ECONOMIC EVALUATION

1. Introduction

Economic evaluation is a quantitative estimate of the expected profitability of a venture scenario, often in comparison with other choices, including the competition. It is part of the analysis that supports the decision-making task in engineering and management. The four essentials of an economic study are problem definition, cost estimation, revenue estimation, and profitability analysis, as well as a characterization of the uncertainty and risk.

2. Problem Definition

An economic definition, or economic scope, evolves during development, implementation, and operation phases as the basis for an ongoing economic evaluation. This definition should clearly differentiate between specifications that have actually been selected and features that have been assumed for the evaluation. In a comparison of alternatives, all of the assumptions, specifications, data, and conditions must be consistent, realistic, and devoid of bias.

Situations where economic evaluation is involved include equipment selection, process retrofits, research commercialization, acquisitions, assessment of competition, market strategy development, corporate planning, labor-management negotiations, financial planning, public safety, environment policy, etc. As a result, there is no general guideline for problem definition. For process ventures, good estimates or firm data about the following items over the life of the proposed scenario are desirable: capital investment (amount, schedule), construction time, project lifetime, manufacturing costs, production capacity and availability, selling price and market projection, financial and tax data, regulatory constraints (environmental, safety, fiscal), societal constraints (perceived risks, probabilities, benefits), economic constraints (material costs and availability, utilities), technical constraints (process constraints), legal constraints (laws, regulations, patents), and competitive constraints (processes, products, future).

3. Cost Estimation

Three cost estimation categories that are important for economic analysis of chemical process facilities are equipment cost, capital investment cost, and product cost.

3.1. Equipment Costs. Equipment cost includes the purchased cost of process and materials handling equipment, storage facilities, waste treatment equipment, structures, and site service facilities. Installation costs such as insulation, piping, painting and finishing, foundations, equipment setting, process structures, instrumentation, and electrical service connections are estimated or factored separately. Actual quoted prices from suppliers provide the best data, but these are not usually available when estimates are made. Consequently, equipment cost estimates tend to be based on personal files, internal company data, or published correlations.

Published Cost Correlations. Purchased cost of an equipment item, fob at seller's site or other base point, is correlated as a function of one or more equipment size parameters. A size parameter is some elementary measure of the size or capacity, such as the heat transfer area for a heat exchanger. Historical cost–size correlations were graphical log–log plots, but the use of arbitrary equation forms for correlation has become quite common. If cost–size equations are used in computer databases, some limit logic must be included so that the equation is not used outside of the applicable size range. Descriptive information accompanying cost correlations is often meager. For example, it is not always clear if driver costs are included in pump costs. When information is incomplete, different correlations should be compared so that the estimate is meaningful. Cost correlations are available for many types of process equipment (1–3).

Time Translation. Cost data for any particular point in time can be corrected to any other time by means of cost indexes in the relation $C = C_B(I/I_B)$, where C is a cost, I is a yearly cost index value, and the subscript B refers to some base year. The accuracy tends to decrease with the length of time involved. Important U.S. cost indicates for the process industries are the Marshall and Swift (M&S) Index, CE Plant Cost Index, Nelson–Farrar Construction Cost Index, and the ENR Construction Index. Similar indicates are available for other countries.

The M&S Equipment Cost Index, formerly Marshall and Stevens, for installed equipment costs, is published monthly in *Chemical Engineering*. The indexes reported are the all-industries, process industries, and several specific-industry indexes. The yearly all-industries index, based on 47 industrial categories, is commonly used for the translation of purchased process equipment costs, even though it was developed for installed equipment.

The CE Plant Cost Index, also published monthly in *Chemical Engineering*, provides index values for various categories of equipment, installation, labor, building, and supervision, as well as a composite plant cost index. The yearly composite plant cost index is also widely used for the translation of purchased equipment costs, even though the equipment component of the index might be better.

The Nelson–Farrar Refinery Construction Index, which appears monthly in *Oil and Gas Journal*, is a weighted construction materials and labor index. The ENR Construction Cost Index, reported in *Engineering News Record*, also weights construction materials and labor.

Process Complexity. Temperature, pressure/vacuum, and corrosive conditions can act as modifiers of the base cost by requiring thicker vessel walls, more expensive alloys, special seals, more expensive fabrication, or special testing procedures. Separate severity factors for temperature, f_T, pressure/vacuum, f_P, and material, f_M, are used as multipliers of the base cost, which is typically given for mild steel. The corrected cost is given as $\mathrm{COST} = f_T f_P f_M(\mathrm{BASE\ COST})$. Typical f factors of this type are available as simple correlations (1,4).

Geographic Modifiers. Equipment costs vary from one region to another due to differences in both purchased and installation cost. For example, there are differences between the northeastern United States and the Gulf Coast due to differences in shipping costs and labor cost rates. Such differences also exist between nations and global regions, where exchange rates, taxes, and other nationality items provide additional differences. Published data for geographic modifiers tend to be meager, dated, and of limited accuracy. Particular items such as labor costs and exchange rates are readily available.

3.2. Capital Investment Cost. The capital investment involved in a proposed project is important because it represents the money that must be raised to get the project started, is used in profitability forecasts, and is reflected in the estimated manufacturing cost of a product. A typical capital investment summary form is shown in Figure 1. The capital investment is classified here for discussion as fixed capital, working capital, and land cost.

Fixed Capital. Fixed capital can be classified as direct plant, indirect plant, and nonplant costs. The direct plant cost includes the process equipment, as well as the material and labor cost associated with installation, instrumentation, piping, electrical, buildings, structures, services, and site improvement. Indirect plant cost includes engineering, construction site expense, and any other plant items that cannot be charged directly to equipment, materials, or labor accounts. Nonplant cost, which is sometimes classified as indirect cost, includes contractor fees, contingency allowances, and occasionally both construction interest and some start-up expenses. The actual cost categories used generally follow internal accounting procedures. For example, some organizations separate the contingency allowance into separate reserve and contingency allowances. In one approach of this type, reserve is a project budget item that provides for the uncertainty in the estimates, while contingency is a higher management item to provide for unforeseen or unknown events. Land cost, while part of the direct plant cost, is placed in a separate capital category because it is not depreciable. Land cost is also site-specific and highly variable.

PRODUCT ______	ESTIMATOR ______
PROCESS ______	DATE ______
LOCATION ______	
CAPACITY ______	DESIGN
BASIS DATE ______	BASIS ______

PROCESS EQUIPMENT	PURCHASED (PEC)			
	DELIVERED (DEC)			
INSTALLATION	@	M		
	@	L		
PIPIING & DUCTS	@	M		
	@	L		
INSULATION	@	M		
	@	L		
ELECTRICAL	@	M		
	@	L		
INSTRUMENTATION	@	M		
	@	L		
BUILDING	@	M		
	@	L		
PROCESS STRUCTURAL	@	M		
	@	L		
FOUNDATIONS	@	M		
	@	L		
SITE & YARD	@	M		
	@	L		
UTILITIES & SERVICES	@	M		
	@	M		
	@	M		
	@	L		
LAND COST				
		A. TOTAL DIRECT PLANT COSTS		
ENGINEERING @				
SUPERVISION @				
CONSTRUCTION INDIRECTS @				
		B. TOTAL INDIRECT PLANT COSTS		
		C. TOTAL PLANT COSTS (A+B)		
CONTRACTOR FEE @				
CONTINGENCY/RESERVE @				
		D. TOTAL NON-PLANT COSTS		
E. FIXED CAPITAL INVESTMENT (C+D)				
F. WORKING CAPITAL @				
G. TOTAL CAPITAL INVESTMENT (E+F)				

Fig. 1. Capital investment estimate form.

There are two bases for the fixed capital estimate of process plants: grassroots and battery-limits plants. A *grassroots* plant is a complete facility at a new location, including all utilities, services, storage facilities, land, and improvements. If a process plant is located at an existing processing complex, it can usually share some of these auxiliary facilities. A *battery-limits* plant can then be defined as the process facility itself, so that the auxiliaries, off-site, and land-related items are excluded from the fixed capital estimation. However, a battery-limits plant may be assigned allocated capital charges for the share of common utility and service facilities used by the plant, as noted below.

The accuracy of a fixed capital estimate tends to be a function of the design effort involved. As the project definition is refined, the estimates evolve from the various preliminary phases (order of magnitude, predesign, factor estimates) into the more detailed construction estimates (budget authorization, project control, and contract). At the same time, the uncertainty in the estimates decreases.

Order-of-Magnitude Estimates. Unit capital cost data (dollars per annual ton of product) are occasionally reported for chemical plants. These data can be multiplied by a selected plant capacity to estimate a capital cost and this is feasible only if the reference process, conditions, and capacity are similar. A unit cost approach is widely used for quick estimates of the capital costs of utilities, waste treatment facilities, and buildings, where data in \$/kW, \$/t of waste, \$/m^2, etc, are available.

At processing complexes, central utilities and other facilities are shared by several battery-limits process plants. The capital cost of a central utility is sometimes charged to the capital cost of each battery-limits plant as an allocated capital cost based on the unit capital cost of the utility facility and the units of capacity of the utility required by the plant. In this case, the use charge per unit consumed only covers operating expenses. The alternative is to recover utility capital costs, as well as operating expense, in the unit usage charge.

A second order-of-magnitude approach is the ratio method, based on the assumption that fixed capital, and even total investment, can be correlated with plant capacity in a manner similar to that used for equipment. These plant costs can then be transferred to any year using the CE Plant Cost Index. However, capital cost data found in the literature should be examined to determine what items are included. Items such as site development, storage, off-site costs, working capital, capitalized construction interest, and start-up costs might be included. Large size extrapolations should be avoided because the need for multiple units, or changes in equipment type because of size, can affect the apparent capacity exponent.

The ratio method is also particularly useful for quick estimates over a range of capacities after a detailed calculation has been made for one capacity. In this approach, equipment can be separated into types 1, 2, ..., with individual exponents $n1$, $n2, \ldots$, and the capital cost C can be separated into groups C_1, $C_2, \ldots$. Then an overall exponent n can be calculated from $(S_b/S_a)^n = (C_1/C)(S_b/S_a)^{n1} + (C_2/C)(S_b/S_a)^{n2} + \ldots$, where S_a is the capacity of the calculated plant and S_b is another capacity.

Predesign Estimates. Methods are available to make a capital cost estimate based on a preliminary flow sheet or block diagram, but before material balances, energy balances, or equipment sizes have been calculated (5). Such predesign methods generally attempt to identify the number of process "units" in a tentative flow sheet and then use an average capital cost per unit. This average cost is correlated in some way with process complexity, process conditions, throughput, and materials of construction.

These predesign methods are empirical methods where accuracy depends strongly on the skill and experience of the user. The value of such approaches has been questioned, but the methods provide cheap estimates without significant design effort. The principal disadvantage is that there is no way to assess the accuracy of the results.

Overall Factor Estimates. The next level of fixed capital estimate is based on a preliminary design that includes a flow sheet, material balances, energy balances, and enough equipment design to size and estimate the cost of all principal process equipment, including pumps and tanks.

An overall Lange factor, F_L, can be used to relate the battery-limits fixed capital investment I_B to the delivered equipment cost E_D so that $I_B = F_L E_D$. A Lange factor value of 3.20 is a suitable average (6) for all types of plants. Another approach, the Hand factor, is based on a separate factor for each equipment class. This factor provides a relationship between the overall cost and the delivered cost for each equipment class. The Hand factors, covering all labor and field materials, indirect costs, but not contingencies, range in value from 4 for fractionators down to 2.5 for miscellaneous equipment. Some companies have a proprietary set of Hand factors.

Category Factor Estimates. Various capital categories can be related to total equipment costs by factors, reported as percentages of equipment cost. Typical categories include all materials and labor (M&L) accounts for piping, insulation, electrical, foundations, structures, and finishes, as well as indirect costs. Both purchased equipment costs, including pumps, tanks, and instruments, and delivered equipment costs, excluding instruments but including some offsites, have been used in this approach (1,2).

Module Factor Estimates. All equipment of a given type can be lumped together into a module, eg, a heat-exchanger module. Factors are available (7) to relate the various capital cost categories for each module type to the purchased equipment cost. The capital cost categories are then summed over all module types. This approach offers the advantage that the cost of commodity materials and labor are usually available in module categories to maintain accurate up-to-date module factors. Although the method requires a larger database, it appears to offer greater accuracy than overall or category factor methods.

Mid-1984 materials and labor factors have been reported for over 30 equipment types (8). The commodity materials include factors for concrete foundations, piping, steel supports, instrumentation, insulation, electrical, and painting. Installation labor factors are given for each of the commodity material categories, as well as for equipment setting. These data, while dated, can still be used with purchased equipment costs to obtain battery-limits installed equipment costs if no recent data are available. Additional factors are given for the balance of direct costs, indirect costs, and other items in the fixed capital investment.

Unproven Technology. When a product involves new or unproven technology, the capital estimates tend to understate the development, construction, and start-up costs. A quantitative approach to account for the capital cost and performance shortfalls associated with unproven technology has been reported (9), but the data are meager.

Working Capital. Working capital is the money required for the day-to-day operation of the venture over and above the fixed investment. The amount varies daily, may be cyclical, and can be a significant part of the investment in some cases. In the accounting sense, working capital is the difference between current assets and current liabilities.

The working capital includes the cost of inventories, such as raw materials, materials-in-process, and products, as well as supplies, accounts receivable less accounts payable, prepaid expenses, other cash needs such as payroll, and some start-up expenses such as materials and wages. Typical inventories can be taken as 1 month's supply of raw materials, products, and materials-in-process. The materials-in-process can be valued as 1 month's sales. Operating cash can be estimated as the actual cash needed for 1 month.

Methods are available for making detailed estimates of working capital (10). Shortcut ratios for estimating working capital are 15–20% of the fixed capital, 15% of total capital, or 10–30% of annual sales.

3.3. Product Cost. An estimate of total product cost is an important part of economic evaluation and management planning from R&D phases through the entire operating life cycle. A total product cost estimate form is shown in Figure 2. The total product cost can be viewed as the sum of the manufacturing cost and the general expense (11).

The manufacturing cost consists of direct, indirect, distribution, and fixed costs. Direct costs are raw materials, operating labor, production supervision, utilities, supplies, repair, and maintenance. Typical indirect costs include payroll overhead, quality control, storage, royalties, and plant overheads such as safety, protection, personnel, services, yard, waste, and environmental control, and other plant categories. However, environmental control costs are frequently set up as a separate account and calculated directly. The principal distribution costs are packaging and shipping. Fixed costs, which are insensitive to production level, include depreciation, property taxes, rents, insurance, and, in some cases, interest expense.

General expense consists of corporate services such as administration, sales and shipping departments, marketing, financial, technical service, research and development, engineering, legal, accounting, purchasing, public relations, human resources, and communications. Accounting groups are responsible for the consistent allocations of overhead and general expense items. Most companies have product cost estimate forms that give the classifications used.

"Joint product costing", when more than one product is manufactured by a single process, is a common situation (12), which can be treated on a weight or a volume basis. If one product is largely a by-product, it might not be assigned any manufacturing cost and is accounted for in terms of a by-product credit based on its sales volume. The suitable allocation of costs should reflect such factors as production level, changing markets, and raw materials.

Another problem is the allocation of costs when a raw material for one process operation is produced internally by another process operation of the same organization (13). The captive or "transfer price" assigned to the raw material can range from the production cost to a market price that reflects a total profit margin for the material producer. The approach used depends on the accounting procedures adopted.

The product cost can be computed on an annual or daily basis, but is frequently reported on a product unit basis ($/product unit). An estimate of the cost for various levels of production is often needed. This can be done by

PRODUCT______________ ESTIMATOR______________
PROCESS______________ DATE______________
LOCATION______________ FIXED CAPITAL______________
CAPACITY______________ OPERATING LABOR (HRS/WK)______________

RAW MATERIAL	UNIT	QUANTITY	$/UNIT	$/YR	$/LB
	BY-PRODUCT (CREDIT)			(-)	(-)
	NET RAW MATERIALS COST				

STEAM					
ELECTRICITY					
PROCESS WATER					
COOLING WATER					
AIR					
REFRIGERATION					
	TOTAL UTILITIES				

RAW MATERIALS (NET)		
UTILITIES		
DIRECT LABOR @		
SUPERVISION @		
MAINTENANCE @		
OPERATING SUPPLIES @		
A. TOTAL DIRECT COSTS		

PAYROLL OVERHEAD @		
STORES & SUPPLIES @		
QUALITY CONTROL @		
SECURITY @		
YARD @		
PACKAGING @		
B. TOTAL INDIRECT COSTS		

PROPERTY TAXES @		
INSURANCE @		
DEPRECIATION @		
C. TOTAL FIXED COSTS		

D. MANUFACTURING COST (A+B+C)		
E. GENERAL EXPENSE @		
F. TOTAL PRODUCT COST (D+E)		

Fig. 2. Product cost estimate form.

separating the manufacturing cost into fixed and variable components, with the variable components being those that vary with production level. On occasion, manufacturing costs are computed on an incremental or marginal basis instead of the usual allocated basis. For example, raw material cost discounts might be available at higher production levels. In this case, the cost of raw materials needed for incremental production might be charged at a lower rate.

Unit Cost Method. Typical operating cost data in dollars per weight or volume basis of product are frequently available. These data, which usually do not include capital costs, can be scaled directly over a moderate range of actual capacities to give rough estimates of annual operating cost as a function of annual capacity. Unit cost data should be carefully assessed to ensure that process type, size, and raw materials are similar to the proposed venture. Operating cost data sometimes are reported for separate categories such as operating labor, maintenance labor, supervision, and utilities.

Factor Methods. A more detailed product cost estimation method is to relate manufacturing cost items to a few calculated items, such as raw materials, labor, and utilities by means of simple factors (1). Internal accounting groups often develop factors for use with this popular method.

Raw material costs should be estimated by direct computation from flow rates and unit material prices. The unit prices are obtained from vendors, company purchasing departments, or publications such as *Chemical Marketing Reporter* (U.S.) or *European Chemical News*. Actual unit prices are based typically on a contract that covers quantity, time duration, grade, and other criteria. As a result, such prices are often less than published price data. For captive raw materials produced internally, a suitable transfer price must be established. Initial catalyst charges can be treated as either a startup expense, working capital component, or depreciable capital, depending on the expected catalyst life, cost, and industry practice. Makeup catalyst is frequently treated as a raw material.

Utility needs such as electricity, steam, process water, cooling water, refrigeration, and waste treatment should be calculated directly from the process material and energy balances. Unit costs for the various utilities can be obtained from suppliers or purchasing agents. Regional variations can be quite large.

Direct labor costs can be estimated using the flow sheet, typical labor needs (personnel/shift) for each item of process equipment, and the appropriate local labor rate. Company files are the best source for labor needs and rates, although some literature data are available (1). The hourly cost of labor in the United States can be estimated from the *Monthly Labor Review* of the Bureau of Labor Statistics. Production supervision costs can usually be taken as a factor, such as 15% of the direct labor cost.

Annual plant maintenance and repair costs average ~6% of the fixed capital investment, but should be calculated directly from person-hour per shift data or estimates. The annual cost for supplies can be taken as 15% of the total maintenance and repair cost.

Annual indirect costs are estimated as percentages of the direct labor and fixed capital costs. Typical direct labor percentage ranges are 25–30% for payroll overhead, 15–20% for stores and supplies, 10–20% for control laboratory, 10–20% for security, 10% for yard, and 10–15% for process improvements. As a result, total indirect costs are usually 80–115% of the direct labor cost (1).

A total capital investment, or a fixed capital investment, can be converted to an equivalent annual cost using an approximate capital charge factor (amortization factor), which multiplies the capital investment to give an annualized capital cost. The capital charge factor, which is provided by finance groups, is typically between 15 and 20% which provides a convenient shortcut approach to use in annual cost estimation.

Property taxes are taken as 1–5% of the fixed capital and insurance is assumed to be 1–2% of the fixed capital. If annual depreciation is estimated separately, it is assumed to be ~10% of the fixed capital investment. The annual interest expense is sometimes neglected as an expense in preliminary studies. (Some economists believe that interest should be treated solely as a return on capital and not as part of the manufacturing expense.)

General expense can be approximated as 15–20% of the total product cost. Typical category factors, as percentage of the total product cost, are 3% for administration, 10% for sales, and 4% for research and development (R&D).

4. Revenue Estimation

Revenues are money inflows from venture activities. In addition to product and asset sales, revenues might also include earnings of unconsolidated subsidiaries, license and royalty fees, gains on foreign currency exchange, investment income, and earnings on other transactions. Product sales, based on the unit product price ($/unit) and the yearly sales volume (units/year), are the only types of revenue considered here. The price and sales volume are related to each other and typically contribute most of the uncertainty in economic forecasts of chemical processes.

4.1. Product Price. If a need is not met by any other available product, then the price can be set as high as the need can support. However, a very high price tends to limit market growth and encourage the introduction of competitive or substitute products. The preferred strategy is to establish a moderately high initial price, but to plan on future price reductions to help expand the market and meet any competitive pressures. Variations of this strategy are seen in the pricing of pharmaceutical products that meet a unique need or have good patent protection.

If a need is met by a variety of products, then the price should reflect both the price of these competitive products and any unique features of the product being priced. For example, some plastic parts for automotive applications can be priced higher than corresponding metal parts because of lighter weight, corrosion resistance, or other features.

From an internal viewpoint, it is desirable that the price be high enough to generate an adequate rate of return, which is reflected in various cost or margin-based pricing policies. The percentage markup is defined as 100 (selling price-cost)/selling price. In situations where a dominant position exists, such as a patented pharmaceutical without significant competition, the price is market-driven and may not be directly related to cost. Pricing policy is discussed more fully in the literature (14,15).

4.2. Sales Volume. The quantity of annual sales is often called the sales volume, even though the units may be mass quantities instead of volume units. The estimation of the annual sales volume over the expected life of a production facility is extremely difficult in most cases. It requires an estimate of the total market, production capabilities, costs of competition, expected market share, selling strategy, and future economic conditions.

The expected annual sales volume is important not only for estimating sales revenue, but also for the selection of plant capacity, process type, and planned expansions. An economy of scale is typical of many process operations because both investment and some operating costs tend to vary with capacity to a fractional power less than unity. Case studies of various sales profiles are developed to assess the effect on profitability.

5. Profitability Analysis

Profitability analysis involves the generation of criteria that characterize the expected financial yield of a proposed investment, especially in comparison with other choices, as well as an assessment of the uncertainty and risk involved. The emphasis herein is on the quantitative profitability analysis of proposed multiyear investments.

A short-term case will first be introduced to illustrate the concept of profitability. Consider a young engineer who could buy a computer in the morning for \$2000 and sell it in the afternoon for \$2400, where the time frame is so short that the cost of capital can be neglected. The three parameters of interest are the investment (\$2000), return (\$400), and return rate (20%). The desirability of this venture depends on the subjective view of the observer. For example, if the selling price were only \$2001, the venture would still be profitable with a return rate of 0.05%, but few observers would consider it worth the effort. As the return rate increased, an increasing fraction of observers would consider the venture worthwhile.

If uncertainty is considered, the desirability changes. For example, if the *expected* selling price were still \$2400, but there was a possibility that this could not be achieved or even that the computer could not be sold at all, then the desirability of the venture would change. The acceptable return rate is an independent choice of each observer, as determined by the individual interpretation of the complete scenario.

The return, in dollars, is the reward for the effort and risk involved in undertaking the venture. The desirability is influenced by how an observer assesses the many factors involved and can even be based on irrational decision criteria. There is no single correct answer. Only future events determine the wisdom of the selection; even then, the results that another decision would have produced are rarely known. This is the essence of profitability.

5.1. Multiyear Case. The multiyear case introduces a new complication—money flows at different times cannot be compared directly because there is a time cost associated with capital. The flows must be translated to a common point using a discount factor $(1+i)^{-n}$ to translate flows backward in time and an encount factor $(1+i)^{+n}$ to translate toward the future. In these factors, i is the weighted average capital cost (WACC) as a decimal and n is the number of time periods, such as years.

As an illustration, consider a venture consisting of two \$500 investments and five \$500 net revenue flows timed as shown. If the cost of capital is assumed to be 10%/year and the present is taken as the end of year 2001, then the equivalent translated flows for this 7-year venture are

End of year:	2001	2002	2003	2004	2005	2006	2007
Money flow:	−500	−500	+500	+500	+500	+500	+500
Discounted flows							
	−500						
	−455	⟵					
	+413	⟵					
	+376	⟵					
	+342	⟵					
	+310	⟵					
	+282	⟵					

The flows have been translated to equivalent flows at a common time point and can be treated in a manner that is *analogous to the elementary computer example above*. Three parameters can be defined:

$$\text{Net present value (NPV)} = \text{arithmetic sum of all translated flows at end of year 2001}$$

$$\text{Discounted total capital (DTC)} = \text{sum of the translated investment flows at end of 2001}$$

$$\text{Net return rate (NRR)} = 100 * \text{NPV}/(\text{DTC} * \text{LIFE})$$

For this example, the results are

$$\text{NPV} = -500 - 455 + 413 + 376 + 342 + 310 + 282 = \$768$$

$$\text{DTC} = +500 + 455 = \$955$$

$$\text{NRR} = 100(768)/(955)(7) = 11.5\%/\text{year}$$

The significance of these three parameters will be discussed briefly.

Net Present Value. This parameter corresponds to a discounted net return. Five features should be noted as follows:

1. The NPV calculation provides for the *cost of capital* if the discount rate is selected as the weighted average capital cost. *Recovery of capital* in the NPV calculation is accomplished by recognizing the discounted investment as a negative money flow that must be offset by the discounted positive revenue flows before any positive net return is apparent.
2. Translated (discounted/encounted) flows lose all association with the original year of occurrence and become equivalent flows at a new time. Once a flow is translated, the flow can only be identified as a flow at the new point. In the example, a 2001 year translated flow of $376 could have originated as a year 2004 flow of $500 or a year 2002 flow of $414.
3. No assumption is made as to how any translated positive flow is apportioned between capital recovery and net return. In other words, no particular annual capital recovery or return pattern can be identified for any of the translated flows. The concept of annual revenue reinvestment can only be addressed in terms of another scenario.

4. The NPV value depends on the particular "present" time selected for the calculation. As an illustration, the sum becomes \$1361 when the flows of the example are translated to the end of year 2007 instead of 2001. The historical name emphasizes the dependence of the sum on the arbitrary present point selected. Popular choices for the present time are the actual present, the start of a venture, or the start of production. However, it is important to recognize the logical meaning of the NPV as a discounted net return.
5. The discount/encount operation is nonlinear with respect to the discount rate. The importance of this point has not been appreciated in profitability analysis.

Discounted Total Capital (DTC). When the capital investment is made in more than one year, the yearly investment amounts cannot be summed directly because of the time cost of money. The DTC calculation provides a translation of the investment flows to the same common time point used in the NPV calculation. While the actual investment capital that must be provided each year is of importance to financiers, the DTC is the *discounted investment* that is needed for economic studies.

Net Return Rate (NRR). Once the money flows have been translated to a common time point, the problem is similar in form to the computer purchase example above. If the NPV is divided by the DTC, the result is a return rate (%) on the investment over the life of the venture. If this, in turn, is divided by the venture life, the result is an *effective annual return on investment* called the Net Return Rate (%/year)

$$\mathrm{NRR}(\%/\mathrm{year}) = 100(\mathrm{NPV})/(\mathrm{NTC})(\mathrm{LIFE})$$

where LIFE is the assumed total venture life from year of initial capital expenditure through year of venture extinction. For the example above,

$$\mathrm{NRR} = 100(768)/(955)(7) = 11.5\%/\mathrm{year}$$

The NRR is invariant with respect to the selection of the present point. As noted above, discounting provides for the cost of capital, while the arithmetic combination of revenue and investment flows in the NPV calculation provides for the recovery of capital. As a result, the NRR is a true profit rate in which the *profitability has been separated from the cost of capital*. A zero value of the NRR represents zero profitability and any positive value represents a profitable situation, with larger numerical values representing greater profitability. The choice of an acceptable value is a subjective judgment, as noted in the context of the computer sale example above.

6. Multiyear Venture Analysis

6.1. Annual Money Flows. The actual profitability analysis of a multiyear venture should be based on the venture "cash flow". The meaning of this

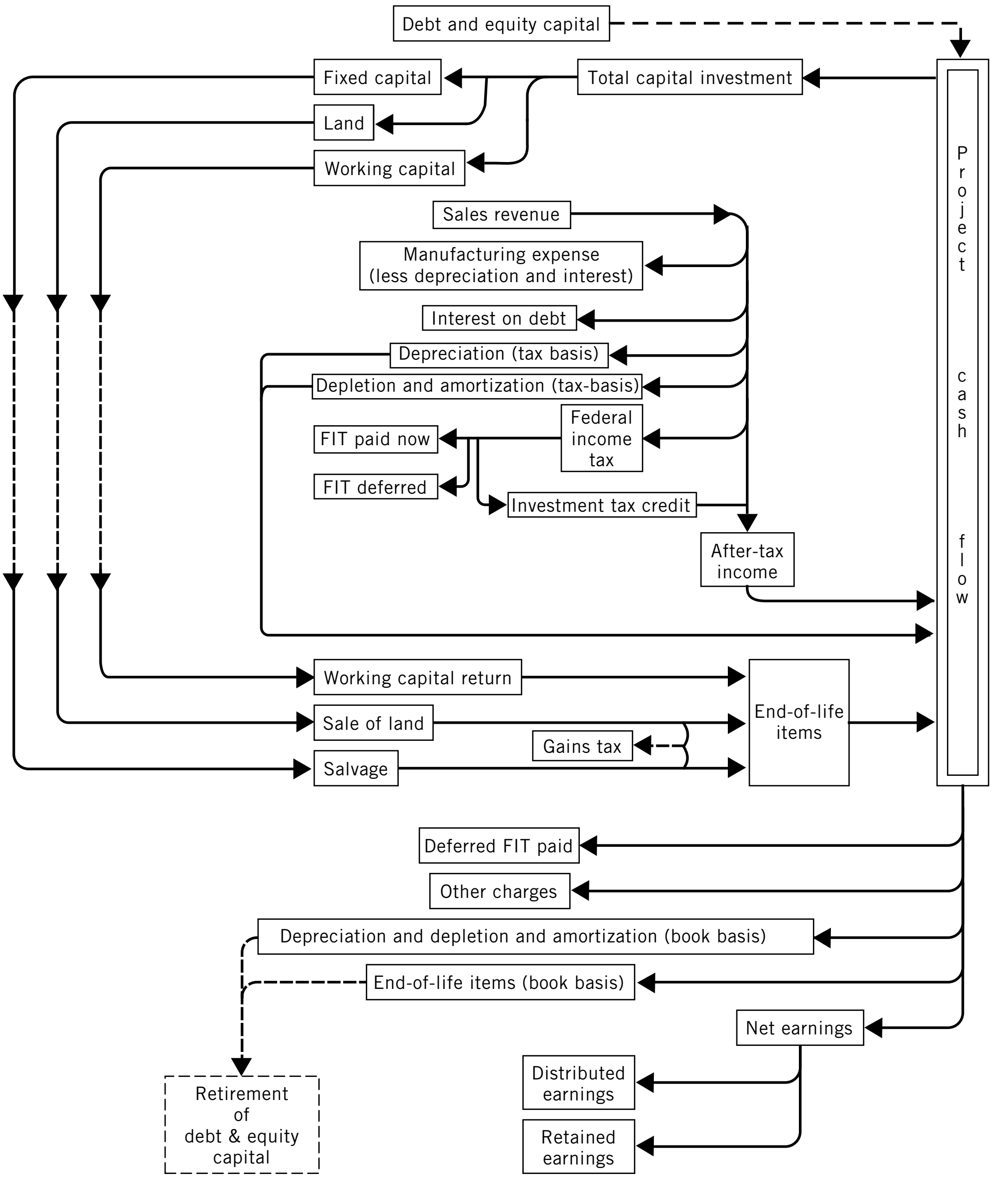

Fig. 3. Typical annual money flows. (Flows to the right are inflows, those to the left are outflows. Annual cash flow is given by the heavy-lined arrows.)

concept will be developed in terms of the annual money flows of Figure 3. The money flows are assumed to be end-of-year flows for simplification. Investment and other outflows are negative; sales revenues and other inflows are positive. Not all of these occur each year. For example, investment flows are typically pre-operational costs; sales revenues do not start until the project is operational. The estimation of sales revenues and manufacturing expenses has been discussed.

Depreciation, a part of the manufacturing expense, and interest are treated separately in the money flow diagram of Figure 3 because of their effect on taxes.

Investment Capital. From the viewpoint of the project, all of the capital that must be raised is external capital. Equity capital is the ownership capital consisting of common and preferred stocks, as well as retained cash, while debt capital consists of bonds, mortgages, debentures, and loans. Nearly all investment involves a mixture of both types so as to maximize the return on investment. Because financial details are not well known during the preliminary phases of project analysis, the investment in early project studies can be viewed simply as the total capital that must be expended to design and build the project.

The investment consists of the fixed capital (equipment, buildings, and facilities), land, and working capital. Interest charges during construction are frequently considered part of the fixed capital, which is called capitalization of the construction interest expense. Some start-up costs are occasionally treated in the same manner.

The nondepreciable investments, such as land and working capital, are often assumed to be fully recoverable at cost when the project terminates. Equipment salvage tends to be an end-of-life item that can represent a significant fraction of the original fixed capital investment. However, most salvage occurs at the end of life and can be difficult to forecast. This salvage is partially offset by dismantling costs. For these reasons, a zero salvage assumption is a reasonable approximation in preliminary analysis.

Interest. The interest block in Figure 3 represents the interest expense associated with the debt capital. It is an allowed corporate pretax expense for federal income tax purposes and is actually paid out to the debt holders as their earning.

Tax Basis Depreciation, Depletion, and Amortization. Depreciation is a loss in value resulting from use or obsolescence. A depreciation allowance on equipment, buildings, and other facilities is a permitted pretax expense for federal income tax purposes. The tax basis depreciation allowance reduces the taxable income, but is not an actual out-of-pocket expense. Consequently, this allowance is limited by tax regulations, which define depreciation methods and allowable tax basis lifetimes for equipment (16). Similar allowances for depletion and amortization are also permitted by tax regulations. The depletion allowance is for exhaustible resources (oil reservoirs, mineral deposits, woodlands, etc) while the amortization allowance is for certain expenses that must be capitalized (most startup costs) and intangibles (goodwill, patents, information base, etc). These are also limited by tax regulations and accounting standards. [The Financial Accounting Standards Board (FASB) proposed that mergers and acquisitions after mid-2001 should be based on purchase accounting instead of pooling-of-interest accounting. This would affect the treatment of goodwill.]

Federal Income Tax. The federal income tax (FIT) is based on the net pretax income. Since 1992 the FIT rate has been 34%, although many organizations utilize special provisions of the tax code to reduce the effective tax rate (16). Sometimes a higher rate is used in profitability studies to account for state and other income taxes. While part of the tax is actually deferred and paid in a future year, it is convenient to assume that any tax due is paid in the current year.

In the past, income tax could be reduced by an investment tax credit. This item, designed to stimulate investment, was a tax credit amounting to some percentage of the new capital investment in certain eligible types of equipment. It was credited when the investment was made and could be used to offset the tax due, until exhausted, for a prescribed period of years. This credit was eliminated in the United States for most equipment, but is frequently advocated for investment stimulation in selected areas, such as environment or energy conservation. It is expected that the investment tax credit will be expanded to broader areas in the near future.

End-of-Life Items. The end-of-life items are working capital return, sale of land, salvage, and site restoration. If there is a capital gain on land sale or salvage, above the remaining tax basis asset value, then this gain is treated as either a capital gain or ordinary income, depending on tax regulations. Historically, capital gains were taxed separately at a lower rate than ordinary income, but this advantage is limited today. Although equipment replacement or changing working capital requirements can occur anytime during the project lifetime, both salvage and working capital return are frequently assumed to be end-of-life items in profitability studies unless other details are known.

Book-Basis Depreciation. Book basis depreciation is arbitrarily determined by management on a year-to-year basis, subject to acceptable accounting practice, which is not an out-of-pocket expense. It is simply a charge for the recovery of capital in earnings calculations and is available as capital for debt reduction, reinvestment, or equity distribution. Some consistent treatment for recovery of capital must be assumed in profitability analysis.

Distributed and Retained Earnings. The dividends distributed to stockholders provide an earning on equity capital in the same way that interest is the earning on the debt capital. However, the dividends are an after-tax expense and represent an arbitrary management decision. After the equity earnings are subtracted from the net after-tax earnings, the balance is called the retained earnings and represent an increase in equity. The retained earnings can be visualized theoretically as the new cash generated beyond that needed to provide a dividend return to investors and orderly retirement of the investment.

In Figure 3, the annual book depreciation is used to retire the fixed capital investment. While this accounting model does not correspond to the typical money flow, it is one possible model for recovery of capital. This model assumes that the investment is reduced each year by the amount of the annual depreciation. Another model assumes that a uniform yearly book depreciation payment is made to an interest-bearing sinking fund that accumulates to the depreciable fixed capital amount at the end of the venture. This also does not correspond to the actual money flow in most cases. Profitability analysis utilizes a third model based on discounted cash flows.

6.2. Cash Flows. The annual cash flow is the actual net cash generated by the project in a given year. From Figure 3, the net annual cash flow can be defined for any project year as the sum of four items: (+ after-tax income + tax basis depreciation + end-of-life items − yearly investment). Other cash flows definitions, such as the EBITDA (earnings before interest, taxes, depreciation, amortization, and other items), are used by entertainment and internet companies to emphasize annual growth and enhance annual reports. However, any cash flow definition used in profitability analysis must reflect all costs.

Because the money flows below the cash flow box in Figure 3 tend to be arbitrary management decisions that are generally difficult to predict, the prediction of profitability is based on the expected cash flows instead of earnings. As a result, some logical assumptions must be made to account for the cost and recovery of capital. The most straightforward approach is to define the discount/encount rate as the weighted average capital cost (WACC) and to use the NPV calculation for the recovery of capital.

Discounted Cash Flows. Before cash flows from different years can be combined, discount/encount factors of the type described above must be employed to translate all of the flows to a common present time. The present time, an arbitrary choice, is typically selected as one of three possibilities: actual present time, the venture inception, or the start of operations. As noted above, the logical choice for the discount/encount rate is the WACC rate, where capital includes both equity and debt components.

Weighted Average Capital Cost. If the debt ratio (DR) is defined as debt/total capital, then the discount rate i can be written in terms of the long-term after-tax debt rate i_D and the equity cost rate i_E as:

$$i = (i_D)(\mathrm{DR}) + i_E(1 - \mathrm{DR})$$

This WACC rate typically goes through a minimum at some intermediate value of DR, as illustrated for a hypothetical case in Figure 4. This DR target provides the optimum leverage for the given rates, but will change as rates change. Since corporate capital is raised incrementally in debt and equity placement, the actual corporate DR will also fluctuate around the optimum over time. This corporate DR is usually assumed to be applicable to all new ventures of a corporation.

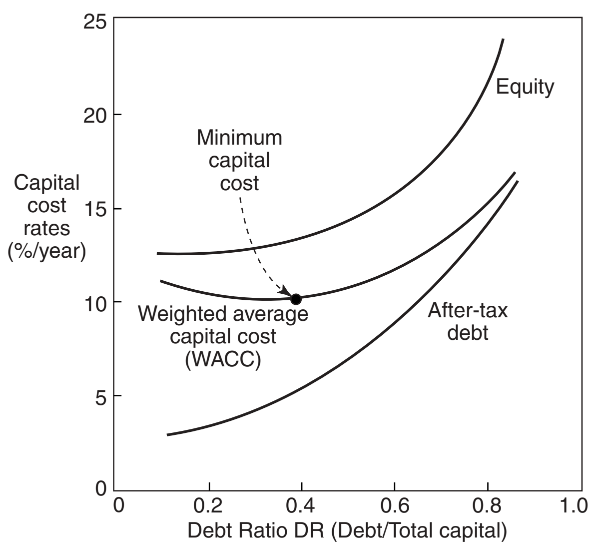

Fig. 4. Typical capital cost rates.

However, for large ventures where the venture capital is a significant part of the total corporate capital or where a venture is funded as an independent entity, the DR can also be a strong function of the perceived risk. Some companies even use different debt allocations for individual projects based on the perceived risk.

Cost of Debt Capital. The cost of debt capital is the after-tax interest on the debt, given by

$$I_D = (1 - r)\ (\text{debt interest rate})$$

where r is the effective annual income tax rate in decimal form. A debt interest rate can be estimated directly from corporate debt data. However, this can range from asset-backed bonds to junk bonds with little, if any, corporate asset base. Further, all of the debt rates supposedly reflect inflationary expectations and, to some extent, corporate income tax rates. Since current debt rates range from $\sim$5% to $>$12%, it is obvious that the risk premium inherent in reported debt rates varies widely.

Cost of Equity Capital. The cost rate associated with equity capital consists of two parts: the annual dividend yield and part of the "investor-expected" equity appreciation. The dividend yield can be determined from corporate data. Equity appreciation presents a more significant analysis problem since it reflects retained capital, anticipated profitability, and general market dynamics. What part of this appreciation should be considered a capital cost component and what part should be an investor reward component? How is the risk premium taken into account? These questions have been addressed with a variety of approximate models by financial specialists, as discussed in the texts listed in General References the Engineering Economics section. It should be recognized that the cost of capital to be used is that expected over the lifetime of the venture and not simply the present or past value. Furthermore, the discount rate used by finance specialists is often an industry or corporate average, rather than a venture-specific value.

6.3. Multiyear Process Example: Venture A. A summary spreadsheet is shown in Figure 5 for a hypothetical Venture A. The input consists of the parameters and assumptions given at the top of the sheet, as well as the first nine line items (above the dashed line). These data estimates must be obtained from the various groups involved in the analysis of the venture such as R&D, engineering, purchasing, sales, and finance. The assumed venture life should be long enough to show the effect of tax basis depreciation correctly. Even though most chemical processes have an actual operating lifetime $>$10 years, the years beyond the 10-year point tend to make a lesser contribution due to discounting and involve more uncertainty. For these reasons, an operating lifetime of 10 years is frequently chosen for preliminary economic analysis. In line items 3 and 4, land cost and working capital are assumed to be recoverable at cost at the end of venture life. Cash flow calculations are given in line items 10–24.

In preliminary project analysis, the debt structure (debt ratio, interest rates, repayment schedules) is usually unknown and a common assumption is to neglect interest as a line item expense (line item 15). This leads to a small error in the line item tax and cash flow, but is a popular and conservative approach. If interest is included as a line item, then the interest should

INPUT PARAMETERS

DEBT INTEREST RATE		PROJ START	2002
EQU RET RATE (REQD)	0.132	PROJ END	2013
FED INC TAX RATE	0.34	PRES TIME	2001
AFTER-TAX DEBT RATE		OPERATION	10 YRS
DEBT/TOTAL CAPITAL		END-OF-YEAR FLOWS	
DISCOUNT RATE	0.100	DEPRECIATION: MACRS 7 YR CLASS	
INVEST TAX CREDIT	0	SALVAGE: NEGLIGIBLE	
LINE ITEM INTEREST	0	SITE RESTORATION NEGLIGIBLE	
LINE ITEM DEBT SCHED	NO		

LINE	END OF	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	OPERATING YEAR	-2	-1	0	1	2	3	4	5	6	7	8	9	10
	DISCOUNT YEAR n	0	1	2	3	4	5	6	7	8	9	10	11	12
1	FIXED CAPITAL		-3500	-3500										
2	ALLOCATED CAPITAL		0	0										
3	LAND/OTHER NON-DEPREC		-300											300
4	WORKING CAPITAL			-600										600
5	SALVAGE													0
6	SITE RESTORATION													0
7	TOTAL CAPITAL		-3800	-4100										
8	SALES REVENUE				7000	7280	7571	7874	8032	8032	8032	7951	7872	7085
9	MFG COST [LESS DEPR & INT]				3600	3000	3120	3245	3375	3510	3650	3796	3948	4106
10	CAPITALIZED FIXED CAP			-7350										
11	CAPITALIZED TOTAL CAP			-8280										
12	DISC TOTAL CAPITAL	-6843												
13	OPERATING INCOME				3400	4280	4451	4629	4657	4522	4382	4155	3924	2979
14	OTHER INCOME				0	0	0	0	0	0	0	0	0	0
15	INTEREST ON DEBT				0	0	0	0	0	0	0	0	0	0
16	DEPRECIATION [TAX BASIS]				1050	1800	1286	918	656	656	656	328		
17	DEPLETION													
18	NET TAXABLE INCOME				2350	2480	3166	3711	4001	3866	3726	3827	3924	2979
19	FEDERAL INCOME TAX				799	843	1076	1262	1360	1315	1267	1301	1334	1013
20	INVESTMENT TAX CREDIT				0	0	0	0	0	0	0	0	0	0
21	NET INCOME				1551	1637	2089	2449	2640	2552	2459	2526	2590	1966
22	CASH FLOW		-3800	-4100	2601	3437	3375	3367	3297	3207	3115	2854	2590	2866
23	CASH FLOW + INTEREST													
24	DISCOUNTED FLOWS													
		-3455												
		-3388												
		1954												
		2347												
		2096												
		1901												
		1692												
		1496												
		1321												
		1100												
		908												
		913												

PROFITABILITY PARAMETERS

NET PRESENT VALUE	8885
VENTURE LIFE [YRS]	12
DISC TOTAL CAPITAL	6843
NET RET RATE (%/YR)	10.8

INT RET RATE(%/YR)	32.3
OVER RET RATE (%/YR)	17.90

Fig. 5. Profitability spreadsheet: Venture A. (Items above the dashed line are specifications or assumptions; items below are calculations.)

be added back to the cash flow in line item 23 before discounting in order to avoid an apparent double return on the debt from interest and discounting. (This addition is not part of the accounting cash flow where interest is treated as a line item expense and there is no discounting of the money flow.) The tax basis depreciation in the example is based on the capitalized fixed capital at the start of operation. A 7-year MACRS approach with no salvage value (16) is used for the depreciation calculation.

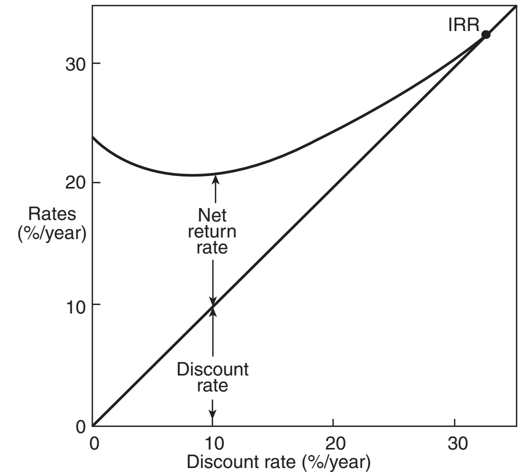

Fig. 6. Profitability diagram: Venture A. (Note that the net return rate = 10.8%/year at a discount rate of 10%/year and that the IRR = 32.3%/year (not a function of discount rate).]

The NPV, DTC, and NRR, as profitability parameters, are given in Figure 5 for a discount rate of 10%/year. These serve as the basis of a profitability analysis in which the desirability of the venture would be assessed in a manner similar to that discussed in the elementary computer sale above. The ORR value for the same discount rate and the IRR, which is not a function of the discount rate, are also shown for comparison.

6.4. Profitability Diagram. An additive-ordinate plot of the discount rate and NRR as functions of the discount rate (WACC), as shown for Venture A in Figure 6, can provide insight into venture profitability. The NRR, as a measure of the profitability, correctly decreases with increasing discount rate (capital cost rate), gives the correct limiting value at a zero discount rate, and is a nonlinear function of the discount rate.

A profitability diagram is a straightforward way to illustrate the effect of discount rate (WACC) on the profitability. This diagram can be used to illustrate the effect of rate changes, debt allocation, perceived risk, process novelty, market uncertainty, and other venture features on the profitability. The use of the profitability diagram in comparative venture analysis has been illustrated before (17).

7. Historical Profitability Criteria

Many profitability criteria have been defined in the past. Several cash flow criteria, which still find application in spite of known flaws, are discussed here.

7.1. Internal Return Rate. Internal return rate (IRR) or discounted cash flow return rate (DCFRR) can be defined as a "calculated discounting rate" that makes the arithmetic sum of the translated cash flows equal to zero. In other words, it corresponds to the discount rate that gives zero profitability. As illustrated for Venture A in Figure 6, this is the single invariant point of

32.3%/year where the NPV (and NRR) equal zero. The IRR still finds wide use because it is an annualized rate concept. However, some of the flaws are as follows:

1. Any meaningful profitability criterion should decrease as the cost of capital increases in most cases, instead of remaining constant.
2. Because of the nonlinear nature of the discounting step, there is no way to separate the IRR into profitability and capital cost rate components at discount rates of interest. Finance specialists have attempted to provide an approximate correction for this flaw by defining an acceptable IRR cut-off value, which is adjusted up or down to reflect an increased or decreased cost of capital. However, this has no logical foundation.
3. The IRR calculation is a search for the roots of a polynomial and can lead, in some cases, to multiple roots, negative roots, and even complex roots. These have no meaning as profitability criteria.
4. Use of the IRR as a profitability criterion can lead to incorrect project rankings in comparative project assessments (17) and the numerical values of the IRR are far larger than the true profitability in most cases. For these reasons, the IRR has no logical foundation as a profitability criterion and should not be used.

7.2. Overall Return Rate. The overall return rate (ORR) was introduced as an improvement over the IRR. This parameter, defined by a variety of closely related forms (18), is found by a two-step procedure. In the first step, the annual investment flows are discounted to some present time and the other annual cash flows are encounted to the end of the venture, with the capital cost rate used for both calculations. In the second step, an encount rate is computed to relate the discounted investment flows to the encounted cash flows. This computed rate is defined as the ORR. For Venture A at a discount rate of 10%/year, the ORR is 17.9%/year, which is not a measure of profitability. There are three general difficulties:

1. The ORR usually increases, rather than decreases, with increasing discount rate (capital cost rate). In normal venture scenarios, any logical profitability criterion should decrease as the cost of capital increases.
2. Although practical discount rates vary only over a moderate range, any profitability parameter should still be theoretically meaningful as the discount rate approaches a limiting value of zero. The ORR value is meaningless at a discount rate of zero.
3. The ORR approach is based on the assumption that both the capital cost rate (discount rate) and profit rate (NRR) can be treated as a common discount operation. However, the first step of the ORR calculation translates money flows to two different time points based on the capital cost rate. The translated flows, at two different time points, can only be compared after translating to a common time point using the capital cost rate. Profitability analysis is then based on those translated flows at a common time point—no further discounting is involved.

7.3. Net Present Value. The net present value (NPV), which is used correctly as part of the profitability approach developed above, has also had a long history as a stand-alone criterion in venture analysis. It is a logical measure of the discounted net return (dollars), rather than a return rate. It is not suitable as a stand-alone criterion in comparative assessments of ventures with different investment levels or lifetimes. In addition, the numerical values of the NPV depend on the location of the arbitrary present point selected for the money flow translation.

7.4. Other Criteria. Numerous other parameters have been developed as approximate profitability criteria (1). These include various return-on-investment (ROI) and payback time (PT) definitions, in both discounted and nondiscounted forms. The payback time formats typically consider only the early venture years and neglect the latter years entirely. They give an indication of the time needed to recover the investment cost, but give little direct information about the lifetime profitability. The economic assessment associated with Life Cycle Analysis can be viewed as a form of cash flow analysis. Levelized formats have also been developed in which annual flows are translated into a single time sum, such as is done with the NPV, and then the sum is translated into a uniform annual series so as to utilize an annualized ROI format.

8. Break-Even Charts

A break-even chart (1) is a visual tool for analyzing operating profitability at various levels of production. In this type of diagram, annual expenses are separated into fixed, variable, and semivariable categories. Fixed expenses do not vary with production level, variable expenses vary linearly with production level, and semivariable expenses vary in some nonlinear way with production level. Annual dollars of sales and expenses are plotted as a function of production level (% of design capacity, eg), as shown in Figure 7. Profitable operation is represented

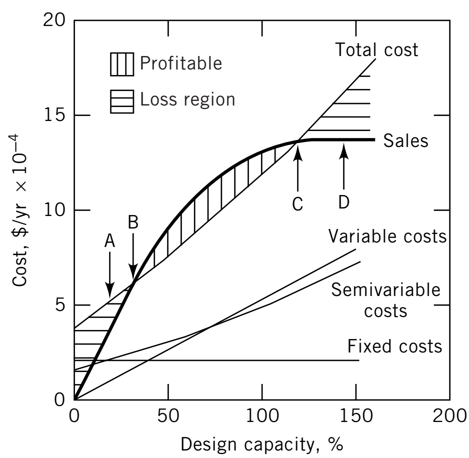

Fig. 7. Typical break even chart. A & D: Shutdown points [total loss=fixed cost] C & B: Marginal points [zero profit]

by the vertically lined region. This diagram also shows break-even levels of production (points B and C) that are marginally profitable. Points A and D represent shutdown points where the total loss equals the fixed cost. At these shutdown points, it is more economical to cease production, paying only fixed costs, than to operate the facility.

Break-even charts are used with production models to predict optimum production levels, break-even points, and shutdown conditions under various scenarios. These models tend to involve a reasonable amount of approximation. For example, sales revenue as a function of production level involves numerous variables and relationships that are not always well known. Such charts, however, can provide useful guides for production operations.

9. Inflationary Effects

Inflation can have a significant effect on the profitability of a venture. However, the U.S. federal tax laws do not allow for indexing the inflationary effects of depreciation schedules, salvage values, replacement costs, or taxable income. Inflation rates can vary unpredictably with time and can differ for certain revenues or expenditures. In a year-by-year cash flow analysis, as described above, sales revenue and manufacturing costs can be estimated in actual inflated money amounts.

Prevailing interest rates and capital cost rates tend to reflect an estimate of future inflation and contain a component that can be attributed loosely to inflationary expectations. Different discount/encount rates could be used for various time intervals in a cash flow analysis, although future rate values are rarely known with any accuracy.

10. Uncertainty and Risk

Most economic analysis is based on a "best-estimate" scenario in which the most probable estimates of all inputs are used. However, uncertainty in these estimates can introduce uncertainty into the profitability parameters. Various approaches have been developed to treat uncertainty and to characterize the associated risk (19).

10.1. Extreme-Case Analysis. Highly optimistic values could be selected for all parameters in one study and highly pessimistic values could be used in another study. Such "best-case" and "worst-case" scenarios provide bounds on the uncertainty in the profitability parameters. However, these scenarios have a very low probability of occurrence and, as a result, are poor indicators of the associated risk.

10.2. Sensitivity Analysis. The percentage change in the NRR due to a percentage change in an input parameter, such as average annual sales volume, can be calculated. Similar calculations can be done for other input variables and plotted on a single diagram to indicate the relative sensitivity of the NRR to percentage changes in various input parameters. While such sensitivity plots are popular graphical tools in profitability analysis, they do not indicate the *probability* of the changes. As a result, there is no related method to directly assess the risk.

10.3. Statistical Methods. In order to treat probability, statistical methods can be employed to characterize the probability distributions. Because most distributions in profitability analysis are not accurately known, the common assumption is that normal distributions are adequate. The normal distribution of a quantity can be characterized by two parameters; the expected value and the variance. These usually have to be estimated from meager historical data.

Decision trees, Monte Carlo simulations, and other approaches have led to the development of quantitative risk assessment methods in economic analysis. However, the historical database is limited and there are no sound methods for projecting the historical database to future scenarios. In spite of these difficulties, statistical approaches have found increasing use in recent years.

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THOMAS J. WARD
Clarkson University