing power of the dollar over a period of time. A dollar now is definitely worth more than a dollar in the future. Discount rate represents the way that the value of future money can be reduced to make it correspond to an equivalent amount today. It is the parameter that enables us to compare costs and benefits that are incurred in different periods.

In practice, a discount rate is usually thought of as the prevailing interest rate. In actual fact, the former is always slightly higher than the latter.

In the evaluation of alternatives, inflation is usually ignored as it affects all alternatives equally. However, this may not be the case for long term projects or the alternatives that have different life spans. Inflation can be handled in the following ways:

1. using "real" dollars, i.e. adjust the discount rate for inflation,

Adjusted discount rate = $$\frac{1 + i^{interest}}{1 + i^{inflation}} - 1$$

1. using "actual" dollars and an unchanged discount rate. In this case, all costs and benefits must be adjusted for the anticipation inflation.

Steps in the analysis

The steps of the analysis can be summarized as follows:
1. determine the alternatives,
2. define the study period,
3. identify all costs and benefits and provide estimates for them,
4. specify a discount rate,
5. determine the value of one or more evaluation criteria,
6. undertake a Sensitivity Analysis, and
7. rank and select an alternative.

The selection process

In general, there are three approaches:

- rational model, i.e. evaluate all alternatives,
- mixed scanning mode, i.e. evaluate a subset only
- muddling through, i.e. look at the ones that they know better.

Determine the study period

When the alternative projects have a different duration, the study period can be one of the ff:

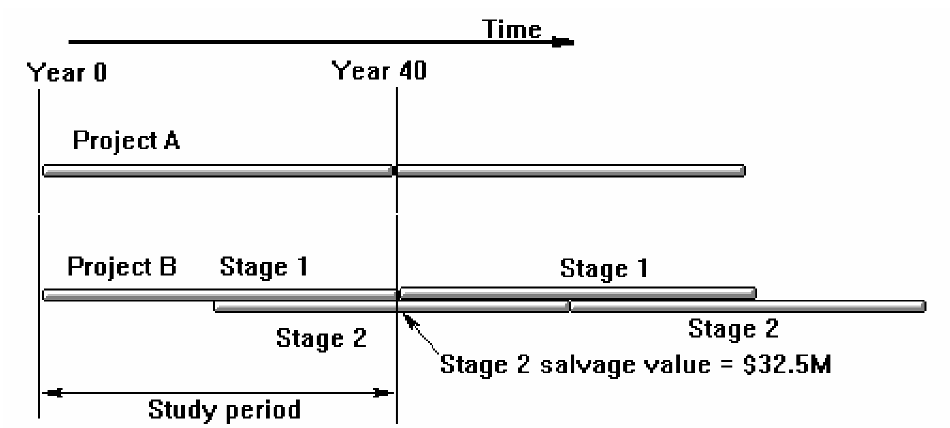
1. The organization's "planning horizon",
2. The life of the shortest-lived alternative,
3. The life of the longest-lived alternative,
4. The lowest common multiple of the life of the alternatives,

An example to illustrate the selection of the study period

Two alternatives with the estimated lifespan are as follows:

1. Project A will last for 40 years.
2. Project B requires an investment for its 2nd stage development in the Year 20. Each stage has an economic life span of 40 years.

Both projects give no salvage value at the end of their economic life. As the projects do not have a common multiple of their economic life, the duration of Project A is chosen as the study period. At the end of the study period, the value of the 2nd stage development is assumed to have a salvage value of $32.5 million based on a linear depreciation method. (see Appendix for more information on this example)



Evaluation methods

The first four of the following methods will be illustrated using the example contained in the Appendix attached to this chapter.

1. Present Worth
2. Annual Worth
3. Rate of Return
4. Benefit-Cost Ratio
5. Cost-effective criteria

Present Worth method

The present worth of a project is defined as the net present value (NPV) of its benefits, minus the net present value of its costs. The Present Worth method is primarily used for the analysis of investment of a lump sum of money. Care must be taken when using NPV to evaluate projects. Under project environment, alternative projects may require a different amount of investment. A selection of alternatives based on pure comparison of NPV disregarding the scale (in terms of its level of investment or total budget) is definitely wrong. NPV suggests profit. However, as previously mentioned, discount rate is always greater than the prevailing interest rate, thus, NPV actually under-estimates the actual profit. In the case of evaluating alternatives, this does not pose any problem as this affects all alternatives equally.

Annual Worth

Annual worth expresses the result of present worth in terms of a uniform series of payments over the study period.

The formula for the conversion is:

$$Annual\_payment = \frac{Present\_worth * discount\_rate(1 + discount\_rate)^{Study\_period}}{(1 + discount\_rate)^{Study\_period}}$$

As most people are accustomed to thinking in terms of annual income and expenditure, the Annual Worth method is more readily understood by most people.

Benefit-Cost Ratio Method

Benefit cost ratio is given by the ratio of the net present value of all benefits to that of all costs. The ratio is always a positive value. Any project with a benefit-cost ratio greater than one is worth proceeding with and the alternatives with the highest ratio should be selected. This method is often used in project evaluation of public sector projects.

In the case where the Present Worth method and Benefit-Cost Ratio method do not provide a consistent recommendation on the selection of alternatives, Incremental Benefit-Cost Ratio method can be used. This method basically uses the difference between the costs as well as the benefits of the two alternatives.

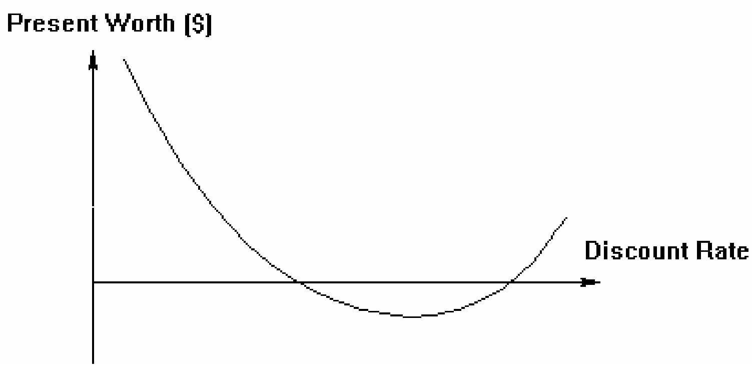
Rate of Return

Internal Rate of Return (IRR) is also known by other names; such as profitability index, discount cash return, etc. The rate of return represents the interest rate for which the net present value of the project is zero. In this method, an alternative with highest rate of return is selected, provided that its rate of return is higher than the minimum acceptable rate of return (MARR).

This method is attractive because of the following reasons:
1. it is readily understandable by people who are familiar with the concept of interest, and
2. it eliminates the need to pre-determine the discount rate.

However, there are disadvantages.
1. Calculation of IRR is tedious.

2. In some cases, there may be no solution if the present worth is zero at more than one discount rate, as shown in the following diagram.



Cost effectiveness

This method is used when the benefits can not be measured in dollar terms.
For a simple example, please refer to Hollict's book (1993) P.443.

Decision making under risk and under uncertainty

Decision making under risk refers to cases where probability that a particular outcome will occur can be estimated, even though the actual magnitude of each outcome may not be predicted. In this situation, the decision tree is the most commonly used tool.

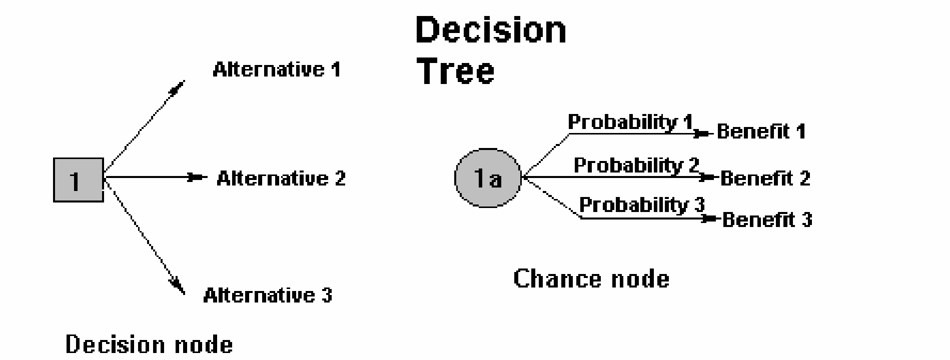
Decision making under uncertainty refers to cases where neither the actual outcome nor the probability that they will occur can be estimated. Sensitivity Analysis, Best and Worse Case analysis and Monte Carlo Analysis (simulation) are the tools that can be used. Under Sensitivity Analysis, the values of the independent valuable are systematically changed (one variable at a time) to determine how the results will be affected. This could reveal which factors the results are more sensitive to. This can allow us to concentrate on reducing the uncertainties associated with these "sensitive" variables.

Decision making under risk

The most common approach is to use expected values and the decision tree. The steps of the method are:

1. Identify all the decision nodes, i.e. the point of decision and the alternatives available at each node (see diagram below)

2. Identify all the chance nodes (i.e. the point of probability) and all the possible outcomes at each node (see diagram below).

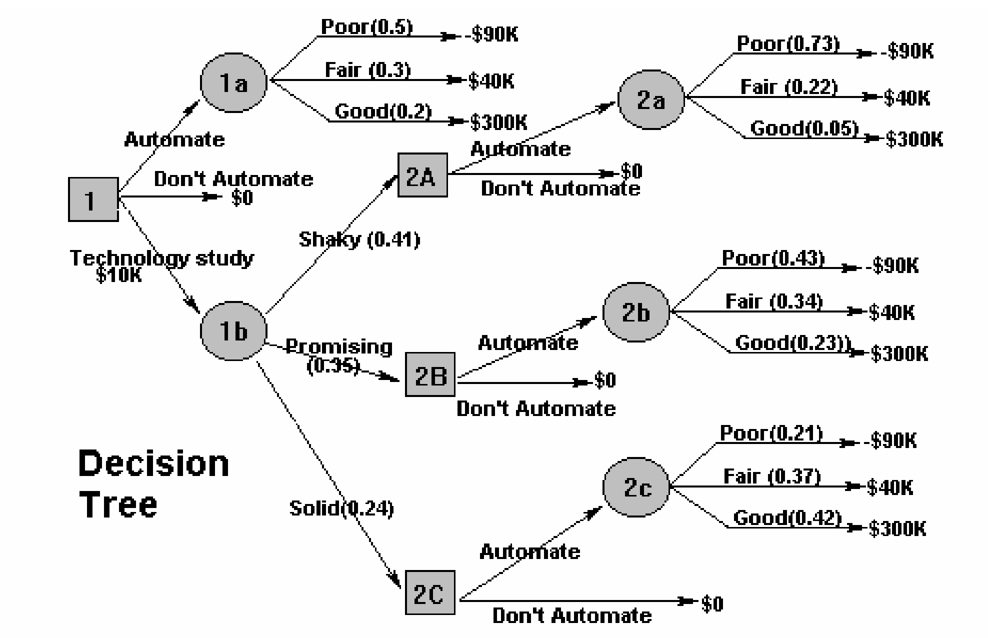


Note that Probability 1 + Probability 2 + Probability 3 = 1

3. Estimate costs/returns of various outcomes and all decision actions and also the probability of each outcome in each chance node.

4. Starting from the most distant chance node and working backwards, choose the best decision at each decision point and roll back all the expected monetary values to the first decision node.

An example of decision making under risk



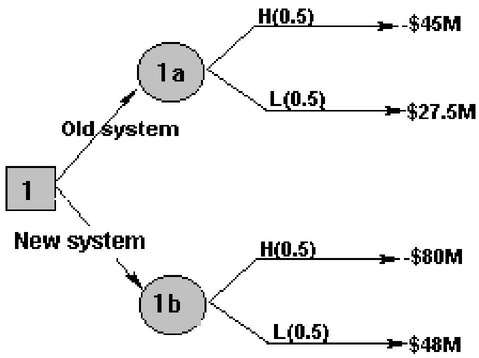
Source: Shtub et. al. (1994)

The decision at each decision point is as follows:

1. The decision at Node 2A is Don't Automate ($0 as compared to -$41.9K)
2. The decision at Node 2B is Automate ($43.0K as compared to $0)
3. The decision at Node 2C is Automate ($121.9K against $0)
4. The decision at the last node is Technology study ($34.62K as compared to $0 for Don't automate and $27K for Automate)

Decision to buy more information

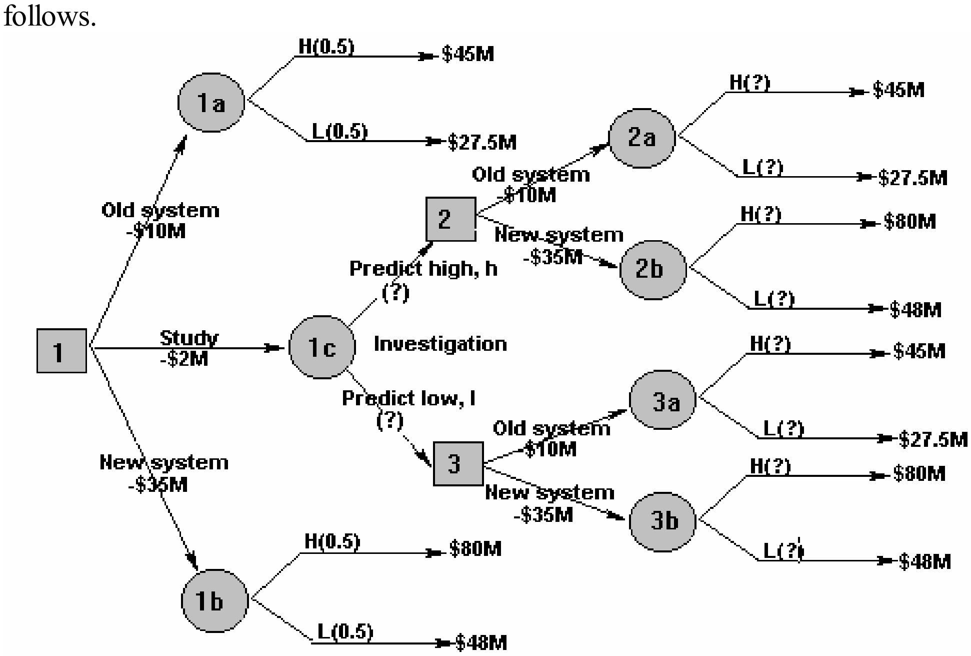
It is not unusual during decision making under risk that the project manager may have to make a decision on whether or not to invest in further research (investigation) to gather more information. The concept of Bayesian Statistics is used to modify the original estimates of probability. To illustrate the concept, the diagram below shows a simple decision tree. For simplicity, we assume that there are only two outcomes, i.e. demand is high and demand is low as shown in the diagram below. There is a 50-50 chance that the demand will go either way,
i.e. P(H) = P(L) = 0.50



Source: Shtub et. al. (1994)

Assuming that the following are the probabilities of the investigation to predict the outcomes.
1. 70% chance that the prediction of high demand is correct, i.e. P(h/H) = 0.70.
2. 80% chance that the prediction of low demand is correct, i.e. P(l/L) = 0.80

These four probabilities, however, cannot be used on the decision tree as shown below. The probabilities that are required for the analysis are shown as **?** on the decision tree in the diagram that follows.



Source: Shtub et. al. (1994)

The required probabilities are:

- the probability of the outcome to be high when the investigation has predicted high demand, i.e. P(H/h). Fortunately, there is a formula to calculate this probability from those that we have. The formula is given by:

$$P(\frac{H}{h}) = \frac{P(\frac{h}{H})P(H)}{\sum(P(\frac{h}{H})P(H)}$$

$$= \frac{0.7 * 0.5}{0.45} = 0.78$$

Where the value for $\sum(P(\frac{h}{H})P(H)$ can be calculated as below:

Outcome	P(Outcome)	$P(\frac{h}{Outcome})$	$P(\frac{h}{Outcome})P(Outcome)$
H (High)	0.5	0.7	0.5*0.7 =0.35
L (Low)	0.5	0.2	0.5*0.2 = 0.10
		$\sum P(\frac{h}{Outcome})P(Outcome)$	= 0.45

The value for

$$P(\frac{L}{h}) = \frac{0.2 * 0.5}{0.45}$$

= 0.22

- The values for

$$P(\frac{L}{l}) \text{ and } P(\frac{H}{h})$$

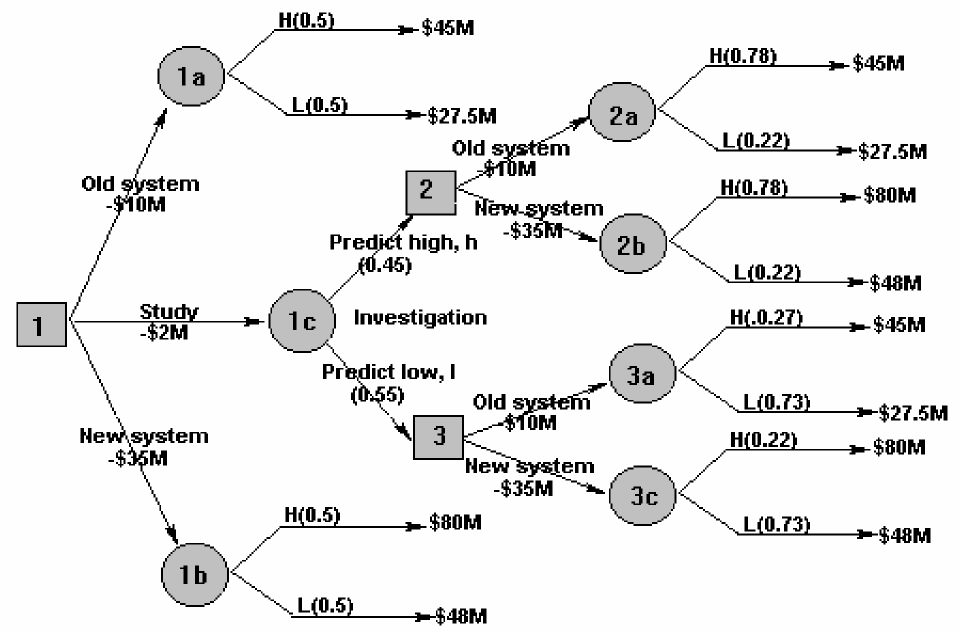
can be calculated in a similar fashion and are 0.73 and 0.27 respectively.

- The probabilities for the investigation chance node are given by

$$\sum P(\frac{h}{Outcome})P(Outcome) \text{ and } \sum P(\frac{l}{Outcome})P(Outcome)$$

and are 0.45 and 0.55 respectively.

The following decision tree can now be used to assist in decision making.



Source: Shtub et. al. (1994)

The decision based on this decision tree is not to go ahead with the Technology study.

Final comments

In this chapter, we have only discussed the use of Cost-Benefit Analysis and decision making under risk. These tools however, may not be powerful enough to handle complex project evaluation. Readers are strongly advised to read about the multiple-criteria tools such as Multiple objective planning and Scaled checklists, and quality analysis methodology such as Analytic Hierarchy Process(AHP).

Appendix

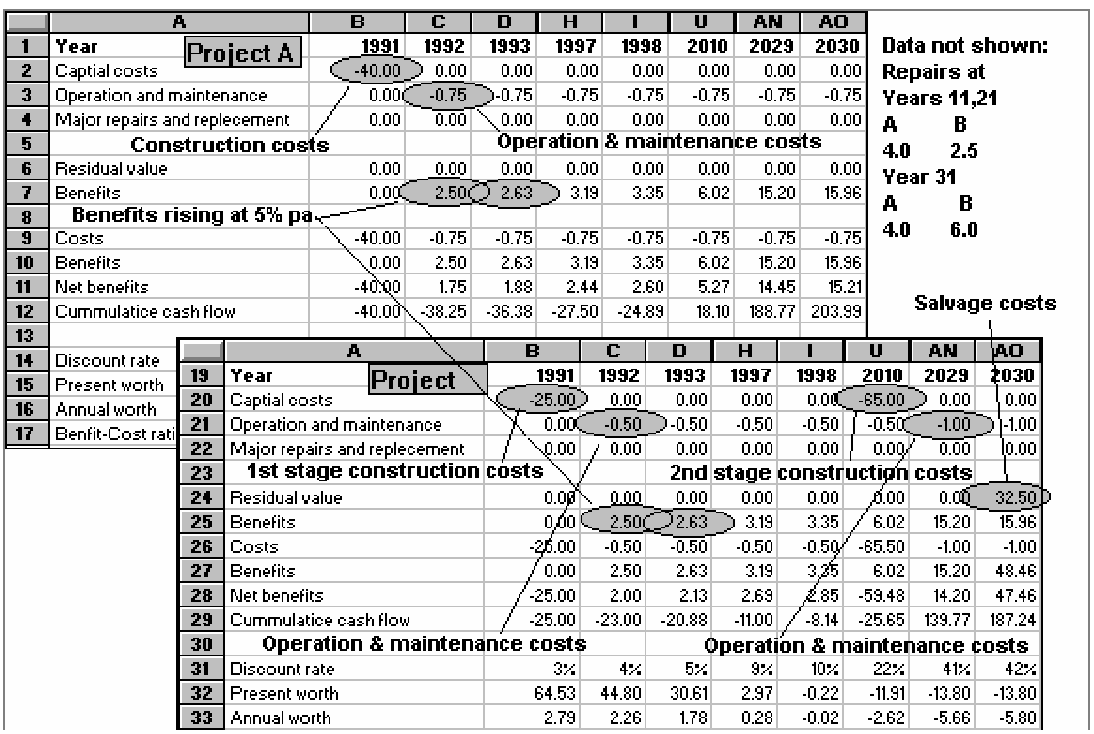
Source: Hollick, M. (1993) "An Introduction to Project Evaluation", Longman Cheshire.

Project A and Project B are the alternatives for selection.

Project A has a life span of 40 years and requires an initial investment requirement of $40M. At the end of the economic life, Project A has no salvage value. Project B has two stages. The initial investment for 1st stage is $25M and that for the 2nd stage is $65M in the Year 20. Both stages have a lifespan of 40 years with zero salvage value at the end. The discount rate is 5% and inflation rate is assumed to be zero.

For project A, the operation and maintenance costs remain constant at $0.75M from Year 2 onwards. Major repairs are $4.0M each at years 11, 21, and 31. For project B, the cost is $0.5M between year 2 to year 20 and is increased to $1.0M from year 21 onwards. Major repairs are $2.5, $2,5 and $6.0 at years 11, 21, and 31 respectively.

Benefit for both projects are $2.5M p.a. commencing Year 2 and rising at 5% p.a.
The following spreadsheet shows the data for both Projects.



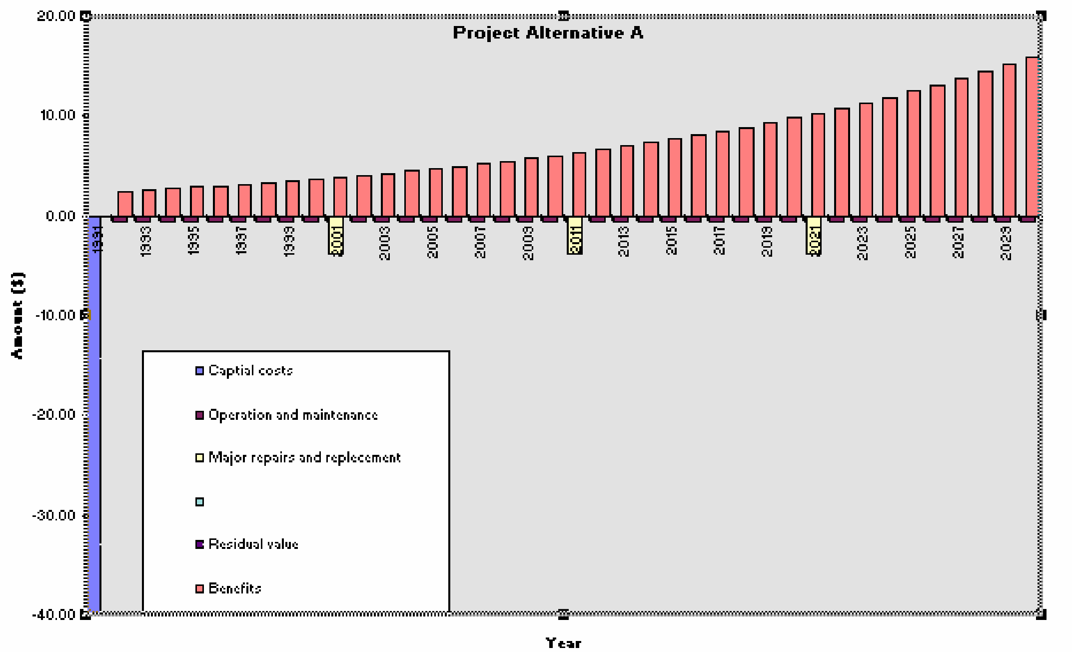
	A	B	C	D	H	I	U	AN	AO
1	Year **Project A**	1991	1992	1993	1997	1998	2010	2029	2030
2	Captial costs	-40.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Operation and maintenance	0.00	-0.75	-0.75	-0.75	-0.75	-0.75	-0.75	-0.75
4	Major repairs and replecement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	**Construction costs**			**Operation & maintenance costs**					
6	Residual value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Benefits	0.00	2.50	2.63	3.19	3.35	6.02	15.20	15.96
8	**Benefits rising at 5% pa**								
9	Costs	-40.00	-0.75	-0.75	-0.75	-0.75	-0.75	-0.75	-0.75
10	Benefits	0.00	2.50	2.63	3.19	3.35	6.02	15.20	15.96
11	Net benefits	-40.00	1.75	1.88	2.44	2.60	5.27	14.45	15.21
12	Cummulatice cash flow	-40.00	-38.25	-36.38	-27.50	-24.89	18.10	188.77	203.99
13									
14	Discount rate								
15	Present worth								
16	Annual worth								
17	Benfit-Cost rati								

Data not shown:
Repairs at Years 11,21
A 4.0 B 2.5
Year 31
A 4.0 B 6.0

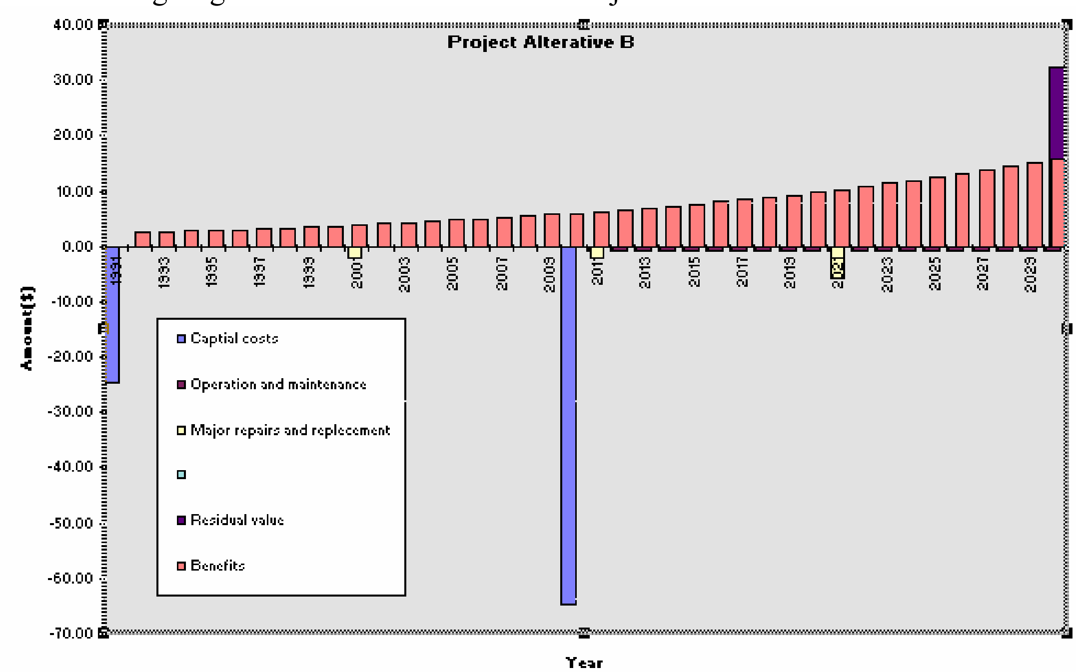
Salvage costs

	A	B	C	D	H	I	U	AN	AO
19	Year **Project**	1991	1992	1993	1997	1998	2010	2029	2030
20	Captial costs	-25.00	0.00	0.00	0.00	0.00	-65.00	0.00	0.00
21	Operation and maintenance	0.00	-0.50	-0.50	-0.50	-0.50	-0.50	-1.00	-1.00
22	Major repairs and replecement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	**1st stage construction costs**			**2nd stage construction costs**					
24	Residual value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.50
25	Benefits	0.00	2.50	2.63	3.19	3.35	6.02	15.20	15.96
26	Costs	-25.00	-0.50	-0.50	-0.50	-0.50	-65.50	-1.00	-1.00
27	Benefits	0.00	2.50	2.63	3.19	3.35	6.02	15.20	48.46
28	Net benefits	-25.00	2.00	2.13	2.69	2.85	-59.48	14.20	47.46
29	Cummulatice cash flow	-25.00	-23.00	-20.88	-11.00	-8.14	-25.65	139.77	187.24
30	**Operation & maintenance costs**			**Operation & maintenance costs**					
31	Discount rate	3%	4%	5%	9%	10%	22%	41%	42%
32	Present worth	64.53	44.80	30.61	2.97	-0.22	-11.91	-13.80	-13.80
33	Annual worth	2.79	2.26	1.78	0.28	-0.02	-2.62	-5.66	-5.80

The following graph shows the Cash flow for Project A



The following diagram shows the cash flow for Project B



The following spreadsheet shows the analysis for Project A

Project A

40 years

	A	B	C	D	H	I	U	AN	AO
1	**Year**	**1991**	**1992**	**1993**	**1997**	**1998**	**2010**	**2029**	**2030**
2	Captial costs	-40.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Operation and maintenance	0.00	-0.75	-0.75	-0.75	-0.75	-0.75	-0.75	-0.75
4	Major repairs and replecement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5									
6	Residual value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Benefits	0.00	2.50	2.63	3.19	3.35	6.02	15.20	15.96
8									
9	Costs	-40.00	-0.75	-0.75	-0.75	-0.75	-0.75	-0.75	-0.75
10	Benefits	0.00	2.50	2.63	3.19	3.35	6.02	15.20	15.96
11	Net benefits	-40.00	1.75	1.88	2.44	2.60	5.27	14.45	15.21
12	Cummulatice cash flow	-40.00	-38.25	-36.38	-27.50	-24.89	18.10	188.77	203.99
13									
14	Discount rate	3%	4%	5%	9%	10%	22%	41%	42%
15	Present worth	73.48	50.62	33.53	-2.56	-7.12	-24.08	-24.84	-24.76
16	Annual worth	3.18	2.56	1.95	-0.24	-0.73	-5.30	-10.18	-10.40
17	Benfit-Cost ratio	2.18	1.87	1.61	0.95	0.84	0.33	0.17	0.16

Cost_A

Benefit_A

Net_benefit_A

$$\frac{pi(i+i)^n}{(1+i)^n-1} = \frac{73.48*3\%(1+3\%)^{40}}{(1+3\%)^{40}-1}$$

$$\frac{NPV(3\%, Benefit\_A)}{NPV(3\%, Cost\_A)}$$

$$NPV(3\%, Net\_Benefit\_A)$$

The following spreadsheet shows the analysis for Project B

Project B

40 years

	A	B	C	D	H	I	U	AN	AO
19	**Year**	**1991**	**1992**	**1993**	**1997**	**1998**	**2010**	**2029**	**2030**
20	Captial costs	-25.00	0.00	0.00	0.00	0.00	-65.00	0.00	0.00
21	Operation and maintenance	0.00	-0.50	-0.50	-0.50	-0.50	-0.50	-1.00	-1.00
22	Major repairs and replecement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23									
24	Residual value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.50
25	Benefits	0.00	2.50	2.63	3.19	3.35	6.02	15.20	15.96
26	Costs	-25.00	-0.50	-0.50	-0.50	-0.50	-65.50	-1.00	-1.00
27	Benefits	0.00	2.50	2.63	3.19	3.35	6.02	15.20	48.46
28	Net benefits	-25.00	2.00	2.13	2.69	2.85	-59.48	14.20	47.46
29	Cummulatice cash flow	-25.00	-23.00	-20.88	-11.00	-8.14	-25.65	139.77	187.24
30									
31	Discount rate	3%	4%	5%	9%	10%	22%	41%	42%
32	Present worth	64.53	44.80	30.61	2.97	-0.22	-11.91	-13.80	-13.80
33	Annual worth	2.79	2.26	1.78	0.28	-0.02	-2.62	-5.66	-5.80
34	Benfit-Cost ratio	1.80	1.63	1.49	1.07	0.99	0.50	0.26	0.26

Cost_B

Benefit_B

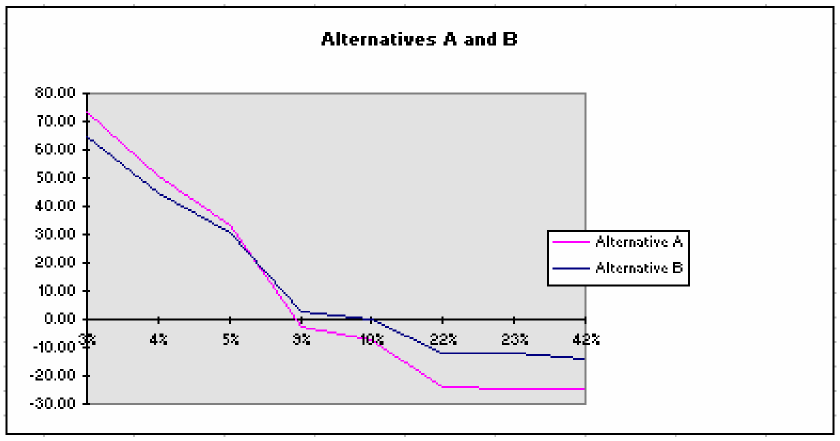
Net_benefit_B

$$\frac{pi(i+i)^n}{(1+i)^n-1} = \frac{64.53*3\%(1+3\%)^{40}}{(1+3\%)^{40}-1}$$

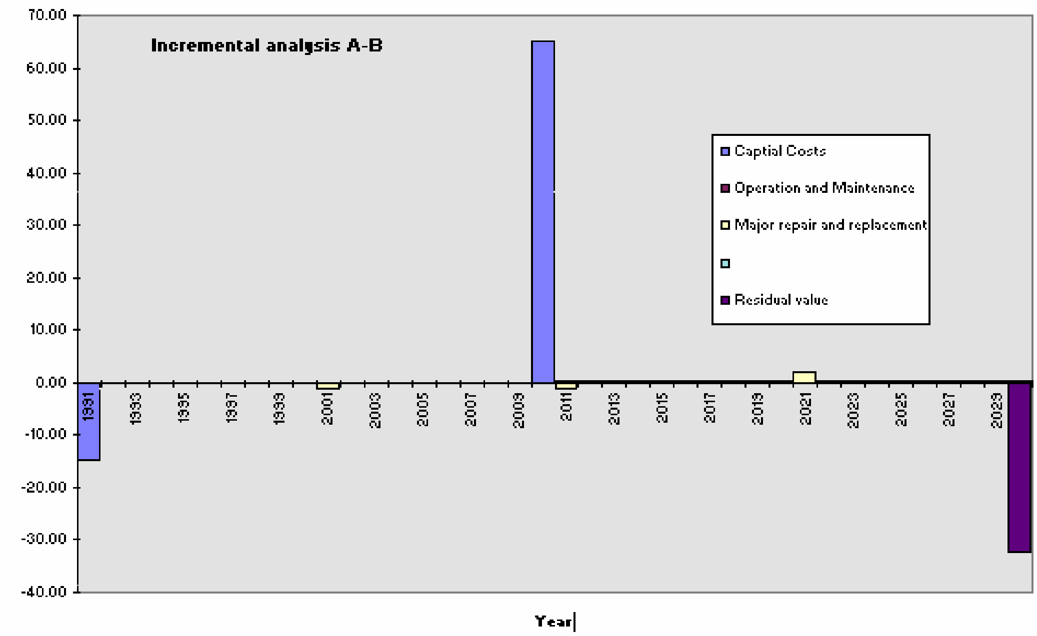
$$\frac{NPV(3\%, Benefit\_B)}{NPV(3\%, Cost\_B)}$$

$$NPV(3\%, Net\_Benefit\_B)$$

The following shows the rate of return for both projects



The following shows the incremental cash flow for A-B



The following spreadsheet shows the incremental analysis data

Incremental analysis of A-B

	A	B	C	D	E	F	G	H	I	U	V	AO
37	**Year**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**2010**	**2011**	**2030**
38	Captial Costs	-15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	65.00	0.00	0.00
39	Operation and Maintenance	0.00	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	0.25	0.25
40	Major repair and replacement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.50	0.00
41												
42	Residual value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-32.50
43	Benefits	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44												
45	Costs	-15.00	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	64.75	-1.25	0.25
46	Benefits	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-32.50
47	Net benefits	-15.00	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	64.75	-1.25	-32.25
48	Cummulatice cash flow	-15.00	-15.25	-15.50	-15.75	-16.00	-16.25	-16.50	-16.75	43.75	42.50	16.75
49												
50	Incremental costs	15.00	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.00	1.25	32.50
51	Incremental benefits	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	64.75	0.00	0.25
52												
53	Discount rate	3%	4%	5%	6%	7%	8%	9%	10%	22%	23%	42%
54	Present worth	8.96	5.83	2.92	0.32	-1.95	-3.89	-5.53	-6.90	-12.16	-12.19	-10.96
55	Benfit-Cost ratio	1.30	1.23	1.13	1.02	0.90	0.79	0.69	0.59	0.09	0.08	0.01

Incremental benefits / Incremental costs

IF(Costs> 0, Costs)+IF(Benefits > 0, Benefits)

IF(Costs< 0, -Costs)+IF(Benefits < 0, -Benefits)

The following shows the rate of return for the incremental analysis