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A Standard Procedure for Cost Analysis of Pollution Control Operations;

Volume I. User Guide

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A Standard Procedure for Cost Analysis of Pollution Control Operations;

Volume I. User Guide

by

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ABSTRACT

A standard procedure has been devised for the engineering cost analysis of pollution abatement operations and processes. The procedure is applicable to projects in various economic sectors: private, regulated and public. The models are consistent with cost evaluation practice in engineering economy and financial analysis. The report presents a recommended format, termed the Specification, that should not exceed eight pages when executed. The guidelines facilitate the choice of procedures open to the estimator and the establishment of factors to be used in the evaluation. The Specification has three segments: descriptive, cost analysis, and reliability assessment. The bulk of the report consists of 11 appendices that provide detailed background material and two comprehensive examples. The appendix subjects are: Capital Investment Estimation; Annual Expense Estimate; The *Cash Flow* Concept; Discrete and Continuous Interest Factors; Measures of Merit; Cost Indices and Inflation Factors; Rates of Return and Interest Rates; Methods of Reliability Assessment; Sensitivity Analysis; Example I -- Cost Analysis of Flue Gas Desulfurization (FGD) Retrofit Facility; and Example II -- Cost Analysis of Chlorolysis Plant.

The Measures of Merit appendix considers: return on investment, internal rate of return, payout time, equivalent annual cost, and unit costs. A glossary is provided.

PREFACE

Several persons within EPA have keenly felt the need of a standard procedure for preparing engineering cost analyses of projects which either affect or are related to pollution abatement (or control). Such standard procedures are not new; even within the government several have been developed over the years and for a wide range of technologies.

Interest in an improved procedure has been prompted by the preponderance of conceptual estimates that proved to be much lower than figures from later more detailed studies or the costs of actual plant construction. Also many of the cost estimates provided to support feasibility studies have proved deficient, incomplete, hard to comprehend, and difficult to apply for comparison and future use because of the absence of a uniform format. In addition, many cost analyses fail to provide a definition of the project scope, an appraisal of the stage of development, and an assessment of the reliability of the economic evaluation. These unsatisfactory conditions can be largely obviated through use of a standard procedure, such as presented in this report for preparing engineering cost analyses.

The essential part of the procedure is the specification which consists of a descriptive segment, a cost evaluation segment, and a reliability-assessment segment; this report includes step-by-step methods for the execution of the three segments. Guidelines have been prepared to aid in the selection of financial and operating factors and the establishment of the level of detail and comprehensiveness required. These guidelines also serve to involve the requestor directly; he must set the appropriate type of estimate and the discretionary factors. The application of the specification and the guidelines are illustrated in two case studies (Appendices J and K).

Some features of this report are:

- The subject has been developed in a complete but concise way.
- The rationale adopted for the evaluation of capital projects is consistent with accepted practice in both financial and engineering circles.
- The appendices (Volume II) review the background required to carry out a cost analysis and to evaluate the results.
- Examples are used where possible.

Adherance to the specification will ensure that cost analyses are prepared with care, thoroughness, and uniformity, and are suitably characterized as to development, scope, and reliability. The analyses would be simply executed, and the results easily comprehended and readily put to use.

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SECTION 1

INTRODUCTION

NEED

Within any technical organization there is a general need for a standard procedure for economic evaluations, also termed engineering cost analyses and life cycle cost analyses. Such a consistent method ensures not only that the results are couched in familiar terms and are in comprehensible form, but also that the analysis is complete and suited to the purposes at hand. EPA has felt a need for such a standard procedure to guide its R&D programs more effectively and for other uses such as:

- Costing projects to characterize the costs to be incurred, and to ascertain their economic feasibility.
- Comparing expected costs of alternative measures to identify the preferred control strategy.

Such an established methodology could also improve the quality and utility of economic assessments to meet additional needs such as:

- Providing information needed to ascertain the economic burden of an abatement process on a specific plant or industry.
- Predicting the costs of pollution control for industrial and government groups in the evaluation of the ultimate costs to the consumer or taxpayer, and in gauging the effect on the economy and the benefit to society.

PURPOSE

The report presents background and step-by-step instructions for a standard procedure of cost analysis. The substantial portion is the specification and a guideline. The specification is actually a uniform format: It organizes the essential information; e.g., for R&D contracts, compliance studies, and critical evaluations of cost analysis from published sources. The guideline provides choices such as the type of capital estimate, and the desired measures of merit; it also aids in the designation of financial and operating factors.

The procedures outlined apply to evaluations for a generalized case. They are not intended for site-specific studies; these require reviews of local circumstances including engineering surveys and detailed designs. Both can have significant effects on cost.

FOR WHOM INTENDED

The standardized procedure presented in this report is specifically designed for those concerned with R&D tasks: contractors, project officers, in-house investigators, responsible persons in EPA, and the users of the end results. However, it should also prove useful to other groups; e.g., departments and agencies of the government, industrial corporations, engineering firms, and consultants.

RANGE OF APPLICATION

A standardized method of estimation must have wide adaptability because the processes and techniques to be costed will embrace a variety of technologies. For example, it must be capable of providing reliable evaluations of chemical plants, liquid waste treatment facilities, a variety of combustion devices, and power plants. In this connection, a number of methodologies have been established for generalized cost estimates for certain fields; e.g., saline water purification, nuclear energy, coal gasification, and wastewater treatment (1-4).* For a valid evaluation of pollution control measures, the procedure must take into account the economic sector that governs; viz., private, regulated (e.g., electric utilities), or governmental (e.g., sewage treatment works).

CHARACTERISTICS OF COST ANALYSES

To serve the foregoing purposes effectively, a cost analysis must possess certain distinguishing features. First, it must be simple and sound; these qualities foster acceptance. Then it must be uniform in organization; this facilitates communication and permits ready comparison. Finally, the method should include an expression of relative reliability; this apprises users of the validity of the analysis.

RELIABILITY

The reliability of cost projections varies widely. Factors are availability of basic data, stage of development, definition of scope,

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*Numbers within parentheses refer to references listed in Section 5.

the time expended on the analysis, and the experience brought to bear. Figure 1 illustrates the effect of these factors on capital costs of projected and actual facilities. It will be noted that estimates in the early stages of development cover a large range: they may be much lower or much higher than the actual capital cost. Generally the initial concept of a project is overly simple, but the opposite can be true. In any case, as more information is developed, the "envelope of variability" (the shaded area) narrows.* In addition, experience obtained in design, construction, and operation of similar plants results in decreased costs, both investment capital and annual expense. This trend reflects the influence of the so-called "learning curve."

The accuracy of cost analyses is sometimes identified only with the capital cost estimate, but reliability assessments must also take into account the accuracy of all of the cash flows associated with the operation; e.g., all operating expenses, and revenues including market value of by-products.

The inability to define scope satisfactorily contributes significantly to the deviation of estimates from actual costs. Naturally this plight is greater for estimates made in the early stages of R&D. As the project moves through the definitive and into the various design phases, the scope becomes better defined with a corresponding improvement in reliability. Elements that especially affect the extent of the scope are location, add-ons, extras for retrofit (if applicable), and purpose of the plant.

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*The area of the "envelope of variability" for a new process, and for processes in new technologies, decreases as experience in estimating costs is gained.

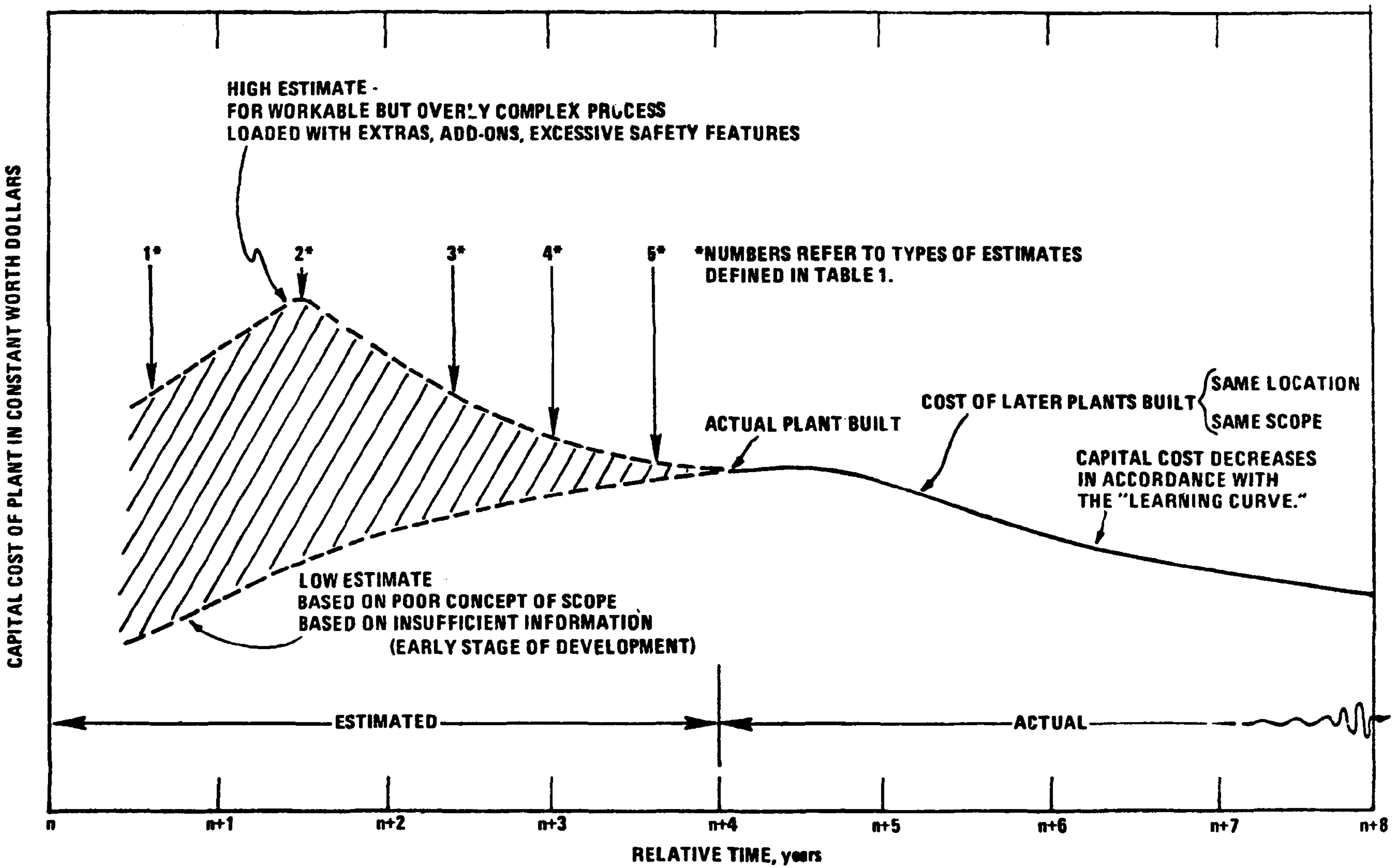

Figure 1. Effect of various factors on projected and actual capital costs.

SECTION 2

STANDARD PROCEDURE FOR AN ENGINEERING COST ANALYSIS

The specification format organizes the information for the economic evaluation under these headings (segments) and subheadings (elements):

- Descriptive Segment
- Cost Analysis Segment
  - Specified factors
  - Cost estimate
    - capital investment
    - annual expenses
    - net profit and *cash flow**
  - Feasibility evaluation
- Reliability Assessment Segment

This section provides general information on each of these items. Specific instructions are given in Section 3. The Specification and Guidelines. Detailed background is presented in the Appendices.

DESCRIPTIVE SEGMENT

The Descriptive Segment provides briefs on these five pertinent items:

- Facility description
- Capacity rating
- Abstract of scope
- Performance specification
- Stage of development

COST ANALYSIS SEGMENT

Specified Factors

Certain key values must be specified; e.g., interest (discount) rate, facility life, depreciation period, time for construction, reference

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**Cash flow* (in italics) means net profit plus depreciation. See Section 6 (Glossary).

year for costs, reference unit for process costs, applicable cost indices, and inflation rates (if applicable). Aid for this purpose is provided by the Guidelines in Section 3.

Cost Estimate -- Capital Investment

Fixed capital is comprised of the funds required to design, build, and bring a facility to acceptable operation.

Specifically, fixed capital is comprised of expenditures for:

- Land.
- Buildings and equipment (physical plant).

In addition, the following may contribute to the fixed capital outlay:

- Spare parts and special tools.
- Interest during construction (allowance for funds during construction, AFDC).
- Cost of modification of the facilities and start-up of the operation.

In addition to fixed capital, a cash reserve, termed "working capital," is needed for day-to-day operation.

Estimation Methods for Buildings and Equipment --

The most critical category of fixed capital is "buildings and equipment;" it is the part of the cost estimate that takes by far the most effort. From the variety of bases available, the ones best suited to the task at hand should be exploited. The actual method used for costing the physical plant, together with the accuracy and availability of the necessary data, determines the level of reliability of the capital investment estimate.

The characteristics, purposes, and reliabilities of five basic types of plant cost estimates are listed in Table 1 and described in Figure 2. This procedure makes use of any one of the first four of these types of capital cost estimates; they are described below.

1. Order of Magnitude Estimates -- The rapid but very approximate Order of Magnitude methods are useful for a "ball park" figure early in the study; later they can provide a check on the results obtained from a more detailed method. Three of these rapid methods, outlined in Appendix A, are: average fixed capital per unit of annual capacity; scaling a known investment for a plant of different size; and turnover ratio (annual revenue divided by total plant investment).

TABLE 1. DEFINITION OF FIVE BASIC TYPES OF ESTIMATES OF TOTAL PLANT COST (adapted from (5))

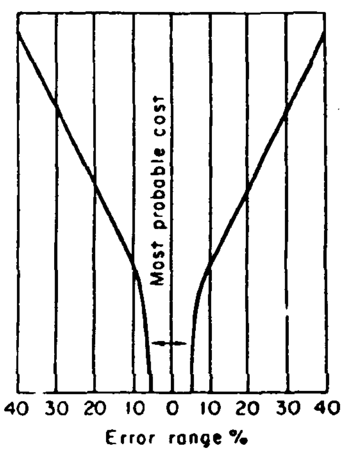
Type[a] (Each has several designations)	Characteristics	Purpose	Usual Reliability[b]
1. Order-of-magnitude[c] Ratio	Rapid. Very rough.	Preliminary indication. Check on result by more detailed method.	About + 30% -60%
2. Study[c] (commonly a so-called factored estimate)	Requires flow diagram, material and energy balance, type and size equipment.[d]	For generalized evaluations. Guidance for further investigation. Basis for process selection. R&D guidance.	± 30%
3. Preliminary[c] Budget Authorization	In addition to above, surveys and some engineering of foundations, transportation facilities, buildings, structures, lighting, etc.[d]	Basis for decision to undertake detailed engineering. Sometimes basis for budget authorization. Can be for generalized evaluation, but usually for site specific installation.	± 20%
4. Definitive Project Control	More detailed engineering, but usually short of complete specifications and working drawings.[d] Requires experienced estimating organization and substantial outlay.	Sometimes the basis for budget authorization. Provides improved estimate of project to be built. For site specific installations.	± 10%
5. Detailed Firm Contractor's	Complete site surveys, specifications, working drawings.[d]	Made to control cost of project being built. For site specific installations.	± 5%

[a]This is a representative and comprehensive list of the types of estimates for total plant cost. Other such lists differ in the number of estimate types and their descriptions.

[b]These apply for well established technologies. For newer technologies, the ranges may be wider, particularly for the first three types of estimates.

[c]The first three types of estimates are also termed "conceptual estimates."

[d]See Figure 2.



	Required information	Order-of-magnitude estimate >±30% range	Study estimate ±30% range	Budget authorization estimate ±20% range	Project control estimate ±10% range	Firm estimate ±5% range
Site	Location		●	●	●	●
	General description			●	●	●
	Soil bearing			●	●	●
	Location & dimensions R.R., roads, impounds, fences			●	●	●
	Well-developed site plot plan & topographical map				●	●
	Well-developed site facilities					●
Process flow sheet	Rough sketches		●			
	Preliminary			●		
	Engineered				●	●
Equipment list	Preliminary sizing & material specifications		●	●		
	Engineered specifications				●	●
	Vessel sheets				●	●
	General arrangement					
	(a) Preliminary			●	●	
	(b) Engineered					●
Building and structures	Approximate sizes & type of construction		●	●		
	Foundation sketches			●	●	
	Architectural & construction			●	●	●
	Preliminary structural design			●		
	General arrangements & elevations				●	●
	Detailed drawings					●
Utility requirements	Rough quantities (steam, water, electricity, etc)		●			
	Preliminary heat balance			●		
	Preliminary flow sheets			●		
	Engineered heat balance				●	●
	Engineered flow sheets				●	●
	Well-developed drawings					●
Piping	Preliminary flow sheet & specifications		●	●		
	Engineered flow sheets				●	●
	Piping layouts & schedules					●
Insulation	Rough specifications			●		
	Preliminary list of equipment & piping to be insulated				●	
	Insulation specifications & schedules				●	●
	Well-developed drawings or specifications					●
Instrumentation	Preliminary instrument list			●		
	Engineered list & flow sheet				●	●
	Well-developed drawings					●
Electrical	Preliminary motor list—approximate sizes		●	●		
	Engineered list & sizes				●	●
	Substations, number & sizes, specifications			●	●	●
	Distribution specifications					●
	Preliminary lighting specifications			●		
	Preliminary interlock, control, & instrument wiring specs.				●	
	Engineered single-line diagrams (power & light)				●	●
	Well-developed drawings					●
Man-hours	Engineering & drafting		●	●	●	●
	Labor by craft					●
	Supervision					●
Project scope standard processes	Product, capacity, location & site requirements. Utility & service requirements. Building & auxiliary requirements. Raw materials & finished product handling & storage requirements.	●				

Figure 2. Estimations guide for capital investment (6; p. 25 - 15).

2. Study Estimates -- For the purposes to be satisfied by the standard procedure, the study type is generally appropriate. These estimates follow a variety of schemes which depend on the form of the cost data and correlations; specific methods are identified with given technologies. For example: the chemical process industries make wide use of factored estimates; the unit process estimate is common for the treatment of liquid wastes.

The common factor methods are identified by the name of their innovators or protagonists; e.g., Lang, Chilton, Guthrie. These call for the purchased cost of the principal pieces of equipment (also called major plant items or MPIs). Sources of equipment cost information are given in Appendix A.

- In the Lang method, the total plant investment is found by multiplying the sum of the delivered MPIs by an appropriate single factor, which varies from about 3 to 5. This method should only be used for a rough check of the sum of the factors to be applied to the sum of the costs of MPIs.

- The Chilton scheme can be grasped from Table 2.

TABLE 2. ITEMS THAT COMPRISE TOTAL PLANT COST -- A TYPICAL LIST (Representative factors for the Chilton method (7) are also shown.)

Item No.	Item	Multiplying Factor	Operating on Item No.	Cost of Item
1.	Cost of delivered equipment (MPIs)	1.0	1	$
2.	Installed, erected equipment cost	1.60	1	
3.	Piping (includes insulation)	0.40	2	
4.	Instrumentation	0.15	2	
5.	Buildings and site development	0.20	2	
6.	Auxiliaries (electric, steam, etc.)	0.25	2	
7.	Other[a]	0.12	2	______
8.	Total physical cost (items 2 through 7), or direct cost			$
9.	Engineering and construction	0.35	8	
10.	Contingency and contractor's fee	0.15	8	______
11.	Total plant cost (items 8 through 10)			$

[a]Includes outside lines (process lines outside the battery limits), site development, etc.

- The Guthrie method applies factors for both (field) material and labor separately to individual MPI costs to identify the contribution of each to the Total Physical Cost. From this sum the Total Plant Cost is found by applying the factors for engineering and construction, contingency, and contractor's fee; these are the same as those used in the Chilton scheme (see Table 2).

Unit process estimates for capital costs sum the contribution of the capital cost for each of the process steps which together comprise the overall operation.

3. Preliminary Estimates -- This category requires the individual independent estimation of each item of physical cost, as listed in Table 2. The Total Plant Cost is then found from the Total Physical Cost by the procedure outlined for factored estimates.

A preliminary estimate is made either when a higher degree of accuracy is sought than attainable by the study type, or the cost data are not available in a form to permit a study type to be readily executed. It will be shown later, Table 12 in Section 3, that a preliminary estimate costs about 3 times as much as a study estimate.

4. Definitive Estimates -- This type calls for detailed information from an engineering design and is costly to prepare. Definitive estimates should not be made unless construction is contemplated or detailed engineering information is available.

Retrofit Versus New Plant --

Often the facility for pollution abatement will represent an add-on, or retrofit, to the basic plant. An example is the retrofit of a flue gas desulfurization process to an existing power plant. As a rule of thumb, retrofits cost 25 to 40 percent more than new construction; however, the variation can be greater. The range is due to factors such as the relative complexity of the system, plant layout, age of basic facilities, and unusual land or structural requirements.

Allowance for Funds During Construction --

For some pollution control facilities, the time from the beginning of the project until the start-up extends over several years. During this period, funds must be available to meet installments due the engineering-construction firms. Private sector companies often use surplus funds, but regulated industries and governmental bodies generally arrange for loans which are repaid when the project is "capitalized;" the interest paid on these loans represents the "interest during construction," or allowance for funds during construction (AFDC). The interest for such loans is usually the prime rate which has been 8 to 12 percent in recent years. See Appendix G. Rates of Return and Interest Rates.

Modification of Facilities and Start-Up --

Substantial outlays are sometimes required for equipment modifications and start-up, particularly for first-of-a-kind installations. Private sector firms generally expense start-up costs, others capitalize them. For estimating purposes, these range from 5 to 20 percent of the Total Plant Cost.

Land --

Land generally represents a small fraction of the investment and for a rough estimate can be taken as 3 percent of the Total Capital Investment. Often it is neglected or included in the contingency. However, when solids are to be disposed of, land requirements can be considerable; in such case the land needs must be carefully evaluated.

Working Capital --

Working capital may be defined as the funds necessary for the normal conduct of business. It can be roughly approximated by 10 to 15 percent of the fixed-capital investment or 15 to 35 percent of the annual revenue. For actual estimates, it is figured from the value of the raw material stocks, in-process inventory, product inventory, and credit extended to customers (accounts receivable). Sometimes a percentage (10-15 percent) of net annual expenses is added to cover current obligations.

Summary Remark-Total Capital Investment --

Several schedules prepared to facilitate the organization of specific kinds of capital cost estimates are presented in Section 3 under the Specification. Other schedules might be used.

Cost Estimate -- Annual Expenses

Net annual expenses are defined as all payments transferred (paid) to entities outside the operating organization. Total annual expenses include the above, plus depreciation for the year which is retained by the organization.

For certain industries or fields of technology (e.g., electric utilities and sewage plants), usually only the direct day-to-day costs of operation, designated as O&M for operating and maintenance costs, are taken into account for cost studies. Note that these O&M costs represent only a portion of the total annual expenses, which include labor additives, plant overhead, depreciation, and general expense.

For most study and preliminary estimates a reasonable basis is a level of operation of 80 to 100 percent of capacity.

Estimate of Annual Expense --

The annual expense consists of the sum of the operating and the general expenses; see Tables 3 and 4. There are two alternate sources of information on total annual expense (or at least the O&M portion): actual costs (suitably adapted) and factored estimates.

Adaptation of Actual Costs -- Records of actual costs of similar or identical operations offer the best basis for cost information where these are available. However, recourse to accounting records requires an understanding of the rationale for the allocation of indirect costs; e.g., labor additives, plant overhead, general expense.

Factored Expense Estimates -- Because of the frequent unavailability of actual operating cost records, or the difficulty of reworking them for estimates of annual expense, factored values are commonly used for indirect costs and some direct cost items.

Mass and energy balances are necessary to determine the quantities of raw materials and the utility duties. The total plant cost (I_F) provides a basis for the fixed charges. The fourth component needed is the direct (operating) labor, usually a rough estimate, from which the overhead items are generally factored. Thus, the total annual expenses are either direct or factored values from these four bases: raw materials, utilities, direct (operating) labor, and total plant cost (I_F).

A list of operating expense items is given in Table 3. Also shown are typical factors for their calculation from the four bases mentioned directly above. Table 4 tabulates the general expense items with typical factors for their estimation.

Use of Only O&M Expenses --

The use of direct expenses, or O&M, is common in studies comparing processes or assessing the financial burden of pollution control in connection with compliance actions. Here one should be careful to include all costs that change in going from one alternative to another; note that often these include overhead items.

Cost Estimate -- Net Profit and *Cash Flow*

Net profit is calculated if there is revenue associated with the operation. In any case, *cash flow* is needed; it represents the benefit to the operating entity or portion thereof. It is comprised of the depreciation plus net profit or net saving.

For comparison of alternate operations where revenue is unaffected, the *cash flow* is equivalent to the depreciation minus the extra net operating expense corrected for the effect of income taxes. Appendix C should be consulted for a development of the *cash flow* concept which applies here.

TABLE 3. ANNUAL OPERATING EXPENSE ITEMS AND INFORMATION FOR THEIR ESTIMATION

Raw Materials	Consult current issue of Chemical Marketing Reporter (8) for rough estimate; secure quotes or consult commodity experts for lower contract prices.
Operating (Direct) Labor	The number of full-time operating personnel times average earnings of $12-15,000/year[a] (includes shift differential and overtime).
Direct Supervision	10 to 25% of earnings of operating labor. Annual earnings of supervisors, $18-24,000/yr.[a]
Maintenance	4 to 10% of total plant cost, I_F (supervision of maintenance is included in plant overhead).
Operating Supplies	6% of earnings of operating labor or 15% of maintenance expenses.
Labor Additives (fringe benefits)	25 to 50% of operating labor earnings; may also include maintenance labor earnings.
Utilities	Develop directly from energy balances plus an allowance for losses.
Plant Overhead	50 to 100% of direct operating and maintenance labor earnings, or 50% of direct operating and 25% of maintenance labor earnings, or 45-50% of operating labor earnings plus 1 to 5% of total plant cost, I_F.
Control Laboratory	$40,000 to $50,000 per analyst,[a] or 10 to 20% of operating labor earnings.
Technical and Engineering	$40,000 to $50,000 per man;[a] may be included in plant overhead.
Insurance and Property Taxes	1 to 2% of I_F.
Depreciation	Varies but common rate is 10% of I_F or total depreciable investment for 10 years.

[a]1977 rates.

NOTE: See Appendix B for sources for the numerical values.

TABLE 4. ANNUAL GENERAL EXPENSE ITEMS AND FACTORS FOR THEIR ESTIMATION

Administration	- 2 to 3% of sales or capital investment.
Sales	- usually 2 to 6% of sales; but up to 30% for specialty items.
Research	- 2 to 5% of sales or capital investment.
Finance	- largely interest on bonds; often not considered in conceptual estimates.

NOTE: See Appendix B for sources for the factors.

Feasibility Evaluation

Expected values of both the capital investment and the annual expenses are necessary to judge the economic feasibility of a project. For a fair comparison between possible alternatives, the investment and at least the affected portion of the annual expenses (such as O&M) must be estimated. These cost data, plus the revenues (if expected), are used to calculate several measures of merit which represent the criteria for assessing economic feasibility.

For the calculation of several measures of merit, an understanding of the *cash flow* concept is required; viz., that the benefit (or burden) to the operating entity or portion thereof is the depreciation plus net profit (or minus net operating expense corrected for income taxes). (See Appendix C.)

Measures of Merit --

Several feasibility criteria are defined below. Details can be found in Appendix E.

Return on Investment -- Annual net profit divided by total capital investment (including land and working capital) gives return on original investment (ROI). This has been a widely used criterion for profitability.

Internal Rate of Return -- Internal rate of return (IROR; also known as Interest Rate of Return, Discounted Cash Flow Rate of Return, and Profitability Index) is a standard criterion. It is the discount rate which gives a value of zero for the sum of the present values of the *cash flow*, capital outlays, and end-of-life recoveries, occurring during the project lifetime. The procedure takes into account the timing of these cash effects and whether they are continuous over a period of time or are discrete (instantaneous) transactions. The calculation of IROR is by trial and error.

Payout Time -- Payout time is frequently mentioned, but actually is only of secondary importance. This criterion is the time in years required, after start of operations, for the accumulation of *cash flow* over those years to equal the depreciable investment.

Equivalent Annual Costs -- These cost procedures make possible life-cycle cost analyses. They can be obtained by calculation, first of the present value of the cash flows of concern* through use of an assigned discount rate. Then the present value is converted (at the same discount rate) to an equivalent annual cash flow or cost over the life of the project. It can be expressed either as a uniform end-of-year amount or as a continuous rate of flow throughout each year.

Unit Costs -- These refer to capital investment, operating expense (total, or only O&M), revenue requirement, or total resource costs per unit of product or service; e.g., for pollution abatement. The revenue or resource requirement per unit of product or service is usually discounted to time zero. For this calculation the units of output (production or service) can also be discounted; in addition, the relative value of the output may be escalated as for costs. Since several possibilities exist, the basis needs to be clearly defined; this matter is treated in detail in Appendix E.

The total resource costs per unit of product or service corresponding to the treating cost per 1,000 gallons (3.8 cu. meters) of liquid waste are used for cost-effectiveness analysis in connection with the EPA construction grants program.

It is to be recognized that unit costs are often based on design capacity. Since facilities generally operate at less than capacity, and the throughput or output may vary with time, these variations may be taken into account.

Characteristics of Specific Measures of Merit --

The internal-rate-of-return method, the equivalent annual cost methods, and usually unit costs (levelized costs) take the time value of money (interest) into account, whereas return on original investment and payout time do not. Accordingly, the former methods are preferred; in fact, one of these is considered essential for determination of economic feasibility. For private sector studies ROI and payout are calculated if possible because of their familiarity, ease of determination, and value as checks.

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*The cash flows of concern depend on the nature of the equivalent annual cost to be calculated which, in turn, is governed by the applicable sector (private, regulated, or public).

If the project under consideration has no revenue or profit associated with it (such as a retrofit, pollution control project), IROR, ROI, and payout can be applied to show the effect of the proposed project on the associated or parent operation. However, a comparison of alternative control processes, without bringing in the unaffected cash flows of the parent plant, is possible with the equivalent annual cost approach. Then the comparison of the alternatives proves to be more striking.

Choice of Specific Measures of Merit --

The specific measures of merit used in a cost analysis are by custom governed by the financial sector: privately financed, regulated, or publicly funded. Privately financed projects with revenue use IROR, with ROI and payout as complements because of their simplicity and familiarity. Equivalent annual cost is used to compare retrofits or add-ons. For public utility (regulated) financed facilities, either equivalent annual (annualized) cost or unit (levelized) costs are computed to give the revenue requirement. Publicly financed projects use either a version of levelized cost called "equivalent annual value," or a unit cost termed "total resource cost per unit of service."

Computation Features --

Selection must be made from these features in computing the measures of merit:

Discounting -- generally applied.

Revenue requirement -- needed in some form for private and regulated.

Investment recovery -- by depreciation charges and end-of-project recoveries.

Accounting for inflation -- not used for public projects; not always advantageous for other sector evaluations.

Annual expenses -- use total annual expenses where revenue is involved; otherwise, O&M may be used.

Interest (discount) factors -- can use discrete or continuous interest factors.

Modes of Cost Analysis --

From custom, different modes of cost analysis have become associated with each of the financial sectors. These are presented in Appendix E and illustrated by examples in Appendices E, J, and K. Each mode generally follows the common principles of evaluation as set forth in engineering economy and financial analysis texts.

Summary Comments

The initiator and the estimator need to judge the degree of detail to be incorporated into the cost analysis. Costs based on a raw concept and a rough process design hardly justify the preparation of a painstaking schedule for cash flows which take into account the fluctuations of capacity and the conjectured effects of inflation. For most study or preliminary estimates then-current dollars should be used, but the reference year needs to be specified, such as the scheduled time of plant start-up. It should be realized that many recent generalized cost studies related to energy and pollution control have used mid-1975 as the reference year.

RELIABILITY ASSESSMENT SEGMENT

Unfortunately many managers and engineers accept a cost estimate as being almost exact regardless of the background for the computation. Accordingly for each cost analysis the audience should be both warned that the estimate is only approximate and informed of the level of accuracy that the background data and costing technique can support.

Factors Affecting Accuracy

Although desirable, it is difficult to establish the accuracy of a cost estimate. This exercise should take into account factors such as the stage of development, the definition of scope, the availability and quality of cost and technical data, and the expertise of the estimator. In addition, there are uncertainties about future events such as business climate, weather conditions, and the capability of the organization used to construct the plant. Each of these items may significantly affect the actual costs.

Accuracy from Available Correlations --

In Table 1 in Section 2, the range of reliability for the capital investment of the plant is exhibited as a function of only one of the above factors, namely, the extent of the engineering or the completeness of the design. Information concerning the effect of other factors on the accuracy of capital investment, such as stage of development and definition of scope, is lacking. Also, there are no guides to the reliability of annual expense items. Little information in a correlated form is available for reliability analyses.

Procedures for Assessing Reliability of a Feasibility Measure --

An indication of the accuracy of a feasibility measure, such as ROI, must take into account the possible range of values of the dominant cash flows (e.g., revenue, total annual expense) as well as capital investment and factors such as plant life, income tax rate, and rate of inflation.

Sensitivity analysis demonstrates the effect on a measure of merit of varying, one at a time, the major cash flows within expected limits. Several cash flows can be scrutinized in this fashion. See Appendix I. Of particular interest is the probability of having a combination of values that would lead, say, to an unacceptably high value of annualized cost, or to a low value of ROI. Such situations can be analyzed for in a statistically sounder manner by means of an uncertainty analysis.

The following two modes are suggested:

- Opinion based on experience and correlations.
- Uncertainty analysis by statistical methods.

Most cost analyses are presented using the "best-guess" or most likely values along with qualifying remarks. The first mode above requires that the estimator put his opinion on the line; an orderly basis for this, at least as it applies to the capital cost of the plant, is delineated in Appendix H. The statistical approaches require a notion of the expected ranges of the major cash flows and factors. In addition the uncertainty analysis generally calls for a program and a computer. Disadvantages of the latter method are that the results are presented in an unfamiliar form (cumulative frequency distribution) and in terms (standard deviation, variance) with which users may not be conversant.

SECTION 3

THE SPECIFICATION AND GUIDELINES

The format that has been devised to present the complete cost analysis is called "the specification." Guidelines are presented to facilitate the choice of various procedures open to the estimator and to establish factors to be used in executing the analysis.

Examples of complete specifications and guidelines are given in Appendices J and K.

THE SPECIFICATION

The specification consists of three segments: descriptive, cost analysis, and reliability assessment.

Descriptive Segment

The descriptive segment should be given in a page and conform to the format of Table 5. Instructions for its preparation are given directly below.

Elements of Descriptive Segment --

The five elements in Table 5 that describe the project under scrutiny are discussed below.

Facility Description -- A few key words should identify the process to be carried out and state the nominal capacity or size of the facility. A schematic flow diagram and process description should be appended or referred to. The plant location needs to be stated (this can be a geographical region). Area construction labor costs should be identified. Construction time should be established.

Capacity Rating -- Besides the capacity of the primary facility, information regarding the rate of pollutant flow and removal (or similar information) is germane. This is illustrated in Appendix J.

Abstract of Scope -- A statement of scope is frequently detailed and lengthy; accordingly an abstract of the scope should be used which conveys the degree to which particulars have been worked out as well as the extent of the subsidiary facilities required. Table 6 demonstrates

TABLE 5. SUMMARY OF ECONOMIC EVALUATION
-- DESCRIPTIVE SEGMENT

FACILITY DESCRIPTION
CAPACITY RATING
ABSTRACT OF SCOPE
PERFORMANCE SPECIFICATION
STAGE OF DEVELOPMENT

TABLE 6. AN ILLUSTRATION OF THE EFFECT OF SCOPE ON FIXED CAPITAL INVESTMENT (Adapted from (9))

Capital Investment	Investment $/kW
Base Investment	
Limestone slurry process (including fly ash removal, but not disposal) - 500-MW new, coal fired (coal: 3.5% S, 12% ash), 90% SO_2 removal, 30 year life, 127,500 hours operation, on-site solids disposal, proven system, only pumps spared, no bypass ducts, experienced design and construction team, no overtime, 3-year design - construction program, 5% per year escalation, cost basis - mid-1974	
TOTAL for base investment	50.30
Add-ons	
Overtime for 50% of labor requirements	3.20
R&D costs for first-of-a-kind technology	5.00
Capital for power generation for lost capacity (one way of handling this item)	4.50
For reliability, redundant scrubbers, and other equipment; also ducts, dampers, instrumentation for changeover, if required	6.00
Additional bypass ducts and dampers	2.00
Retrofit difficulty	10.00
Fly ash pond; module closed-loop provisions	5.50
500 foot (152 meter) stack	6.00
Air quality monitoring system	0.70
Cost escalation of 10%/year instead of 5%/year	4.80
Possible delay of 2 years because of slow material deliveries	15.00
TOTAL of add-ons	62.70
TOTAL PLANT INVESTMENT, INCLUDING ADD-ONS	113.00

the importance of a defining scope; here the investment, including the add-ons, is more than double the value of the base investment.

Performance Specification -- The types and quantities of pollutants being removed should be identified; the desired concentrations of pollutants in the effluent should be stated. The regulation which governs the pollution control should be noted.

Stage of Development -- An essential part of a cost estimate is the qualification on the stage of development. If there are critical data gaps, if some of the information is poorly understood, or if the basis is a raw concept for which the process is only sketchily established, the reader will automatically be conditioned to expect an uncertain cost estimate. By the same token, a process backed by experience or pilot studies should provide a basis for a reliable cost estimate.

Cost Analysis Segment

This is made up of the specified parameters, the cost estimate, and the feasibility evaluation. The cost evaluation segment, with its several elements, should be condensed into four or five pages; it generally follows the schedule given in Table 7. Several optional forms for capital cost estimation are displayed. The cost evaluation segment is concluded by a statement that characterizes the economic feasibility.

Specified Parameters --

Values for the following parameters must be postulated and entered in the appropriate space near the top of Table 7.

Interest (Discount) Rate -- The value used can vary widely depending mainly on the variation of the prime lending rate and the financial expectations in the industry of application. The subject is reviewed in Appendix G. For an organization existing for profit, this rate is generally higher than the commercial lending or debt rate. Figures of 10 and 15% are common. For a regulated industry, rates near 10% prevail at present. For the electric utility example in Appendix E it is about 10%. This interest rate is not the same as that used for interest on construction which corresponds to the commercial lending or debt rate and therefore would be less.

Facility Life and Depreciation Period -- The plant life covers the period from start-up until the facility is shut down and dismantled. The depreciation life is usually less and for estimating purposes is generally determined from IRS guidelines; e.g., for a steam-power plant, plant life may be 30 years, and depreciation life, 22 years. The second example in Appendix E illustrates this. Ordinarily, the straight-line method is used.

Construction Time -- This varies with the size and complexity of the project; e.g., construction of a small chemical plant or a retrofit pollution control facility might extend over 2 years, but a large

TABLE 7. SUMMARY OF ECONOMIC EVALUATION
-- COST ANALYSIS SEGMENT

FACILITY DESCRIPTION Plant Location --	CAPACITY RATING

DISCOUNT RATE ___%; FACILITY LIFE ___ YRS; DEPRECIATION PERIOD ___ YRS;

CONSTRUCTION TIME _____; REFERENCE UNIT FOR PROCESS COST _____;

REF. YR FOR COSTS ____; COST INDEX ____; INFLAT'N RATE (if appl.) ____.

CAPITAL INVESTMENT ESTIMATION (see Appendix A for detailed information)

Schedules A to G are used for Total plant cost; schedule H is for Total capital investment. See Table 8 for guidance.

Schedule A. Chilton method. Factored costs of sum of major plant items (MPIs), ΣE, delivered. Corresponds somewhat to Table 2.

Item	Factor	Operating On	Cost of Item
1. Sum of major plant items (MPIs), ΣE, delivered[a]	--	--	
2. Installed, erected equipment cost		#1	
3. Piping (includes insulation)		#2	
4. Instrumentation		#2	
5. Buildings and site development		#2	
6. Auxiliaries (electric, steam, etc.)		#2	
7. Other		#2	
11. Total physical cost (Direct cost), DC (sum of 2 to 7)			

Use Schedule C to get the Total plant cost, item 31.

[a]Same as FOB job site.

Table 7 (Continued). Summary of Economic Evaluation -- Cost Analysis Segment

Schedule B. Guthrie method. Sum of each MPI (this includes adjuncts, such as solids handling facilities, site development, industrial buildings, off-site facilities).

1. MPIs, purchased[a] ΣE
2. Direct (field) material, m
3. Direct (field) labor, L

    11. Sum of direct costs, (Total physical cost) DC, for each MPI and adjunct

Use Schedule C to get Total plant cost, item 31.

Schedule C. Calculation of total plant cost using direct cost from schedule A or B

11. Total physical cost (Direct cost) DC
12. Indirect cost (20 to 50% of DC, avg 34%), IC

    21. Total bare module cost, BMC

22. Contingency (10 to 50% of BMC; avg 15%)
23. Contractor's fee (about 3% of BMC)

    31. Total plant cost (Total module cost), I_F

Schedule D. Lang method

Use equation: $I_F = \Sigma E \times L$

where: I_F = total plant cost (total module cost; fixed capital investment for equipment, buildings, site development);
ΣE = the same as item 1 in schedule A;
L = Lang factor. See Appendix A.

[a]Same as FOB; i.e., free on board, at vendor's plant.

Table 7 (Continued). Summary of Economic Evaluation -- Cost Analysis Segment

Schedule E. ICARUS method

8. Sum of installed costs for MPIs - includes indirect costs associated with each item
9. Total of special items which correspond to adjuncts under schedule B

    21. Base plant cost (Total bare module cost), BMC

22. Contingency (see schedule C)
23. Contractor's fee (see schedule C)
27. Retrofit increment (if applicable)

    31. Total plant cost, I_F

Schedule F. Sum of unit process modules

Process module identification	Total Cost
1. Process module No. I -	
2. Process module No. II -	
3. Process module No. III -	
4. Process module No. IV -	
5. Process module No. V -	
6. Process module No. VI -	
etc. -	
31. Total plant cost, I_F	

Schedule G. Total plant cost from typical definitive estimates

	Process Modules			
	I	II	III	etc.
1. Equipment cost, purchased ΣE				
2. Direct (field) materials, m				
Piping				
Concrete				
Steel				
Instrumentation				
Electrical				
Insulation				
Paint				
Total ΣE + m for each module				

Table 7 (Continued). Summary of Economic Evaluation -- Cost Analysis Segment

3. Direct (field) labor, L
4. Adjunct facilities, etc.

    11. Direct cost (Total physical cost), $(\Sigma E+m) + L$, for all process modules and adjunct facilities

12. Indirect cost
    Freight, insurance, sales tax, etc.
    Construction overhead
    Engineering, etc.

    21. Base plant cost (Total bare module cost), BMC

22. Contingency
23. Contractor's fee

    31. Total plant cost (Total module cost), I_F

NOTE: From data for schedules F and G, representative Guthrie factors can usually be calculated.

Schedule H. Total capital investment

31. Total plant cost, I_F, from schedule C, D, E, F, or G
32. Interest during construction, if applicable, and capitalized
33. Modification of the facilities and start-up costs, if capitalized

    35. Total depreciable investment

36. Land
37. Working capital

    41. Total capital investment

Table 7 (Continued). Summary of Economic Evaluation -- Cost Analysis Segment

ANNUAL OPERATING EXPENSE SUMMARY
(From the subtotals in Table 9. Annual Operating Expense Estimate and Table 10. General Expense Estimate.)

53. Raw materials
70. Processing
74. Plant overhead, control lab and technical
76, 77. Fixed charges less depreciation
78. Depreciation
87. General expense

90. Total operating costs ______

PROFIT AND *CASH FLOW* (ANNUAL) SUMMARY

91. Revenue including value of byproducts ______
92. Gross profit[a] (Revenue - annual operating expense) ______
93. Net profit[a] (Gross profit - income tax) ______
94. *Cash Flow*,[b] (Net profit + depreciation) or (Depreciation - net operating expense corrected for income tax) ______

FEASIBILITY EVALUATION SUMMARY

Privately Financed Mode

101. ROI ______%
102. Payout time ______%
103. IROR ______%
104. Revenue requirement given IROR = _____% $______
105. Equiv. annual cost; this is Uniform annual cost for privately financed projects; see Eq. E-8 $______/yr

---

[a]Applies only to facilities that produce independent revenue.

[b]Applies both to plants which produce independent revenue, such as a power plant or smelter, and to modifications in facilities such as the addition of pollution control equipment which involves no or only incremental changes in revenue. Consult Appendix C for a development of this matter.

Table 7 (Continued). Summary of Economic Evaluation -- Cost Analysis Segment

Public Utility (Regulated) Financed Mode	
106. Equiv. annual cost; this is annualized cost for regulated mode projects; see Eq. E-1, E-2	$_____/yr
107. Revenue requirement/unit of output -- using lifetime average costs (Eq. E-4)	$_____/unit output
108. Revenue requirement/unit of output -- by levelized costs using typical utility approach (Eq. E-5)	$_____/unit output
109. Revenue requirement/unit of output -- by levelized costs using METREK approach (Eq. E-6)	$_____/unit output
Publicly Financed Mode	
110. Equiv. annual cost; this is equivalent annual value for government projects; see Eq. E-3	$_____/unit output
111. Total resource costs/unit of service	$_____/unit output
General	
112. Total capital cost/unit of capacity	
113. Operating expense/unit of output	

Descriptive appraisal of the financial merit of the venture:

TABLE 8. CAPITAL COST ESTIMATING ALTERNATIVES FROM TABLE 7
(Letters A to H refer to Schedules in Table 7)

Cost Items	Start at Top						
Direct Cost	A Chilton[a]	B Guthrie[a]	D Lang[a]	E ICARUS[a]	F Unit Process[a]	G Defin- itive[a]	Other Methods
+	↓	↓					
Indirects Contingency Fee	C	C					
+	↓	↓	↓	↓	↓	↓	
Construction Interest Modification and Start-up Expense Land Working Capital	H (gives total capital investment)						
=							
Total Capital Investment							

[a]Identifies method of estimating total plant cost (I_F).

TABLE 9. ANNUAL OPERATING EXPENSE ESTIMATE

Name of Process

(Brief Description of Process and Product (if any) and Pertinent Information on Size. Put added details in footnotes.)

Basic Unit of Capacity or Production _____. Total Plant Cost, I_F ____.
Depreciable Investment _________. Stream time _______ hr/yr.

	Unit	Units /Year	Value $/Unit	Units/Basic Unit of Production	Total Costs $/Basic Unit	Total Costs M$/yr
51. Raw Materials						
52. By-Product Credit:						
53. Subtotal Raw Materials						
56. Operating (Direct) Labor	hr					
57. Direct Supervision						
58. Maintenance Labor	hr					
59. Maintenance Material						
60. Operating Supplies						
61. Labor Additives						
62. Steam	10^3 lb[a]					
63. Electricity	kWhr					
64. Compressed Air	10^3 cf[b]					
65. Water	10^3 gal[c]					
66. Fuel	10^6 Btu[d]					
67. Effluent Treatment & Disposal						
68. Preparation for Shipping						
69. Other						
70. Subtotal Processing						

[a]Multiply 10^3 lb by 454 to convert values to kg.

[b]Multiply 10^3 cf by 28.32 to convert values to m^3.

[c]Multiply 10^3 gal by 3.785 to convert values to m^3.

[d]Multiply 10^6 Btu by 1.055×10^6 to convert values to kJ.

Table 9 (Continued). Annual Operating Expense Estimate

71. Plant Overhead
72. Control Laboratory
73. Technical and Engineering
    74. Subtotal Overhead

76. Insurance & Property Taxes
77. Royalty
78. Depreciation
    79. Subtotal Fixed Charges

80. Total Manufacturing Cost

Adapted from Perry and Chilton (6, p. 25-28)

TABLE 10. GENERAL EXPENSE ESTIMATE

35. Depreciable Investment ________
41. Total Capital Investment ______
91. Sales Revenue ________________

81. Administration, % of Capital Investment or Sales	K$________
82. Selling Expense, % of Sales- - - - - - - - - - -	________
83. Corporate Research, % of Capital Investment or Sales- -	________
84. Interest on Debt - - - - - - - - - - - - - - - - -	________
85. Other- -	________
87. General Expense- - - - - - - - - - - - - - - - -	K$________

petroleum refinery complex might require 4 years. Where special regulations apply and official approvals must be secured, the construction time might be of even longer duration; e.g., nuclear power plants for which 7 or more years is not unusual.

Reference Unit for Process Cost -- For characterization and ready comparison, costs should be reduced to a basis typical for the technology. Examples are cents/kWhr for a power plant, \$/1000 gal. (13.8 cu. meters) of feed for a waste treatment plant, and \$/million Btu (1.055×10^6 joules) for a coal cleaning plant.

Reference Year for Costs -- This is generally taken as the year that the facility started up, which usually corresponds to the year that construction was completed.

Cost Index -- The selection of the index to be used to correct costs from previous time to the reference year may either be specified by the requestor or decided by the estimator. In either case, it should be one that is in common use and appropriate to the technology. The various cost indices are listed in Appendix F.

Inflation Rate -- This item is to be provided only if inflation is to be accounted for in the cost analysis. Projected values for inflation vary depending on the source. Also, for a given operating entity (e.g., fuel oil), a different rate may be conjectured than for general inflation, which is considered to correspond with the cost index for the Gross National Product. Costs which take into account inflation are corrected to constant worth dollars evaluated at the reference time, usually the start-up of the facility.

Cost Estimate --

This represents the major portion of Table 7 and includes: (1) capital investment, (2) annual expenses, and (3) profit and *cash flow*. Alternative schemes are given for the determination of the capital investment.

Capital Investment -- The entries should be tabulated if at all possible according to the sample schedules in Table 7. Schedules A to G are for Total plant cost; Total capital investment is found by the use of Schedule H. A guide for the proper combination of the several schedules to use for a given capital cost estimating alternative is delineated in Table 8. If unique data sources or special circumstances obviate the exploitation of any of the schemes embraced by Table 7, a custom tabulation can be designed; however, it is suggested that the schedules in Table 7 be used as a model insofar as they apply.

A numbering system has been devised to keep track of the several entries of the cost estimate. The significance of the numbers used for capital cost items in Table 7 is explained below.

- 1, 2, 3, ... identify direct cost items.
- 11 is always for Total Physical Cost.
- 12, 13, ... indicate indirect cost elements.
- 21 is always for the Total Bare Module Cost (Base Plant Cost).
- 22 is always for the Contingency.
- 23 is always for the Contractor's Fee.
- 27 is always the Retrofit Increment, if applicable.
- 31 is always for the Total Plant Cost (Guthrie uses Total Module Cost).
- 32, 33, ... apply to capital cost items other than those related to the Total Plant Cost; e.g., land (always number 36), and working capital (always number 37).
- 35 identifies the Total Depreciable Investment.
- 41 is always the Total Capital Investment.

For any estimate, the identifying numbers will not be consecutive.

Annual Expenses -- The tabulation in Table 7 entitled Annual Operating Expense Summary is made up of subtotals from Table 9. Annual Operating Expense Estimate, and the total from Table 10. General Expense Estimate. The composition of these tables has been reviewed in Section 2, particularly under Tables 3 and 4. The basis for the numbering system used in Tables 9 and 10 should be readily apparent.

Profit and Cash Flow -- This is also tabulated in Table 7. The only new item is "revenue" which applies for profit generating projects. The values generated are used in the feasibility evaluation discussed directly below.

Feasibility Evaluation --

The measures of merit tabulated in Table 7 under Feasibility Evaluation Summary are computed from cost and other data listed above and from relations described in Section 2, and explained in detail in Appendix E. Note that the summary in Table 7 provides for a descriptive appraisal of the financial merit of the venture.

Reliability Assessment Segment

A sensitivity and/or an uncertainty analysis can be required. At least an opinion of the reliability of the estimate is demanded based on experience and existing correlations. The results for a sensitivity study can be illustrated graphically or tabularly. The uncertainty investigation is generally prescribed in graphical form using a cumulative frequency distribution for the measure of merit. The form to be used is open. For some examples see Appendices H, I, J, and K.

GUIDELINES

Guidelines help decide among the available approaches and thereby serve to establish the level of effort appropriate for the project at hand. Also they facilitate the selection of values for the financial and operating factors needed in the analysis; e.g., discount rates. Table 11 lists the guideline information which must be provided and aids in its determination. Additional comment is offered below for certain items.

Capital Investment Estimate

The type of capital investment estimate (see Table 1) essentially determines the level of effort for the entire cost analysis. The two major concerns are: (a) that the detail requested is consistent with the technical information (e.g., an expensive definitive estimate would be wasteful for a conceptual process); and (b) that the cost analysis can be executed within the budget. Table 12 provides guidance for the cost of the capital cost estimate.

Many schemes have been evolved for finding physical plant cost. Their form varies with different technologies. The method to be used should be appropriate for the project, namely that for which the best information is available. For chemical and petroleum processes the factored estimate, with refinements, is in wide use. Also, for some chemical operations and liquid waste treatment plants, the unit process method is well established. The various schemes available are explored in Appendix A.

Estimation methods for the other portions of the capital investment are straightforward. These include interest on construction costs (if money is borrowed), start-up costs (these can also be charged as annual expenses), land, and working capital.

Annual Expense Estimate

The total annual expense is comprised of the operating costs plus the general expense. For the comparison of different processes, often only the annual operating and maintenance (O&M) expenditures are considered. This is the practice for some technologies such as the treatment of liquid wastes (government sector) and electric power generation (regulated sector). Here the O&M is considered to represent the portion of the annual expenses that varies from one process to another or with different levels of operation. Actually this is not always the case; usually some overhead items vary with the specific process or the level of production.

TABLE 11. INFORMATION TO BE PROVIDED BY GUIDELINES

DESCRIPTIVE SEGMENT	
Facility Description	
Plant Location	This is usually a geographical region (not site-specific); e.g., Gulf Coast, St. Louis area.
Index for area construction labor costs	There are a number of indices for this purpose, but most are proprietary. For assistance consult the paragraph on construction labor efficiency in Appendix A.
Capacity Rating	Known.
Abstract of Scope	Several factors should be stipulated that affect the scope: terrain, soil conditions, extent of spares, retrofit or not, elaborateness of facility.
Performance Specs.	Specify the regulation which governs pollution control or otherwise qualify the expected performance.
Stage of Development	Known.
COST EVALUATION SEGMENT	
Specified Parameters	
Interest (Discount) Rate	This represents the return to be expected from the investment; it is also termed the cost of capital, or the discount rate. Usually 10 to 15% is used. Consult Appendix G.
Facility Life and Depreciation Period	Generally these two time intervals are taken as the same. For first cut, 10 years is used. Where refinement is called for, either experience or IRS Publication 534 (10) is used. Sometimes, as for electric utilities, the facility life is taken as somewhat longer than the depreciation period; e.g., the utility example in Appendix E.
Construction Time	State or, if to be developed, so note.

Table 11 (Continued). Information To Be Provided by Guidelines

Reference Year for Costs	This is generally taken as scheduled start-up time which generally corresponds with completion of construction. Consider that many recent generalized cost studies related to energy and pollution control use mid-1975 as the reference time.
Reference Unit for Process Cost	These are basic units typical for the technology.
Cost Index	This should be a commonly used index; it can be specified or decided by estimator. See Appendix F.
Inflation Rate	If inflation is to be taken into account, its expected rate needs to be stated. Sometimes more than one rate is postulated; e.g., general inflation and specific escalation of certain cost components. See Appendix F.
Cost Estimate - Capital Investment	
Types of Capital Investment Estimates (more than one may be specified)	Specify whether established scheme is called for or if another basis may be used. The established schemes are favored and their order of preference, presuming that data are available, ordinarily is: Study type - Guthrie ICARUS Unit process Chilton Preliminary - Only if above do not apply or greater accuracy is needed. Preliminary estimates can cost about 3 times as much as a study type. Definitive - Ordinarily only if detailed engineering has been done and can be used. Definitive estimates cost about 5 times as much as the study type. Study Type - Lang; only to check factors. Order-of-Magnitude - Only for preliminary "ball-park" value and/or as a check. NOTE: The type of the capital cost estimate as indicated in Table 12 determines largely the cost of the total economic study.

Table 11 (Continued). Information To Be Provided by Guidelines

Allowance for Funds During Construction	Specify the interest rate. It may be less than the interest (discount) rate specified above for return on the investment. Regulated industries and government bodies generally capitalize the interest paid on funds for construction, private sector firms tend to expense using funds generated from current operations (depreciation plus retained profits).
Modification of Facilities and Start-up	Private sector firms tend to expense; regulated industries and government bodies will capitalize as a rule.
Cost Estimate - Operating Expense	
Total Operating Expenses vs. Only O&M	Total annual operating expenses should be determined except when alternative projects are to be compared, in which case only O&M expenses may be used.
Stream Time	It can vary over the life of the facility; e.g., as in the utility example in Appendix E. Also time must be allowed for periodic maintenance and overhaul of facility. Expressed as hr/yr or percentage level of operation.
Pre-production Expenses	Note if pre-production expenses are to be included.
Direct (Operating) Labor Rate	The direct labor rate varies with the regional location within the U.S. See Appendix B.
Depreciation	For private and regulated sector only. Generally use straight-line method.
Cost Estimate - Profit and Cash Flow	
	If facility generates profit or revenue (as from byproduct), provide details to compute the net benefits; viz., savings or profits. State applicable income tax rate.
Feasibility Evaluation	
Modes of Cost Analysis	State whether privately financed, public utility (regulated), or publicly funded mode is to be followed.

Table 11 (Continued). Information To Be Provided by Guidelines

Measure of Merit	For private sector, if revenue is generated specify IROR and also ROI and Payout. If the choice is between alternatives that do not yield profit, use uniform annual cost. For utility (regulated industry) financing, use annualized cost for revenue requirement or levelized cost; for the latter specify if typical utility or METREK approach is to be followed. For public funded works use version of equivalent annual cost termed "equivalent annual value" or "total resource cost/unit of service."
Computation Features	These features must be established; the financial sector largely determines the choice as illustrated by the schedule below.

	Private	Regulated	Public
Discounting	Yes except for ROI and payout	Preferred	Always
Revenue	Yes except for choice between alternatives	Yes; need cost of capital	No
Investment Recovery	Yes[a]	Yes[a]	No
Accounting for Inflat.	Optional	Preferred	No
Annual Exp.	All when there is revenue; otherwise O&M	Total	O&M
Interest	Trend is to continuous	Discrete	Discrete

[a]Investment recovery is generally by straight-line depreciation. However, accelerated depreciation methods or a combination can be used, as in the second public utility example in Appendix E: straight-line depreciation is used for capital recovery (paid to investors) and sum-of-the-digits depreciation is used for income-tax computation.

Table 11 (Continued). Information To Be Provided by Guidelines

RELIABILITY ASSESSMENT SEGMENT	
Sensitivity Analysis	The factors considered to vary enough to affect markedly the measure of merit should be identified. Also the form described for depicting the sensitivity analysis (e.g., Strauss chart) should be specified.
Uncertainty Analysis	The mode should be identified: opinion or statistical; e.g., Monte Carlo technique. If a method such as the Monte Carlo is specified, information concerning the ranges of the critical variable and the kinds of probability distributions is required.

TABLE 12. TYPICAL COST RANGES FOR PRODUCING CAPITAL COST ESTIMATES[a]

Type of Estimate	Total Plant Cost, I_F		
	Less than $2 million	$2 million to $10 million	$10 million to $100 million
Order-of-Magnitude	$ 2,000 - 10,000	$ 5,000 - 20,000	$ 8,000 - 25,000
Study	$ 4,000 - 12,000	$10,000 - 24,000	$16,000 - 32,000
Preliminary	$12,000 - 30,000	$24,000 - 50,000	$40,000 - 80,000
Definitive	$20,000 - 50,000	$ 50,000 - 100,000	$ 90,000 - 200,000

[a]The figures, based on a schedule in Bauman (11) are intended only as a rough guide. The range of activities covered by these costs can be considerable; depending on the type of estimate, it can include engineering, drafting, surveys, travel, copying, communication, office overhead, besides the actual cost analysis.

There are two ways to fashion an estimate of annual expenses. The most reliable is to resort to accounting records for similar operations; however, often these are difficult to obtain or interpret. The second is to follow Tables 9 and 10 using factors such as suggested in Section 2 (Table 3) and discussed in Appendix B. The estimator should base the estimate on actual cost data if at all possible.

Feasibility Evaluation

Often with privately financed facilities, only the efficacy of a part of the operating unit (such as a flue gas desulfurization unit) is to be evaluated. This involves the comparison of several alternative retrofits or add-ons. In such cases uniform annual costs are employed but without seeking or needing the revenue requirement. An example of such a calculation is given as the third illustration under the privately financed examples in Appendix E.

For publicly funded works the version of equivalent annual cost termed "equivalent annual value" involves only the resources of initial capital and O&M. See Appendix E.

Reliability Assessment

The recommended assessments are of two kinds: the limited sensitivity analysis, and the comprehensive uncertainty analysis. Either one or both can be called for.

When reliability is assessed, either opinion or a formal uncertainty analysis (such as the Monte Carlo technique) is to be used. The Monte Carlo technique requires that a suitable computer program be available either in-house or by one of several organizations that provide this software system service.

The form to be used is open.

SECTION 4

SOME GENERAL COMMENTS AND CAUTIONS

A background in technical economics and reliable sources for cost data should provide more thoughtful, thorough, and hence accurate economic evaluations of pollution abatement operations. Also in the preparation of the analysis, several cautions should be observed.

BACKGROUND IN TECHNICAL ECONOMICS

If the standard procedure is routinely followed, the estimator should be assured of a complete and appropriately detailed cost analysis. Also, the estimator should be confident that the rationale outlined by the specification is consistent with current accepted practice in both financial and engineering circles for the cost evaluation of capital projects. However, persons requesting and carrying out this kind of work would do well to become conversant with both the nuances and the development of the subject known variously as, engineering economy, financial analysis of capital projects, and technical economics. It is believed that the methodology can be readily grasped by one having an understanding of the material in Appendices C, D, and E. For further instruction, from the vast amount of literature on this subject, the reader is particularly referred to Grant _et al_. (12), Canada (13), Taylor (14), Ostwald (15) and Helfert (16).

SOURCES FOR COST DATA

The building blocks for any economic study are the cost data. The sources are various and often should be used for checking. For capital cost data for large items, the estimator should resort to vendors; however, checks from experience and literature correlations are strongly advised. Similarly, information on operation should be drawn from a variety of authorities.

QUALITY OF COST ANALYSES

The quality (i.e., the reliability of a cost analysis) depends on the competence of the people involved and the adequacy of the cost information. Feedback and review are important for enhancing the skill of cost analysts and improving the quality of the data. Comparisons with similar estimates also serve these purposes.

CAUTIONS

These several cautions should be observed in preparing cost estimates and the more comprehensive economic evaluations.

- The procedures outlined are intended to render evaluations for a generalized case.
- The cost evaluation cannot improve on shoddy technical work and poor experimental data.
- The detail in the economic evaluation should be consistent with the level of the technical effort.
- The results should be in a form which can be readily apprehended and used.
- All costs (capital and operating) should be included for evaluation of a grass roots unit; all costs that are likely to vary from one alternative to another must be accounted for in the case of a retrofit or add-on facility.
- The peculiarities of a particular technology must be understood and taken into account.
- The measures of economic feasibility must be in terms that are familiar and that have significance.
- Both the estimating team and the requestor should give serious attention to the question of the reliability of the cost analysis.
- Results should be arrived at by two or more different methods to provide checks, particularly if the evaluator is relatively inexperienced.
- Computers save time and make for more comprehensive studies, but they are no substitute for experience or wisdom.

For Generalized Cases

The standard procedure can serve as a guide for costing site-specific projects, but it should never be used directly for this purpose. Wide cost variations are caused by factors unique to any given project; e.g., site conditions, local deviations in material, and labor costs. The prime purpose of this standard procedure is to develop a cost analysis for generalized cases.

For actual estimates of site-specific projects, either preliminary (budget authorization) or definitive estimates are required. Their scope is described in Table 1 and Figure 2. More information on these types of estimates can be found in Appendix A.

Adequate Technical Effort

An estimate should be based on good process design, sound laboratory data, or well-executed pilot plant work. The technical data should be up-to-date and reflect up-to-date technological advances. There are no specific rules for excellence in design and R&D work, but competence is eventually recognized in the results.

Estimate in Harmony with Technical Effort

Often comprehensive cost estimates of the definitive type are carried out for conceptual processes, ones for which there may be little data or no experience. For the economic evaluation to be in balance with the technical effort, it would be more proper to base it on a study type of capital cost estimate. Inconsistencies of this kind betray poor judgment on the part of the requestor of the cost analysis, and they can result in unnecessarily high estimate charges.

Acceptable Form

Any technical or evaluation effort is unsatisfactory if it is not easily understood and in a form which can be directly used and compared with other related evaluations. The specification format was developed with these purposes in mind.

Inclusion of All Pertinent Costs

Many cost estimates prove to be confusing because they do not consider all the capital costs, or the operating cost may not include overheads, or general expenses. For ready apprehension, it is desirable for a system that is intended for different economic realms (viz., private sector, regulated industry, and municipalities) to follow the same form. For revenue producing operations this means the inclusion of all costs, and for add-on facilities, all costs that are likely to vary from one alternative to another.

Peculiarities of Particular Technologies

Examples of this as it applies to different technologies relate to the manner in which certain disbursements are handled. Although utilities capitalize interest on construction costs, private industry may expense this at the end of the first year of operations. Also, productivity drops off sharply with plant age for utilities, whereas production for a private sector plant depends on the market or profits.

Measures of Economic Feasibility

Three difficulties are encountered with respect to the measures of merit of economic feasibility. One is the plethora of measures used with the same or almost the same identification. Examples are rate of return (it can be ROI, IROR, or others) and annualized cost (it can be on a number of different bases). These distinctions need to be appreciated and, when one of these criteria is used, its basis must be carefully defined.

Another difficulty is the failure of many decision makers to apprehend the criteria for feasibility. This is the reason such measures must be simple and in common use, and follow consistent standards.

The third is the effect on the measures of merit from the manner of handling inflation. The use of both then-current and constant worth dollars is acceptable, but each results in a different value of the various measures of merit. As a rule then-current dollars result in higher calculated values of the measures of merit; this must be appreciated.

Measures that are solely in dollars, such as annualized cost, are not satisfactory. Much to be preferred are percentages, ratios, or dollars per some basic unit identified with a technology. Examples of the latter unit costs, as they apply to utilities, are $/kW capacity for capital costs and mills/kWhr for operating costs.

Assessing the Reliability of the Cost Analysis

The technical group doing the work, such as a contractor, should make an appropriate assessment of reliability. The project director or project officer should also consider this matter.

Using Checks

In certain costing and evaluation procedures, several methods are in common use. Also, there are rules of thumb, such as turnover ratios and Lang factors, which provide quick verification. Such checks using available approaches should be used, particularly by less experienced evaluators, and also in review by management.

Computer Programs

Computer programs can be invaluable in connection with economic evaluations; examples are for uncertainty analyses, sensitivity analyses, and internal-rate-of-return calculations. However, the reams of paper they generate can be deceptive; the results can only be as good as the quality of the data provided. The results need to be boiled down to a significant figure or two and accompanied by a cogent commentary.

SECTION 5

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SECTION 6

GLOSSARY

The meanings of most of the terms specific to engineering cost analysis and in particular those used in this procedure can be comprehended from their general-use connotation. But occasional expressions may require a refined explanation to obviate confusion. Words that seem likely to cause such difficulties are defined below. References 6-1 and 6-2 are provided for a number of glossaries for further evaluation of the plethora of terms peculiar to this field.

add-on: Two meanings: charges in addition to the base investment (see Table 6); and a retrofit added to the base plant as for pollution abatement.

AFDC: allowance for funds during construction (which see).

allowance for funds during construction (AFDC): Interest on funds from loans paid to engineering-construction firm during the progress of building; usually capitalized.

annual expense: All expense payments for the year; see expenses.

annualized cost: The equivalent annual cost equal to the revenue requirement. See Equation E-1.

battery limits plant: The part of the plant within the geographic boundary around all the process equipment, but excluding storage, utilities, administration buildings, or auxiliary facilities.

"best guess" estimate: Same as most likely estimate.

book value: Current investment value as recorded in the accounts calculated as the original total plant cost less depreciation accruals.

capital, working (I_w): Funds in reserve necessary for the normal conduct of business.

capital investment: Investment for long-term use (over a year), which is therefore capitalized.

capital structure: The proportionate portions of capital from sources such as common stock equity, preferred stock equity, and debt (bonds).

capitalize: To consider as an investment; it can either be depreciated (buildings and equipment) or recovered (land or working capital).

cash flow: Annual cash receipts in the form of net profit (after taxes) plus the depreciation charge; also called cash inflow and cash flowback. For comparisons of alternatives with the same revenue, it can be the depreciation charge plus net saving or minus extra net operating charge adjusted for income taxes.

cash flows: The various sources and outlays for funds in an active project.

cash flow diagram: Same as money flow diagram; see Figures C-1 and C-2.

conceptual estimate: An estimate for a new process or operation, one that has not been built or operated to date.

constant worth dollars: [Then-current dollars] X [1 + annual inflation rate]$^{-n+1}$, where n is the number of years from the year in question to the reference year. Sometimes these are termed constant dollars, real dollars, or deflated dollars. For an example calculation, see footnote *.

cost analysis segment: The major of the three segments of the economic evaluation; see The Specification in Section 3.

cost effectiveness: A term often used in lieu of cost-benefit studies. Cost effective analysis is called for by the EPA construction grant program but at present it only takes actual costs into account. (References E-3, E-4.)

cumulative frequency distribution: The probability of the occurrence of a given value or less from a set of values; e.g., ROI. See Figure K-2.

depreciation: The allocation in a systematic and rational manner of the cost of fixed capital assets less salvage (if any), over the estimated useful life of the facility.

descriptive segment: The first of the three segments of the economic evaluation; see The Specification in Section 3.

discount rate: The interest rate used either to discount future cash flows to a reference time (zero) or to compound past cash flows to the same reference time.

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*It is desired to convert the value of an investment of $3,000,000 in 1982 to 1975 constant worth dollars. The inflation rate is estimated at 8% per year. The 1975 value = [$3,000,000] X [1 + 0.08]$^{-7+1}$ = $1,891,000 (1975 constant worth dollars) (then-current dollars).

discounted cash flow rate of return: See internal rate of return.

engineering cost analyses: The application of techniques to the expected capital investments, annual operating expenses, and other cash flows to ascertain the economic feasibility of a project by computing measures of merit.

enter to costs: An accounting term -- accrual of depreciation charges; the process of recovering capital invested.

envelope of variability: The curves that bound the upper and lower percentage accuracy for cost estimates of increasing quality; for example in Figure 2, see the inset to the left.

equivalent annual cost: A generic term to describe equivalent cash flows; it can be calculated either as an uniform end-of-year value, or a uniform continuous flow throughout the year.

equivalent annual value: A version of equivalent annual cost used in evaluating public sector projects. An example is described by Equation E-3 for the EPA construction grants program.

equivalent uniform cash flow or cost: Corresponds to equivalent annual cash flow (or cost) when it is calculated as a uniform end-of-year value. See Grant *et al*. (E-1).

escalation: Inflation in the cost of a particular item in contradistinction to general inflation.

expense: Net expenses are all payments transferred (paid) to entities outside the operating organization for costs incurred for and related to the plant operation; total expenses include depreciation charges in addition to the above.

expensed: The accounting operation in which an outlay is classified as an expense (which see) and included in an account of expenses, generally classified by type; e.g., operating labor, maintenance materials.

factored estimate: A form of capital cost estimate; usually it is a form of study estimate.

figures of merit: See measures of merit.

financial factors: Percentages and ratios set by policy which pertain to sources of funds and their rate of recovery.

fixed capital: Corresponds to depreciable investment (buildings and equipment) plus land; excludes working capital.

general expense: An indirectly attributable expense for administration, sales, research, and financing activities.

grass roots plant: A complete plant erected on a virgin site; the investment includes all costs of site preparation, battery limits units, and auxiliary facilities.

I_F: Symbol to denote total plant cost; usually equivalent to the depreciable investment; corresponds to total module cost.

I_w: See capital, working.

inflation index: Also termed cost index; the relative value of the dollar at a point in time in a particular segment of the economy as compared to its value at an earlier reference time when it is arbitrarily given a value of 100.

interest, continuous: Interest computed by assuming an instantaneous time period for compounding; generally expressed as a nominal interest rate per year. This nominal interest rate works out to be less than the effective interest rate for the year.

interest, discrete: Also termed simple interest; interest on the principal for the period (usually 1 year).

interest rate of return: See internal rate of return.

internal rate of return: (IROR) Rate of interest at which outstanding investment is repaid by proceeds of a project to achieve a zero present worth; also, called interest rate of return, discounted cash flow rate of return, and profitability index.

IROR: Symbol for internal rate of return (which see), and equivalent measures of merit.

K: One thousand (1000), when used in connection with dollars.

learning curve: A graphical relation that demonstrates or predicts the improvement in productivity or costs of production with time because of tidying up, bottleneck elimination, and fine tuning.

levelized cost: A form of unit cost equal to the revenue requirement; annualized cost per unit of output where this unit of output is usually discounted in the same fashion as the cost.

life-cycle analyses: The systematic analytical process of evaluating various alternative courses of action over the entire life of the venture to ascertain the most economical.

major plant items: (MPIs) Synonymous with major equipment items; excludes process piping, insulation, electric switchgear, instrumentation, and components for erection such as foundations, walkways, structural supports.

MARR: See minimum acceptable rate of return.

measures of merit: Also termed figures of merit, criteria for evaluation, feasibility criteria; ratios, percentages, and other indices that characterize the economic feasibility of a project; e.g., return on original investment (ROI), payout time, internal rate of return (IROR), annualized cost.

minimum acceptable rate of return: (MARR) This is the lowest return that will be considered attractive for the investment of new capital; it is often taken as the average current return on investment capital; it is not to be confused with the cost of capital and should be somewhat higher. Note that the kind of return (e.g., ROI or IROR) needs to be specified.

module: The MPI with appurtenant equipment that carries out either a unit operation (e.g., heat transfer, distillation, solids separation) or a unit process (e.g., biodegradation of liquid wastes).

MPI: See major plant items.

O&M: Direct operating and maintenance costs; represent only a fraction of the total annual expense.

payout time: The time in years to recoup the fixed (depreciable) capital from *cash flow*; also called payback time or period.

present value: Same as present worth (which see).

present worth: The sum of the discounted (and compounded) values of the cash flows for a given project or operation. The discount rate must be specified.

private sector: Refers to projects financed by private capital and for which the price of the output is set by the market.

profitability index: See internal rate of return.

R&D: Research and development.

regulated sector: Refers to projects financed by private capital, but for which the price of the output is regulated by law or a government body. Examples are electric utilities, the telephone company, public carriers.

reliability assessment segment: The last of the three segments of the economic evaluation; deals with uncertainty and risk measures; see The Specification in Section 3.

resources requirement: Refers to financial means required to support public sector projects; viz., original capital, interest on capital, and operating expenses.

retrofit: The construction or the actual facility appended to an operable process for some purpose such as to abate pollution. See add-on.

retrofit increment: The extra or added cost required for a retrofit facility above that for the basic plant.

return on original investment: (ROI) Net profit divided by total capital investment.

ROI: Return on original investment (which see), a measure of merit.

scope: A description of the essential features and extent of the physical installation.

sensitivity analysis: A cost analysis that demonstrates the effect on a measure of merit of varying, one at a time, the major cash flows within expected limits.

specification: In this standard procedure, the format for organizing and presenting the engineering cost analysis.

standard deviation: A measure of variability of values about their mean.

standard procedure: The method of economic evaluation outlined in this report.

then-current dollars: Real dollars which vary in relative value with time because of inflation; sometimes these are termed nominal dollars, current dollars, inflated dollars, or escalated dollars.

UAC: Uniform annual cost (which see).

UNACOST: Same as equivalent uniform cost. See Jelen (E-2, p. 25).

uncertainty analysis: The computation of a probability distribution of a measure of merit from projected probable values of the major elements of cash flows.

uniform annual cost: An equivalent annual cost that takes into account cash flow, capital outlays, and end-of-life recoveries. See the Third Private Financing Example in Appendix E.

unit cost: As applied to fixed investment - cost divided by an appropriate output per year; as applied to annual expenses - total expenses divided by output per year; as applied to annualized cost - required revenue divided by annual output. For the latter case the output may be "discounted" and escalated in the same fashion as the costs.

variance: The arithmetic mean of the sum of the squared deviations of a set of values; the same as the square of the standard deviation.

working capital: See capital, working.

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16. ABSTRACT Volume I is a user guide for a standard procedure for the engineering cost analysis of pollution abatement operations and processes. The procedure applies to projects in various economic sectors: private, regulated, and public. The models are consistent with cost evaluation practices in engineering economy and financial analysis. It presents a recommended format, termed the Specification, that should not exceed eight pages when executed. The guidelines facilitate the choice of procedures open to the estimator and the establishment of factors to be used in the evaluation. The Specification has three segments: descriptive, cost analysis, and reliability assessment. Volume II, the bulk of the document, contains 11 appendices (providing detailed background material) and 2 comprehensive examples. Appendix subjects are: Capital Investment Estimation, Annual Expense Estimate, The Cash Flow Concept, Discrete and Continuous Interest Factors, Measures of Merit, Cost Indices and Inflation Factors, Rates of Return and Interest Rates, Methods of Reliability Assessment, Sensitivity Analysis, Example I--Cost Analysis of Flue Gas Desulfurization (FGD) Retrofit Facility, and Example II--Cost Analysis of Chlorolysis Plant. The Measures of Merit appendix considers: return on investment, internal rate of return, payout time, equivalent annual cost, and unit costs. A glossary is provided.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Cash Flow	Pollution Control	13B
Cost Analysis	Interest	Stationary Sources	14A
Cost Estimates	Inflation	Measures of Merit	05A
Reliability		Rates of Return	14D
Fixed Investment		Sensitivity Analysis	05C
Operating Costs			

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