

Information Sheet No. 11

Economic Evaluation

DEFINITION OF TERMS

1. Cash Flow

- 1.1. A cash flow is an amount of money flowing across an imaginary boundary drawn around a project. **Cash inflows into an investment are positive, cash outflows are negative.** The location of the boundary drawn around an investment will depend on the case being considered. For example it could be a country, a grassroots site, a plant battery limits, or around a piece of equipment. Any movement of money across this boundary is a cash flow.
- 1.2. Cash flows must be actual movements of money (such as a transaction with another party outside the boundary). Notional allocations of money such as depreciation and allowances against tax are not cash flows.
- 1.3. Cash flows used in economic analysis are:
 - Fixed Capital
 - Working Capital
 - Revenue
 - Fixed Costs
 - Variable Costs
 - Scrap Value
- 1.4. The sum of all cash flows in any one year is called the annual Net Cash Flow.

Time Value Of Money

2. Money has a value depending on when it is received or paid. This is due to money having an alternative earning power through investment.
 - 2.1. An investment of £100 made today, earning compound interest of 10% per year, will have a value in 5 years time of:
 - 2.2. $£100 \times (1 + 0.10)^5 = £161.0$
 - 2.3. In summary, £100 received today has a value equivalent to £161 received in 5 years time, at the interest rate of 10%. Conversely, £161 received in 5 years time has a value equivalent to £100 received today.
 - 2.4. The above example shows the Time Value Of Money. That is, the value of money depends on when it is received or paid.

2.5. The process of converting future cash flows to their value now (or *Present Value*) is called Discounting. The process of converting cash flows now to their future value is called Compounding. The percentage rates used in the above processes are called the Discount Rate and Interest Rate respectively.

2.6. In any economic evaluation, the discount rate to be used should be sought from the client, due to its importance in all calculations. In the absence of any data, a discount rate of 10%/year is normally used as a first pass. This will need revision as the evaluation exercise proceeds. When presenting results from an economic evaluation exercise, a range of discount rates should be used and the effect of each evaluated (i.e. the investment robustness to change in the discount rate should be investigated).

3. Net Present Value

3.1. Investments in production facilities result in expenditure in the first few years of the project, whereas revenue is generated later. This poses a problem in making evaluations of projects, as the time dependant value of money makes it impossible to make a direct comparison between capital expended in year 1, with revenue generated in, say, year 20. Equal revenue generated in different years do not have the same value on a present day basis (e.g. £100 revenue in year 20 has a present value of £14.86, £100 revenue in year 10 has a present value of £38.55, when discounted at 10%/year).

3.2. The problem is overcome if the net cash flow in each year of the project is discounted to the present time, i.e. their Present Values are calculated.

3.3. The sum of all the present values throughout the life of the project is called the Net Present Value (NPV), at the given discount rate.

3.4. This is illustrated in the following example. A project has an initial investment of £10 million in year 1, and generates a profit (net cash flow) of £4 million in years 2, 3, 4 and 5. Discount rate is 10%/year.

Year	Net Cash Flow (£ M)	Discount Factor	Present Value (£ M)
1	-10	$(1 + 0.1)^0$	-10.00
2	+4	$(1 + 0.1)^1$	+3.64
3	+4	$(1 + 0.1)^2$	+3.31
4	+4	$(1 + 0.1)^3$	+3.00
5	+4	$(1 + 0.1)^4$	+2.73

Summing the final column gives an investment Net Present Value of + £2.68 million.

3.5. NPV is a very important measure of a project's economic performance. It can be viewed as *the lump sum (in present value terms) generated by the project after paying back its capital expenditure, over and above the return generated by the investment at an interest rate equal to the discount rate, over the project life.*

4. Discounted Cash Flow

- 4.1. In the above example, to calculate the NPV, the Present Values are totalled over the life of the project. The Present Values in the final column are the project cash flows, discounted to the present time, or the Discounted Cash Flows. The sum of the Discounted Cash Flows is the NPV.
- 4.2. When discounting cash flows, assumptions have to be made as to when the cash flow occurs. In a real project, cash flows occur throughout the year, not all at one time. To be completely rigorous, this would have to be taken into account and the appropriate discount factor used. This however is not practicable, and so the cash flows are either assumed to entirely occur at the start of the year, or at the end. This decision can have a large impact on the results of the economic evaluation exercise.
- 4.3. **The usual convention is to assume that all the cash flows occur at the end of the year.** It is important that the client is consulted over the basis of the evaluation exercise, and that basis is stated when reporting the results. In the example above (section 3.4), the cash flows were assumed to occur at the start of the year (NPV of +2.68). If they occurred at the end of the year, the NPV would be +2.43. Be careful when using computer packages that can automatically perform discounting calculations, as the basis for the timing assumptions is not always stated. Lotus 1-2-3 assumes cash flows at the end of the year.

5. DCFIRR

- 5.1. In the example used to demonstrate NPV (section 3.4), a discount rate of 10%/year was used. This gave a project NPV of + £2.68 million. If the discount rate is raised, the project NPV will fall. This can be seen by using the same example, and varying the discount rate:

Discount Rate (% / Year)	Net Present Value (£ M)
5	4.18
10	2.68
15	1.42
20	.35
25	.55

As this example shows, a point is reached when the NPV of the project becomes zero.

- 5.2. The value of the discount rate which forces the NPV to zero is called the Discounted Cash Flow Internal Rate of Return (DCFIRR). This is usually abbreviated to IRR. In the above example, the DCFIRR or IRR is 21.86%.
- 5.3. IRR is a method of measuring the efficiency of using money. Two projects with different NPVs, Capex, etc can have the same IRR. NPV gives a measure of the total profit or loss that can be expected from the investment.

6. Return On Investment

- 6.1. Return On Investment (ROI) is calculated as a simple percentage as follows:

$$\text{ROI} = \frac{\text{Annual Profit}}{\text{Capital Cost} - \text{Scrap Value}} \quad \% / \text{year}$$

- 6.2. Capital cost and scrap value are defined in sections 1 and 9 respectively.

6.3. The ROI can be calculated for each project year, or based on an average project profit. ROI takes no account of the timing of the capital expenditure or subsequent profits, nor the life of the project (in accounting terms) and does not include the time value of money. The profit is usually expressed as accounting profit, and not a cash flow.

6.4. In the NPV example (section 3.4); the Return On Investment is (assuming zero scrap value):

$$\text{ROI} = \frac{4}{10 - 0} \times 100\% = 40\%/\text{year}$$

6.5. Note that Return On Investment is sometimes defined via Book Value of the investment. This term comes under Financial Analysis and is covered in section 10.

7. Payout

7.1. Payout is defined as the number of years, after the start of operation, required before an investment cumulative cash flow becomes zero.

7.2. Payout takes no account of the timing of the capital expenditure or subsequent profits, and does not include the time value of money. It also does not take into account any cash flows after the payout period. It is sometimes used when evaluating small revamps, or individual pieces of equipment.

7.3. In the NPV example (section 3.4), the Payout is:

Year	Net Cash Flow (£ million)	Cumulative Cash Flow (£ million)
1	-10	-10
2	+4	-6
3	+4	-2
4	+4	+2
5	+4	+6

Therefore the Payout is 3 years.

7.4. A similar property to Payout is Simple Payback. This is also calculated in years, and is defined as:

$$\text{Simple Payback} = \frac{\text{Total Capital Expenditure}}{\text{Average Yearly Net Cash Flow}}$$

7.5. In the above example, the Simple Payback is 2½ years. Note this property takes no account of the expenditure profile or varying yearly net cash flows.

8. Profitability Index

8.1. NPV is useful in evaluating project profitability. However, in many real situations there are limits on available capital. Choosing between project alternatives based solely on NPV might lead to a decision to go for one project which uses a disproportionate amount of capital.

8.2. The Profitability Index is defined as:

$$\text{Profitability Index} = \frac{\text{Net Present Value}}{\text{Capital Expenditure}}$$

8.3. Use of the profitability index allows projects of roughly similar NPVs to be ranked in order of preference. Projects with a high Profitability Index will achieve the required NPV with less initial outlay.

The following examples demonstrate this:

	Project 1	Project 2
Capital Expenditure (US\$ million)	10	40
NPV (US\$ million)	15	20
Profitability Index	1.5	0.5

8.4. This example shows that on the basis of NPV alone, project 2 would have been chosen (US\$20 million vs. US\$15 million). However the Profitability Index shows that this project uses disproportionate amount of capital to project 1, and that project 1 might be a better alternative as it makes "better use" of its capital (IRR demonstrates a similar result).

INPUT DATA

For an economic analysis exercise it is important to ensure that all input data is on a **consistent basis**, and that the basis is clearly stated when reporting results. Before starting an evaluation exercise, all input data must be for a consistent year (capital costs, feed prices, product prices etc), and these must **not** be escalated or inflated over the life of the project.

1. Capital Cost

1.1. The capital cost of the project should include the following, where appropriate:

- Cost of process plant
- Cost of offsite and utilities facilities
- License fees
- Engineering costs
- Start-up costs
- Land costs and site preparation
- General infrastructure costs
- Miscellaneous Owners Costs

1.2. These costs can be obtained from a number of sources:

- Estimating Department
- Previous project estimates
- Client supplied data
- Literature data
- Vendors

1.3. The cost of the above items should preferentially be provided by Estimating Department. Where other sources are used, the information should be validated by Estimating Department. When reporting the results of an Economic Evaluation exercise, it is important to state the basis and source of all costs used.

1.4. The required accuracy, basis, scope, and detail required in the capital cost estimate is dependent heavily on the particular case being evaluated. For example, the capital cost estimate for an economic evaluation of a new grassroots refinery for a feasibility study will be very different to that for a decision on what type of pumping circuit to install in a unit revamp. In both these cases, economic evaluation can be used to guide decisions.

1.5. For large projects with high capital costs, where the capital cost includes engineering costs, construction costs, commissioning costs etc, this capital may be spent over a number of years. For this reason, an Expenditure Profile is required for the capital cost. For example, a large grassroots refinery may have an expenditure profile lasting 3 to 4 years or more. This expenditure of capital will progress over the first few years of the project before any product revenue is generated.

1.6. Expenditure profiles depend on the case being considered. Below are given some typical profiles for a variety of cases (numbers refer to % of total):

Case	Large Grassroots Refinery	New Unit in Existing Complex	Unit Revamp	New Equipment Item(s)
Year 1	5	3	10	100
Year 2	15	10	40	-
Year 3	25	50	50	-
Year 4	35	37		-
Year 5	20			-

1.7. Guidance on typical expenditure profiles should be sought from Cost and Planning and Estimating Departments.

1.8. The capital costs are not escalated or inflation taken into account, for the duration of the economic evaluation. Such factors and influences are addressed in Financial Analysis.

2. Feedstock Cost

2.1. Feed costs can mean different things, depending on the case being evaluated. For economic evaluation of a petrochemical complex which involves conversion and separation processes, feed costs are those costs that are due to plant feedstock crossing the cash flow boundary. Feedstock costs may not be appropriate to economic evaluation of non-conversion or separation processes (e.g. a pumping circuit).

2.2. Feed costs may need adjustment for factors such as:

- Shipping costs
- Import duties and taxes
- Harbour dues and demurrage
- Insurance

2.3. The feed cost is composed of the following discrete factors:

- Feed flow rate
- Feed price
- Factors given above

2.4. Feed costs may need to include these factors to account for movement of feed to the plant battery limits. The cash flow boundary is usually drawn at the plant battery limits, but feed movement may still need consideration. As a base case CIF costs should be used for feed stocks (i.e. cost of feed delivered at project cash flow boundary). FOB (Free on Board) costs are defined as costs charged for product at the site battery limits, i.e. they do not include transportation costs, loading/unloading costs, insurance etc. When FOB (Free on Board) costs are corrected for the factors listed in section 2.2 they are then called CIF costs (Carriage, Insurance and Freight).

2.5. Feed flow rate depends on the facility being evaluated. Note that for most new installations, feed flow will not immediately jump to 100% straight after construction and commissioning (see section 5 Operating Factors).

2.6. Feed prices can be estimated from a number of sources:

- Corporate Planning Department
- Previous project estimates
- Client supplied data
- Literature data
- Consultants

2.7. In the absence of information, Corporate Planning Department should be contacted for guidance. Even if feed price information is obtained from other sources, it should also be discussed with Corporate Planning Department to see if the data is reasonable. **In all cases the basis of the costs should be fully understood and clearly reported at the end of the evaluation.**

2.8. Other factors that need to be considered when developing and using feed costs are:

- Availability of feedstock
- Changes in feedstock quality
- Changes in local/global trading conditions
- Spot prices vs. long term contract prices
- Government incentives

The effect of these factors needs to be addressed before the correct information can be obtained from any source.

2.9. Feed costs are not escalated, or inflation taken into account, for the duration of the economic evaluation. Such factors and influences are addressed in Financial.

2.10. Other factors that need to be considered are *Opportunity Costs*. This is usually associated with the location of plant and markets. For example, if a plant is close to its feedstock source and product markets it will be better placed than if it was located hundreds of miles away. The opportunity cost will reflect raw material and product movement, infrastructure, and the ability to rapidly respond to its market.

3. Product Cost (Revenue)

3.1. Product costs can mean different things, depending on the case being evaluated. For economic evaluation of a petrochemical complex which involves conversion and separation processes, product costs are those costs that are generated as plant products cross the cash flow boundary. Product costs may not be appropriate to economic evaluation of non-conversion or separation processes (e.g. a pumping circuit).

3.2. Product costs may need adjustment for factors such as:

- Shipping costs
- Import duties and taxes
- Harbour dues and demurrage
- Insurance

3.3. Product costs may need to include these factors to account for movement of product to the product markets. The cash flow boundary is usually drawn at the plant battery limits, but product movement may still need consideration. As a base case FOB prices should be used for products (i.e. price for product produced at the battery limits). The decision whether to account for the above factors depends on the import/export nature of the product in the marketplace, and these may need to be added in later.

3.4. The product cost is composed of the following discrete factors:

- Product flow rate
- Product price
- Factors given above

3.5. Product flow rate depends on the facility being evaluated. Note that for most new installations, product flow will not immediately jump to 100% straight after construction and commissioning (see section 5 Operating Factors).

3.6. Product prices can be estimated from a number of sources:

- Corporate Planning Department
- Previous project estimates
- Client supplied data
- Literature data
- Consultants

3.7. In the absence of information, Corporate Planning Department should be contacted for guidance. Even if product price information is obtained from other sources, it should also be discussed with Corporate Planning Department to see if the data is reasonable. **In all cases the basis of the costs should be fully understood and clearly reported at the end of the evaluation.**

3.8. Other factors that need to be considered when developing and using product costs are:

- Product demand patterns
- Changes in product quality
- Changes in local/global trading conditions
- Spot prices vs. long term contract prices
- Government incentives

3.9. The effect of these factors needs to be addressed before the correct information can be obtained from any source.

3.10. Product costs are not normally escalated or inflation taken into account, for the duration of the economic evaluation. Such factors and influences are addressed in Financial Analysis.

3.11. Other factors that need to be considered are *Opportunity Costs*. This is usually associated with the location of plant and markets. For example, if a plant is close to its feedstock source and product markets it will be better placed than if it was located hundreds of miles away. The opportunity cost will reflect raw material and product movement, infrastructure, and the ability to rapidly respond to its market.

4. Operating Costs

4.1. Operating costs are a vital input to any economic evaluation model. It is the operating costs that reduce the economic margin of a particular installation, for a fixed feed and product cost set. For evaluation of small options, the economic evaluation may only consist of capital costs and operating costs (e.g. a pumping circuit).

4.2. Operating costs are made up from the following list of contributors:

- Labour cost and other payroll burdens (inc maintenance labour)
- Maintenance materials cost
- Catalysts and chemicals
- Fuel costs
- Utilities costs
- Waste disposal costs
- Insurance
- Administration costs
- Marketing and distribution costs
- License fees (capacity related)
- Land charges

4.3. The exact make-up of the total operating cost will depend on the particular case being evaluated (e.g. a large grassroots refinery may not have utilities costs as utility units are part of the new facility, but a new unit in an existing complex may incur costs through use of existing utilities).

4.4. In addition to the annual maintenance costs, sometimes mechanical and electrical equipment replacement costs are included at around 15 years, for those items where the design life is less than the economic project life.

5. Operating Factors

5.1. The Operating Factor (%) is defined as:

$$\text{Operating Factor} = \frac{\text{Actual Feed Processed In The Year}}{\text{Design Annual Feed Capacity}}$$

5.2. For large scale installations, after construction the plant rarely operates at full capacity for the year. Reasons for this include:

- Staggered start-up of units
- Performance test runs interrupting continuous production
- Unexpected shut-downs
- Teething problems

5.3. For smaller installations, the plant throughput might well be up to maximum almost immediately after installation.

5.4. Certain cost burdens and revenues will depend on the operating factor. These include:

- Feed costs
- Product costs
- Some aspects of operating costs

- 5.5. Whilst some aspects of the operating costs will depend on the operating factor, most will not (e.g. labour costs usually remain constant and independent of plant throughput). These are often referred to as variable and fixed operating costs respectively.
- 5.6. Most plant operating factors will only be less than 100% for 1 year - usually for the commissioning and start-up year. For these installations average throughputs of between 40% and 70% are typical during this period. For large complex facilities, especially with multiple trains and staggered construction, the build up to full capacity may take longer. In these cases, the build up to full capacity can be estimated from the staggering of the trains, and the numbers given above for the first year of operation of each train.
- 5.7. Operating Factors used in economic analysis are different from stream and calendar day factors. The economic operating factor is used to measure actual capacity in any given year against design capacity. Calendar and stream days account for known shutdown periods to give an indication of actual capacity against usual annual capacity. Any plant will have periods over its life when it is shutdown for maintenance, catalyst changes etc. For this reason the plant capacity is different when quoted on a stream (operating) day basis than a calendar day basis. The calendar day basis is the capacity averaged over a full calendar year, whereas the stream day basis is the capacity averaged over operating days. The economic operating factor is defined as the actual annual feed processed in any given year, divided by the design annual feed processing capability. (for example, if a refinery has a design annual feed capacity of 34.6×10^6 Bbl/year, and operated for 346 days/year, then its capacity is 100,000 BPSD or 95,000 BPCD. If in one particular year it processed a total of 34.6×10^6 Bbl then that year's economic operating factor is 100%, or for 31.1×10^6 Bbl 90%. The plant capacity is still 100,000 BPSD and 95,000 BPCD).

6. Working Capital

6.1. Working capital is composed of the following items:

- Feedstock stock
- Product stock
- Accounts payable
- Account receivable
- Other miscellaneous items required for operation

6.2. Working capital is additional capital required at the start of the project to establish feed stocks etc, and is recovered at the end of the economic project life. It is defined as the difference between current assets (such as feed and product stock, trade debtors) and current liabilities (such as trade creditors, bank overdraft).

6.3. In order to calculate these items, stock days and account days need to be decided. Feed and product stock days define the storage capacity of stock for feeds and products. Typical values used for large complexes such as refineries

- | | |
|-----------------------|--------------------------------------|
| • Feedstock stock | 10 - 15 days (dependant on location) |
| • Product stock | 30 days |
| • Accounts payable | 30 days (1 month) |
| • Accounts receivable | 30 days (1 month) |

The client should be asked to specify these values whenever possible.

6.4. Feedstock stock is built-up at the project start and so results in a negative cash flow, and sold or processed with no further stock purchased at the project end, which results in a positive cash flow. Product stock is built-up at the project start and so results in a negative cash flow, and sold at the project end, which results in a positive cash flow. Account days define the days credit you get from feed suppliers before payment is due, and similarly for products it defines the days credit off takers are given before payment is received.

6.5. The above items can be calculated as follows:

Item	Calculation
Feedstock stock	Feed worth x days of stock held
Product stock	Product worth x days of stock held x operating factor
Accounts payable	Feed worth x account days x operating factor
Accounts receivable	Product worth x account days x operating factor
Miscellaneous	As required

In the above table feed/product worth is defined as feed/product costs multiplied by feed/product flow.

6.6. In years of constant operation of the installation, the working capital will remain constant, and thus there is a zero associated cash flow. Where there are working capital changes, is when there are fluctuations in the installation capacity, i.e. at the project start and end. To calculate the cash flows resulting from working capital, it is best to use the concept of Delta Working Capital. When carrying out the cash flow calculations, calculate the required working capital for each year of the analysis. This value is then subtracted by the previous year's value to obtain the Delta Working Capital, which is used in the cash flow calculations.

This method will therefore automatically take into account of varying plant capacities (as a check, if you sum the delta working capital over the project life, it should come to zero, but not after it has been discounted). The delta working capital calculated in this way will also demonstrate when there are cash flows associated with working capital.

6.7. The rationale behind the working capital calculation is:

- In the initial year as capacity of the installation is built up from zero, the feedstock storage will also be built up to full capacity. Therefore the working capital required will be calculated from feed worth and feed storage capacity.
- In the initial year as capacity of the installation is built up from zero, the product storage will only be built up in line with the current production capacity. Product will be sold in line with production rate, and the product storage will not be built up fully to that of full production levels. Therefore the working capital required will be calculated from product worth, product capacity and operating factor.
- Accounts payable and accounts receivable refer to days of credit given and taken for feed and product payments. This will be in line with current production capacity and so will be calculated from feed/product worth, account days and operating factor.

7. Project Life

- 7.1. Project life, economic project life, or economic evaluation period bears no relation to design life. Design life of process plant equipment is typically 20 to 25 years, and is used to set design margins, corrosion allowances, and other associated physical parameters.
- 7.2. Project Life is used in economic analysis to define the time period over which the economic evaluation will be performed. Usually at the end of this period, a scrap value is recovered (see section 9), and the working capital reclaimed (see section 6).
- 7.3. For economic analysis, a period of 15 years from the initial project capital expenditure to the reclamation of working capital is generally used, however it is not uncommon to use 25 years which some clients prefer. This is the usual for most economic evaluation exercises, but in some cases, such as evaluation of small pieces of equipment, this time may be reduced.
- 7.4. Extending the economic evaluation period beyond 15 years has little impact on the results generated, due to the reducing time value of money (£100 received in 15 years time has a present value of £23.94, and received in 20 years time has a present value of £14.86, at a discount rate of 10%/year).

8. Sunk Costs

- 8.1. Sunk costs are those expenditures made in the past and are irreversible (e.g. costs for past feasibility studies). As these costs were incurred in the past and cannot be recovered they should not be included in the economic evaluation of the project. Sunk costs should not affect the decision to accept or reject a project.

9. Scrap Value

- 9.1. Scrap value is a portion of the project fixed capital cost which is recovered at the end of the economic project life. Credit is usually taken during economic analysis of a project for the scrap value of the installation, less any decommissioning, dismantling and disposal costs.
- 9.2. Values typically used are 10% to 25% of the project fixed capital cost. The higher end of this range usually applies to processes with large inventories of precious metal catalysts. For small installations and single pieces of equipment, this value will be nearer zero. If, at the end of the economic life the project site is to be dismantled and the site sold, then the scrap value will be zero, or in some cases even negative, to account for dismantling and clean-up costs (e.g. North Sea oil platform). For a conservative base case for a new plant or site, zero scrap value should be used as a first pass.

THE ECONOMIC MODEL

10. Model Basis

10.1. Before building the economic model, the data developed in section 5 (Input Data), should be checked for the following:

- Currency - Are all the monies expressed in the same currency units. Analyses are usually done in US\$, with fixed currency exchange rates over the economic project life.
- Location - Are all the developed capital costs, transport costs, product prices expressed on the same location basis (e.g. all Indonesia, all US etc).
- Year - Have all costs, prices etc been adjusted to the start year (present day) of the project. Note costs should not be inflated or escalated over the course of the project, but, for example, a capital cost estimate for a similar installation done five years ago will need adjustment to the present day.
- Installation - Do all costs include all relevant engineering fees, construction costs, delivery costs and other costs that may be "hidden", but still need consideration?

10.2. Checks to ensure consistency of input data are vital, before undertaking the economic evaluation exercise.