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Chapter 16

Methodologies for economic and financial analysis

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1. Introduction

Methods for financial evaluation of projects are an important part of today's corporate life. In a world of increasing competitiveness and shrinking margins the careful analysis of investments is of the utmost importance for decision making.

On the other hand, successful innovation is generally accepted today as the key to the competitiveness of the chemical industry. Unfortunately much attempted innovation resulted unsuccessful in practice or at least far less beneficial than hoped at the outset. As financial and human resources are more and more in short supply, while the costs of research are soaring, it is necessary to increase the degree of (economically) successful innovation.

This paper reviews the methodologies for economic evaluation of projects in the belief that R&D projects can be evaluated and ranked on the basis of their expected benefits.

2. The life cycle of industrial projects

The life cycle of industrial projects can be broadly divided into three phases: pre-investment, investment and operational. Each of these phases comprises several stages and several parallel activities; however it is generally acknowledged that the success or the failure of an industrial project largely depends on the adequacy of the pre-investment phase activities. Moreover the degree of project control (that is the ability to influence/modify it) decreases as we proceed along the project life: it is easier and far less costly to use eraser and pencil than cutting torch and welder. It is therefore useful and advisable to devote time and resources to develop adequately the first stages of the project life.

During the pre-investment phase several stages can be identified, progressing towards the investment phase. These are:

(a) identification of project opportunities (opportunity studies)

(b) preliminary project selection and definition (pre-feasibility studies)

(c) project formulation (feasibility studies)

(d) final evaluation and investment decision.

R&D work belong to stage (a) and as such an R&D project should take into consideration and analyze

· the cost and availability of production factors (e.g. raw materials)

· the future supply/demand pattern for the products or for the consumer goods with which the product will compete

· if related or targeted on an area, imports in order to identify potential import substitution

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· possible integration/interlinkage with other industries/sectors and in general the economics/profitability of a project based on the R&D results.

3. Profitability assessment based on the time value of money

A myriad of methods for profitability assessment are available. However they can be divided into two major classes: those that consider the time value of money and those that do not. This paper will focus on the first class methods, providing at the same time some description of the others.

The evaluation of the profitability of a project consists in the comparison of the project capital cost with the expected benefits of the project itself. Unfortunately capital cost and benefits are relevant to different periods in time, so that it is not advisable simply to sum them algebraically to determine the net benefit. A dollar earned today, in fact, is better than a dollar earned in the future.

The concept of interest can be used to translate future value in present value. Interest represents the earning power of money. It is the premium paid to compensate a lender for the loss of use of the borrowed money and for the risk of non-repayment. In the same way it is the reward an investor would expect from a project for the sole reason of having employed the money in the project instead that in an alternative use.

In both cases time elapses between investment or loan (commitment of funds) and receipt of benefits (earnings): the time value of money.

For any assumed interest value of money, an equivalence can be established between money received or spent at different times, according to the following expression:

$$F = P \cdot (1+i)^n \qquad (1)$$

where: F = future worth of money amount; P = present worth of money amount; i = interest rate per period (e.g. years) or discount rate per period; n = number of periods (e.g. number of years); i and n are to be consistent, that is if i is the interest rate per period (years, semesters, quarters, months, etc.), n must be the number of periods (years, semesters, quarters, months, etc.).

Conversely:

$$P = \frac{F}{(1+i)^n}$$

where $1/[(1+i)^n]$ is also known as the discount factor.

This formula makes possible to determine equivalent numerical values at different times, but not values with equivalent purchasing power. The amount of goods that can be purchased with a given sum of money varies up and down as a function of nationwide and worldwide economic conditions. Inflation effects can be taken into account through the consideration of an appropriate inflation rate with an expression similar to Eq. (1).

4. Cash-flow construction

The methodologies for economic evaluation of projects presented in this paper are based on the projected cash-flow of the project.

Cash-flow is defined, for each of the years of the project life, as the algebraic sum of all cash in-flows and out-flows. As the cash-flow statement deals only with cash movements, non-cash items, such as depreciation, bad debt write-offs, reserves and others will not appear on it. Moreover each in-flow or out-flow will appear at the time it actually occurs.

Cash-flow can be projected by analyzing the single items generating or requiring cash. In a typical industrial project two broad phases can be identified:

- implementation
- operation

During these phases it is possible to identify expenditure and income items as shown below.

Phase	Implementation	Operation
Cash Outflows	Investment Cost Pre-production Costs	Working Capital Operating Costs Repayment of Loans Interests on Loans Taxes
Cash Inflows	Loans	Revenues

Details for cash-flow construction are given in the following paragraphs.

4.1. Capital requirements

The total requirement of funds of a project can be summarized as follows:

(a) Facilities cost
(b) Pre-production costs
(c) Fixed investment (a + b)
(d) Working capital
Total capital requirement (c + d)

Facilities cost is the cost of the process units, of the utility and off-site units dedicated to the project, of infrastructure required for commercial operation of the project such as fences, roads, port, housing for workers, etc.

Cash-flow analysis requires that each disbursement of funds is associated with the relevant timing. As the implementation phase of industrial projects can last up to four or five years it is important to determine the disbursement curve (or S-curve from its shape, see Fig. 1 and Table 1).

Pre-production costs (also pre-operating expenses or owner's costs) are all the expenses to be borne by the owner in relation with the project implementation prior to the beginning of commercial operations, such as:

· project management (owner side)
· preliminary and capital issue expenditure (registration and formation of the company, share allotment and commissioning, legal fees)
· training and manpower costs before the beginning of commercial operations
· consultancy and other advisory services
· commissioning and start-up
· commercial and market advertising

Pre-production expenses are usually capitalized and depreciated over a period of time briefer than the plant cost depreciation period.

Working capital indicates the funds necessary to make the project operational in addition

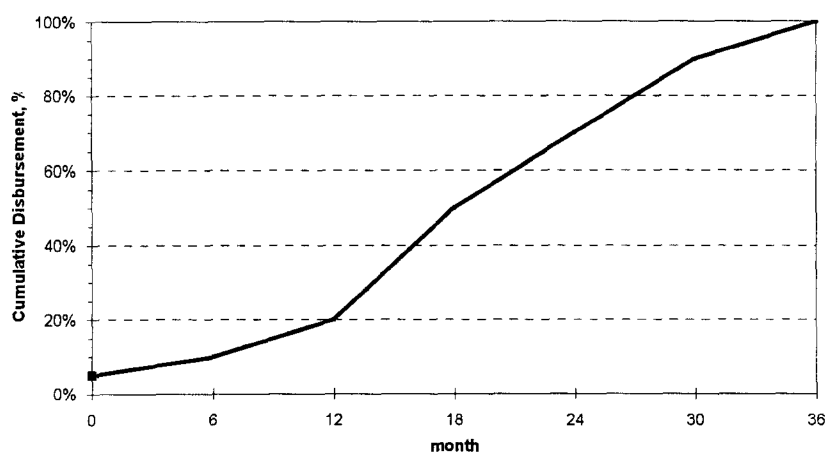

Fig. 1. Investment disbursement curve.

Table 1
Investment disbursement curve

Year	1			2		3	
Month	0	6	12	18	24	30	36
Disbursement (M$)	6.5	6.5	13.0	39.0	26.0	26.0	13.0
% of total	5	5	10	30	20	20	10
Cumulative disbursement (M$)	6.5	13.0	26.0	65.0	91.0	117.0	130.0
% of total	5	10	20	50	70	90	100

to the fixed capital cost. It is an investment renovated continuously by the Company and whose level varies depending on operating rate and inventories. It is defined as follows

(a) accounts receivable
(b) inventories (raw materials, work-in-progress, products, spare parts)
(c) cash-in-hands and bank accounts
(d) current assets (a + b + c)
(e) accounts payable (or current liabilities)
net working capital (d − e)

Accounts receivable represent the worth of goods already sold, but whose payment has not yet been received by the company that is the delay, with respect to the time of selling, in receipt of revenues.

Similarly accounts payable represent the delay, with respects to the time of purchasing, in payment of goods and services.

4.2. Revenues

Projection of revenues, year by year, for the whole operating life involves:

· projection of sales
· projection of market price
· projection of transport costs from the producing plant to the market place.

Revenues are calculated through the expression:

$$\text{Revenues}_i = \sum_{j=1}^{NP} Q_{ij} P_{ij}$$

where: Revenues_i = sales revenues in year i; NP = number of products; Q_{ij} = sales volume of product j in year i; P_{ij} = ex-plant price of product j in year i.

Ex-plant price of products can be obtained deducting from product market prices the costs of transportation from the production site to the marketplace.

4.3. Operating costs

A projection of the operating costs need to be prepared, on yearly basis, through the life of the project. The build-up of operating costs is shown below:

Raw materials
Utilities
Other variable costs
(a) Total variable costs
Manpower

Maintenance
Insurance
Overheads
(b) Total fixed costs
(c) Total operating costs (a + b)

Variable costs change roughly with the operating rate of the plant, in close proportion to the variation of the production volume.

Raw material cost can be evaluated through the expression:

$$\text{Raw material cost}_i = \sum_{j=1}^{NRM} RM_{ij} C_{ij}$$

where: $\text{Raw material cost}_i$ = raw material cost in year i; NRM = number of raw materials; MP_{ij} = volume of raw material j in year i; C_{ij} = unit cost at plant gate of raw material j in year i.

In a similar way the cost of purchased utilities can be determined:

$$\text{Utility cost}_i = \sum_{j=1}^{N} U_{ij} CU_{ij}$$

where: Utility cost_i = utility cost in year i; NU = number of purchased utilities; U_{ij} = volume of utility j in year i; CU_{ij} = unit cost at plant gate of utility j in year i; other variable costs include cost of catalysts, cost of chemicals, cost of packaging, cost of other operating supplies, etc.

The projection of revenues and variable costs requires on one hand the projection of prices and costs at plant gate for products, raw materials and utilities, on the other hand, of course, the development of the overall material and utility balance.

Fixed costs remain unchanged regardless of the level of production and include the following:

Manpower – cost of labour including not only wages, but also taxes, social security, fringe benefits.

Maintenance – maintenance costs should be inclusive of materials, manpower and external services for maintenance. Usually it is estimated as a percentage of investment cost ranging between 2 and 4% per year. The level of maintenance cost is dependent on plant type.

Insurance – premium for insurance coverage for fire, damages,... It depends on Company policy, but for project evaluation purposes it is usually estimated as a percentage of the investment cost ranging from 0.5 to 1% per year.

Overheads – include the non direct manpower and all the expenses not analytically considered in the other items of operating cost. Some examples are R&D, public relations, canteen, infirmary, furniture, etc. Overheads are generally related to number of workers considering a percentage of manpower cost ranging from 50 to 150%.

4.4. The project cash-flow

On the basis of the above described data it is possible to project year by year the project cash-flow. An example is given in Table 2.

In general, for an industrial project, the curve of cumulative cash-flow vs. time changes in sign only once, that is after a period of negative cash-flows (investment), a period of positive cash-flows (operation) follows. Fig. 2 shows a typical cash-flow curve for an industrial project.

5. Sources of funds

The initial capital investment for an industrial project can be covered mainly by equity and long-term loans.

Equity funds can be derived internally, from the operation of the Company (that is from retained profits and from cash generated by the annual depreciation of the existing assets) or externally from the sale of ordinary or preference shares.

Sources of long-term loans are of four main categories, each with special characteristics and field of application: commercial banks, national

Table 2
Project cash-flow

Year	1994	1995	1996	1997	1998	1999	2000	2001
Facilities cost	−26.0	−65.0	−39.0	0.0	0.0	0.0	0.0	0.0
Preproduction expenses	−1.3	−3.3	−2.0	0.0	0.0	0.0	0.0	0.0
Working capital	0.0	0.0	0.0	−4.6	0.0	0.0	0.0	4.2
Revenues	0.0	0.0	0.0	195.0	180.0	200.0	195.0	190.0
Operating costs								
Variable costs	0.0	0.0	0.0	−103.4	−95.4	−106.0	−103.4	−100.7
Fixed costs	0.0	0.0	0.0	−35.2	−35.2	−35.2	−35.2	−35.2
Cash-flow before tax	−27.3	−68.3	−41.0	51.8	49.4	58.8	56.5	58.3
Taxes	0.0	0.0	0.0	−14.7	−12.3	−18.2	−18.1	−18.1
Cash-flow after tax	−27.3	−68.3	−41.0	37.1	37.1	40.6	38.3	40.2

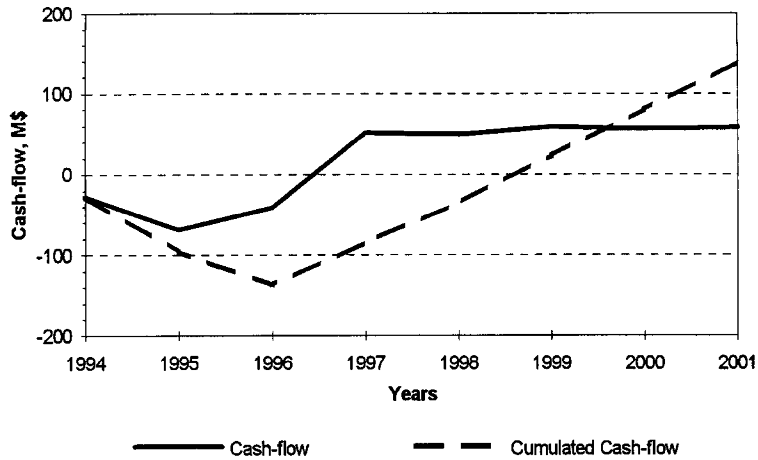

Fig. 2. Project cash-flow.

export credit agencies, national aid organizations and international agencies.

However, whichever the source of the money, a loan is characterized by its terms, which mainly are: interest rate, repayment period, repayment profile, holiday period.

The *interest rate* can be fixed, that is constant throughout the life of the loan, or variable, that is adjusted according to the cost of money during the repayment period. Interest rates tend to be higher for commercial loans and lower for export credits and aid loans.

Repayment period also varies from relatively short (5–8 years) for commercial to long and very long (15–25 years) for aid loans.

Repayment (or amortization) profile can follow mainly three ways:

(a) debt service with equal principal instalments and gradually decreasing interest

(b) debt service with equal instalments of both principal and interest

(c) amortization following the project cash-flow, especially used in project financing schemes

Examples of loan amortization according, respectively, to (a) and (b) are given in Table 3.

It is important that the firm can have an *holiday period* (lasting at least the project implementation period) before being obliged to begin the loan repayment. In general interests

Table 3
Loan Amortization

Year	1994	1995	1996	1997	1998	1999	2000	2001	Total
Net loan	19.1	47.8	28.7						95.6
Interest									
During construction	1.9	6.9	10.4						19.2
Total loan	21.0	54.7	39.1						114.8
a. Principal repayment				23.0	23.0	23.0	23.0	23.0	114.8
Interest payment				11.5	9.2	6.9	4.6	2.3	34.4
Total instalment				34.4	32.1	29.8	27.5	25.3	
b. Principal repayment				18.8	20.7	22.8	25.0	27.5	114.8
Interest payment				11.5	9.6	7.5	5.3	2.8	36.7
Total instalment				30.3	30.3	30.3	30.3	30.3	

during construction are capitalized and repaid, along with the capital, during the operational phase.

6. The main profitability indicators

6.1. Pay-out time

The pay-out method or pay-back method is often used for quick and rough estimates of project profitability or more properly of the time an investment takes to pay for itself. This method is based on project cash-flow, but usually not on *discounted* cash-flow.

The yearly cash-flow is algebraically summed up until the cumulated cash-flow changes its sign. In the example of Fig. 3 cumulated cash-flow becomes positive between year 1998 and year 1999 and provides a pay-out time of 5 years and 7 months, or 2 years and 7 months with reference to the beginning of operations.

The major drawbacks of this method are:

· it does not take into account the time value of money (sometimes, in order to overcome this problem, pay-out time is calculated on discounted cash-flow. The method, of course, yields a higher figure with respect to the simple pay-out time)

· it does not consider cash-flow after the pay-out time (two projects with the same pay-out time can perform in a very different way).

In spite of this, pay-out time is extremely popular for at least two reasons:

· it is simple to calculate and understand

· It addresses the concept that funds invested in a project should rapidly be recovered to be available for other desired projects. The riskier the project, the shorter the required pay-out time.

6.2. Net present value (NPV)

Net present value or net present worth (NPW) is obtained by discounting separately year by year the cash-flow at a fixed discount rate and then algebraically summing up the discounted figures.

It represents the difference, at today's value of money, between benefits (cash in-flows) and costs (cash out-flows). Therefore, the higher the NPV, the more desirable the project. See Table 4.

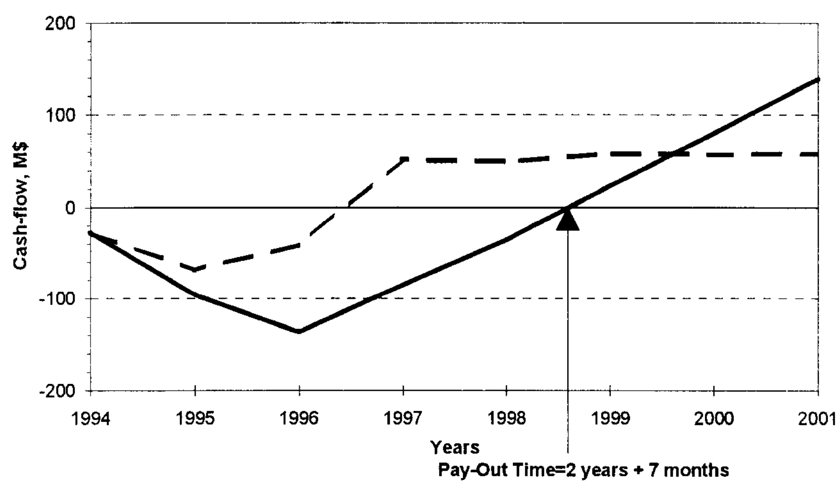

Fig. 3. Pay-out time.

Table 4
Calculation of net present value

Year	1994	1995	1996	1997	1998	1999	2000	2001	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	k
Project cash-flow	−27.3	−68.3	−41.0	51.8	49.4	58.8	56.5	58.3	F_k
Discounted cash-flow @ $i=10\%$	−24.8	−56.4	−30.8	35.4	30.7	33.2	29.0	27.2	$F_k/(1+i)^k$
$NPV=\Sigma_k \frac{F_k}{(1+i)^k}=43.4$ M$									
Discounted cash-flow @ i = 15%	−23.7	−51.6	−26.9	29.6	24.6	25.4	21.2	19.1	$F_k/(1+i)^k$
$NPV=\Sigma_k \frac{F_k}{(1+i)^k}=17.6$ M$									

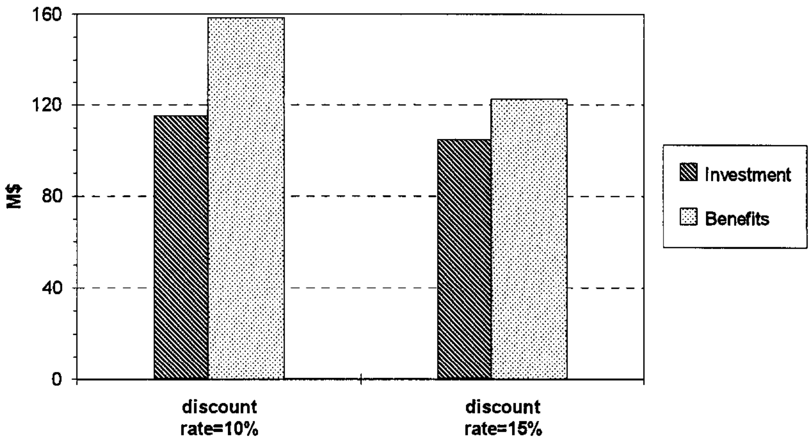

Fig. 4. Net present value vs. discount rate.

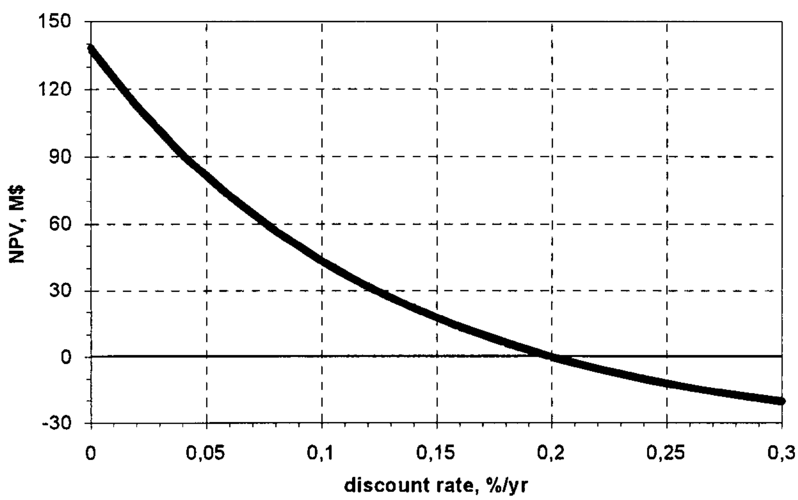

Fig. 5. Calculation of DCFRR.

Table 5
DCF rate of return in practice

Year	1994	1995	1996	1997	1998	1999	2000	2001
Project cash-flow	−27.3	−68.3	−41.0	51.8	49.4	58.8	56.5	58.3
Unrecovered investment	−27.3	−101.0	−162.2	−142.8	−121.9	−87.5	−48.6	0.0
Capitalized interest	0.0	5.5	20.2	0.0	0.0	0.0	0.0	0.0
Interest earned on unrecovered investment	0.0	0.0	0.0	32.4	28.6	24.4	17.5	9.7
Capital recovery	0.0	−5.5	−20.2	19.4	20.8	34.4	38.9	48.6

As the cash-flow for an industrial project is typically negative in the first years and positive afterwards, the higher the discount rate used for the calculation of NPV (that is the lower the value ascribed to the money earned in the future), the lower the NPV itself. See also Fig. 4.

6.3. *Discounted cash flow rate of return (DCFRR)*

If the calculation of the NPV is repeated with several values of the discount rate, the curve of Fig. 5 is obtained.

The value of the discount rate for which the NPV of the project equals zero is the DCFRR or internal rate of return (IRR). In other words it is the interest rate at which the benefits are equivalent to the costs.

Another way of expressing the same concept is the following:

for a given cash-flow, the DCFRR represents the interest rate earned on the unrecovered portion of the investment, such that the unrecovered portion equals zero at the end of the life of the investment. (See also Table 5 for an example).

For the investor, who puts equity at risk in the project, it is also interesting to calculate the Equity DCFRR, based on the equity cash-flow.

The equity cash-flow is derived from the project cash-flow, summing algebraically for each year the loan cash-flow.

In the example of Table 5 the equity DCFRR is about 32%/yr and represents the profitability of the portion of the investment which is not financed, in the example 41 M$.

Such profitability is higher than the project profitability (20%/yr), the latter being higher than the cost of the external finance (10%/yr). In fact the project yields an average 20%/yr on the whole investment and, as 70% of the investment itself receives only 10%/yr of the average profitability, a much higher portion (i.e. 32%/yr) is available for the equity remuneration (Table 6).

According to this principle (known as *financial leverage*) the higher the debt/equity ratio (or *gearing ratio*) and the wider the spread

Table 6
Equity cash-flow

Year	1994	1995	1996	1997	1998	1999	2000	2001
Cash-flow before tax	−27.3	−68.3	−41.0	51.8	49.4	58.8	56.5	58.3
Loan	19.1	47.8	28.7	0	0	0	0	0
Principal repayment	0	0	0	−23.0	−23.0	−23.0	−23.0	−23.0
Interest payment	0	0	0	−11.5	−9.2	−6.9	−4.6	−2.3
Equity cash-flow	−8.2	−20.5	−12.3	17.4	17.3	29.0	28.9	33.0

Table 7
Effect of financial leverage on equity profitability

Project DCFRR, %/yr	20.0			
Case	A	B	C	D
Debt/equity ratio	70/30	60/40	70/30	60/40
Loan interest rate, %/yr	5	5	10	10
Equity DCFRR, %/yr	41.8	35.1	32.5	28.6

between the Project DCFRR and the cost of loans, the larger is the difference between Equity DCFRR and Project DCFRR.

Table 7 shows the effect of debt/equity ratio and loan interest rate on equity profitability for a given project.

6.4. *Other profitability indexes of common use*

Return on investment (ROI) is sometimes used in the calculation of the production cost in order to take into account a profit as a percentage of the initial capital cost. Table 8 shows an example of production cost calculation.

ROI is calculated on "typical year" values and does not reflect either the entire life of the

Table 8
Calculation of production cost

Case: oxidative coupling of methane + ethane steam cracking					
Capacity	450 000 ton/yr of ethylene				
Plant investment	400.00 M$				
Pre-production costs	20.00 M$				
Total fixed investment	420.00 M$				
Working capital	21.15 M$				
Total capital cost	441.15 M$				
			Price	Annual cost	
	unit	unit/kg of ethylene	$/unit	M$/year	$/ton of ethylene
Raw materials					
Methane	M BTU	0.0783	1.75	61.63	136.96
Ethane	ton	0.3928	90.00	15.91	35.35
Oxygen	Nm^3	1.1441	0.06	30.89	68.65
Catalysts and chemicals				3.15	7.00
Total raw materials				111.58	247.96
By-product credits					
Propylene	ton	0.0430	368.00	(7.12)	(15.82)
Fuel gas	M BTU	0.0303	1.75	(23.87)	(53.05)
Carbon dioxide	Nm^3	0.3554	0.00	0.00	0.00
Total by-product credits				(30.99)	(68.87)
Utilities					
Fuel gas	M BTU	0.0175	1.75	13.77	30.59
Electric energy	kWh	0.0494	0.06	1.33	2.96
Cooling water	m^3	0.7119	0.03	9.61	21.36
Boiler feed water	m^3	0.0010	0.50	0.23	0.50
Total utilities				24.94	55.42
Total variable costs				105.53	234.50
Fixed costs					
Labour	(50 men @ 40 000 US$/year)			2.00	4.44
Maintenance	(3% of plant cost)			12.00	26.67
Insurance	(0.5% of plant cost)			2.00	4.44
Overheads	(50% of labour cost)			1.00	2.22
Total fixed costs				17.00	37.78
Cash cost of production				122.53	272.28
Depreciation				44.00	97.78
10% ROI				44.12	98.03
Full cost of production				210.64	468.09

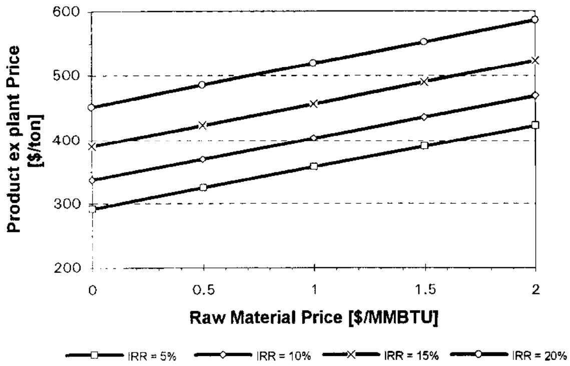

Fig. 6. Break-even product price vs. raw material price.

project or the time value of money. Actually it should not be used except as a quick and rough estimate of profitability. The only indication the use of ROI can provide is the perception of the production cost being over or below the selling price (see Fig. 7) or, in other words, if there is scope for a more reliable economic analysis.

Break-even analysis also gives a perception of the product selling price (or raw material cost) necessary to "break-even" at a fixed rate of return, thus allowing the comparison (on a more rigorous basis than production cost) between market price and project requirements. The product price break-even point is defined as the price value that would yield a given DCFRR for the project. Fig. 6 shows the product break-even price vs. the raw material cost for various levels of the project DCFRR.

7. Decision making through profitability analysis

As seen in the previous paragraphs, the calculation of the various profitability indicators is fairly simple and today's computers make it possible to perform any economic evaluations "at the touch of a button".

Unfortunately the calculation of the profitability indexes does not solve the problem of decision-making, that is establishing which values of the profitability indexes we require to judge a project attractive.

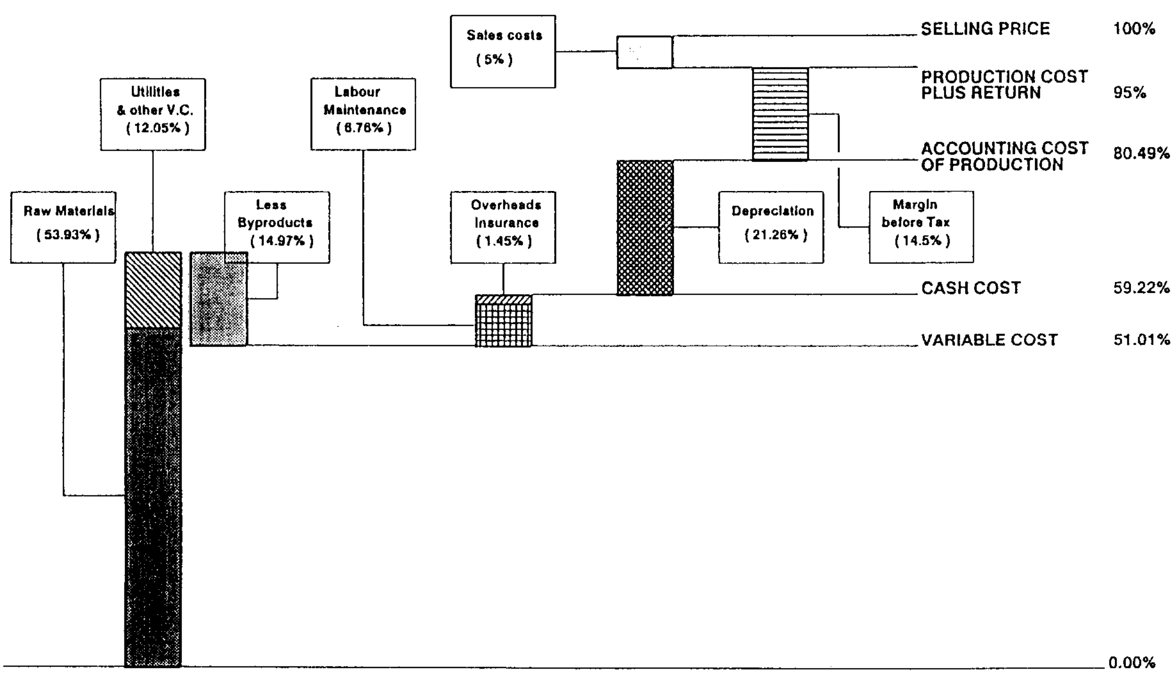

Fig. 7. Buildup of production cost.

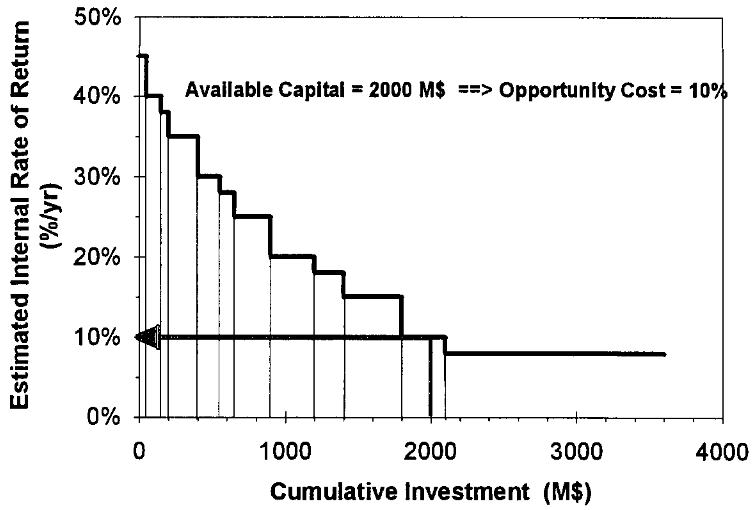

Fig. 8. Determination of opportunity cost of capital.

Using both NPV and DCFRR we need a discount rate either to calculate the index (NPV) or to compare the index with (DCFRR). This is also known as the Minimum Acceptable Rate of Return (MARR), the hurdle rate or the cut-off rate.

In this respect, first of all the *cost of borrowed money* should be considered. In fact it would be ill-considered to borrow money at 10%/yr to use it in a project yielding 6%/yr.

As a second step an investor should consider the *cost of capital*, that is the weighted average of the cost of the borrowed money and the remuneration expected from equity. Table 9 shows an example of calculation of cost of capital.

The cost of capital for this investor is therefore 11.5%/yr.

Finally the *opportunity cost of capital* should be taken into account. In a normal situation a Company has a broad range of investment opportunities, in general exceeding the amount of capital available.

Moreover the measure of the profitability of a project is always a comparison with the option of *doing nothing*. In this case money would be used in the most profitable, non-risk application available (let us say, for example, government bonds). If we plot the DCFRR of each project vs. the cumulative investment required for all projects the graphic of Fig. 8 is obtained.

The amount of capital available determines the rate of return of the best rejected project. This is also known as the opportunity cost of capital.

The minimum acceptable rate of return should be the highest among

- the cost of borrowed money
- the cost of capital
- the opportunity cost of capital.

Table 9
Calculation of cost of capital

	Invested capital M$	Rate of return %/yr	Interest annual amount M$
Equity	30	15	4.5
Loans	70	10	7
Total	100		11.5

8. Final considerations

When carrying out the economic analysis of a project, we are likely to become absorbed in the selection of the most appropriate methodology, the collection of data, the analysis of the results.

However we should not lose sight of two important aspects:

· the reliability of the profitability indexes can not be better than that of the data used for calculations. This statement could sound discouraging, as most of the input data for economic analysis are estimates or projections. However sensitivity analysis can offer some mitigation of the uncertainty or at least highlight the riskiest factors of a venture.

· the economic analysis is not meant to surrogate decision-making. Although the ultimate responsibility for implementing or not a project stays with the investor, however the economic analysis is a valuable support for giving an insight of the most significant aspects of a project, for ranking different alternatives and for simulating the project outcome in different economic scenarios.

9. For further reading

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