8.0 Costing and Economic Evaluation

The software tools of the Pro-Designer family facilitate estimation of capital and operating costs and perform preliminary economic evaluation and profitability analysis of manufacturing and pollution control processes. The calculations are performed when the user selects **Tasks/Perform Economic Calculations**. The key results of the economic calculations can be viewed by selecting **View/Executive Summary**.

Initialization of stream related cost parameters must precede the economic evaluation calculations. This is done through the **Tasks/Stream Classification ...** menu item (see section 8.3 for more information on this subject).

Pro-Designer generates three types of economic evaluation reports, the traditional *Economic Evaluation Report*, the *Itemized Cost Report*, and the *Cash Flow Analysis Report*. The structure of the first report is shown in Table 8.1.

The *Economic Evaluation Report* includes information on Fixed Capital Cost, Operating Cost, and Profitability Analysis. Pro-Designer is equipped with capital cost correlations for all of its processing equipment. The user has the option of supplying his/her own values or correlations (see section 8.4 for more information). Pro-Designer uses a **factor method** to generate estimates for certain direct fixed capital cost items, such as installation, process piping, instrumentation, etc. The various factors can be modified by the user through appropriate dialog windows (see sections 8.4 and 8.5). Similar factors are used in the estimation of operating cost.

Tip

Note that the current version of the software uses a **single set of factors** derived from data that primarily apply to relatively large chemical and biochemical plants. The default factors may be substantially off for small plants that produce high value products or for very large bio/chemical plants that produce commodity products. To store your own factors for different types of plants, generate template design cases and use them as starting points whenever you wish to analyze a new process that resembles one of the template design cases. Future versions of Pro-Designer will support generation of settings file for storing default values of multipliers and settings.

The *Itemized Cost Report* includes information on the various costs (e.g., Capital, Raw Materials, Consumables, Utilities, Maintenance, and Waste Treatment/Disposal) that are associated with each process step. The process-step-related costs are displayed in multiple units (e.g., $/year, $/hr or $/batch, $/kg of product, etc.). At the bottom of this report there is a table that provides comparative information on the various process steps of a flowsheet. Further, in the same table, the column on the far right provides the percent cost contribution of each process step in order to facilitate the identification of expensive process steps. Note that the overall operating costs displayed at the bottom of this file do not include certain costs, such as overhead, that cannot be easily distributed to the various process steps of a flowsheet.

The *Cash Flow Analysis Report* includes information on the cash flow breakdown for each year the plant is expected to be in operation, on amount of money borrowed, a breakdown of capital outlay and a breakdown of loan payment.

The reports can be created in different formats, including Excel spreadsheets. For more information on the format / file type of the reports see Chapter 11.

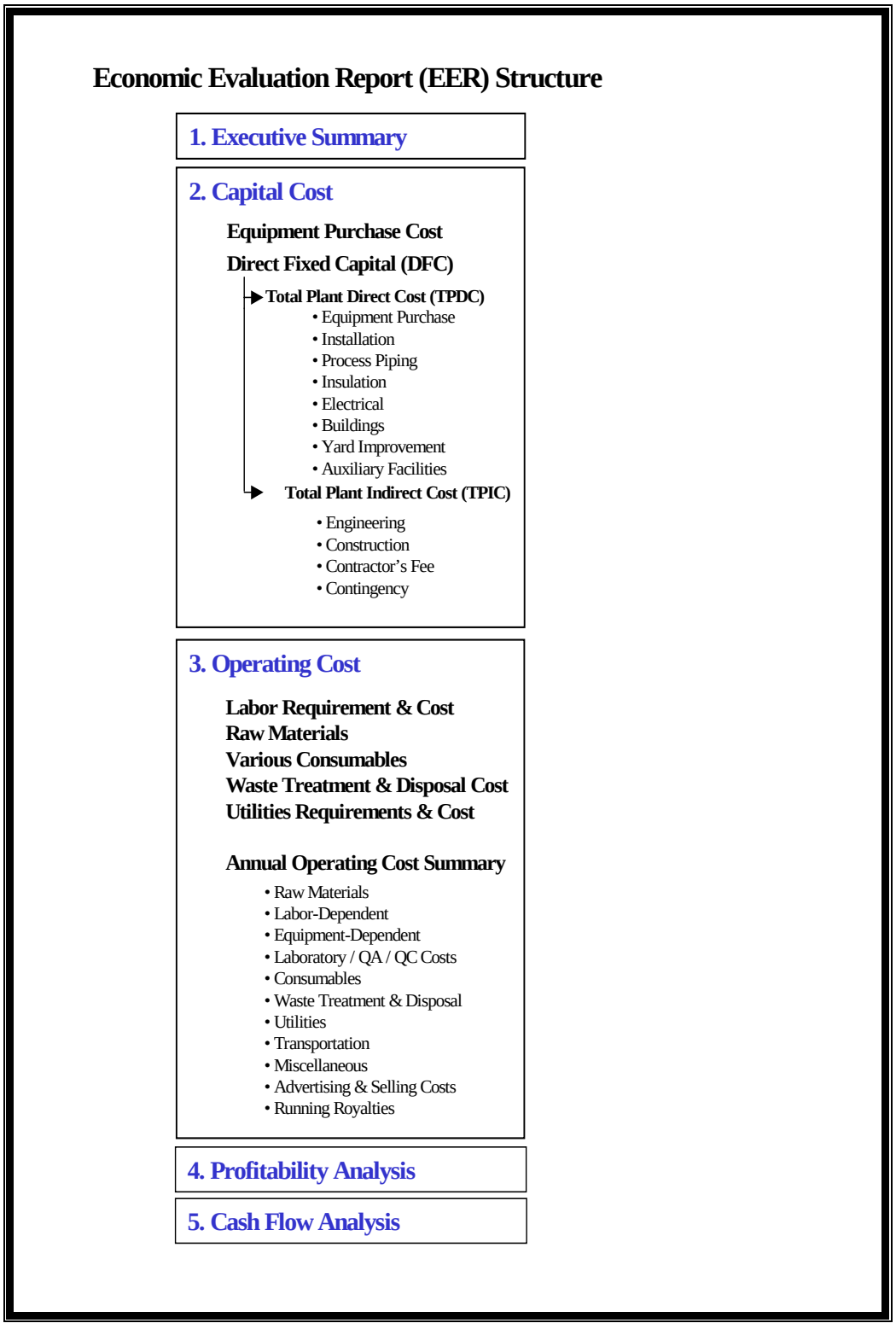

Table 8.1: Economic Evaluation Report Structure

8.1 Definitions

This section provides definitions of the various parameters that appear in the economic evaluation reports.

Fixed Capital Cost Estimation

Equipment Purchase Cost (PC)
The vendor's selling price of major equipment. It excludes items such as taxes, insurance, delivery and installation. It is also known as the *bare cost*. Pro-Designer provides correlations for estimating the purchase cost of all major equipment. The user has the option to provide his/her own cost values or cost correlations. A factor method is used to account for the cost of unlisted (overlooked) equipment (the default value is 20% of total equipment cost).

Installation
This cost element refers to the in-place erection of equipment at the new plant site, and it includes cost of foundations, slabs, supports, and local equipment services. Unit-specific factors are used for the estimation of installation cost of each processing step.

Process Piping
This element incorporates process fluid piping that connects the equipment, as well as connections to the main utility headers and vents. Included are valves, piping supports, insulation, and other items associated with equipment piping. The cost of process piping is estimated by multiplying the total equipment cost by a factor.

Instrumentation
It includes transmitters and controllers, with all required wiring and tubing for installation; field and control room terminal panels; alarms and enunciators; indicating instruments, both in the field and in the control room; on-stream analyzers; control computers and local data-processing units; and control room display graphics. The cost of instrumentation is estimated by multiplying the total equipment cost by a factor.

Insulation
The cost of insulation and painting is usually included in the recommended factors for equipment installation and piping. In low temperature plants, however, insulation cost can become unusually high. An insulation surcharge is recommended for such plants. The cost of insulation is estimated by multiplying the total equipment cost by a factor.

Electrical
These include battery limits substations and transmission lines, motor switch gear and control centers, emergency power supplies, wiring and conduit, bus bars, and area lighting. Separate equipment estimation is required for electrolytic installations. The cost of electrical is estimated by multiplying the total equipment cost by a factor.

Buildings
Includes process towers, subsidiary concrete slabs, stairways and catwalks (not equipment-specific), control rooms, and other battery limits buildings-change rooms, cafeteria, furnished offices, and warehouses. The recommended factors incorporate costs for non-electric building services as well as a variety of safety-related items. The cost of buildings is estimated by multiplying the total equipment cost by a factor.

Yard Improvement
Includes excavation, site grading, roads, fences, railroad spur lines, fire hydrants, parking spaces, and others. The cost of yard improvement is estimated by multiplying the total equipment cost by a factor.

Auxiliary Facilities
Satellite process-oriented service facilities vital to the proper operation of the battery limits plant. An example of an auxiliary facility is a steam plant. The cost of auxiliary facilities is estimated by multiplying the total equipment cost by a factor.

Total Plant Direct Cost
The sum of all the above cost items constitutes the Total Plant Direct Cost (TPDC).

Engineering
Includes the preparation of design books that document the whole process; design of equipment; specification sheets for equipment, instruments, auxiliaries, etc.; design of control logic and computer software; preparation of drawings; and others. The cost of engineering is estimated by multiplying TPDC by a factor.

Construction
Costs associated with the organization of the total construction effort; they do not include the cost of construction labor. The cost of construction is estimated by multiplying TPDC by a factor.

Total Plant Indirect Cost
The sum of engineering and construction costs constitutes the Total Plant Indirect Cost (TPIC).

Total Plant Cost
The sum of TPDC and TPIC constitutes the Total Plant Cost (TPC).

Contractor's Fees
The contractor's profit. It should be added even if a corporation does its own construction, because the construction division is expected to show a profit. It is estimated by multiplying TPC by a factor.

Contingency
The more speculative a process is, the more likely it is that key elements have been overlooked during the project's early stages. The contingency factor attempts to compensate for these missing elements. However, even advanced-stage estimates will include a contingency to account for unexpected problems during construction, such as strikes, delays, and unusually high price fluctuations. The value of contingency is estimated as a multiple of TPC.

Operating Cost Estimation

Raw Materials
This accounts for the cost of all raw materials (pure components and stock mixtures). The user specifies the unit cost during the component registration. Default prices are available for a good number of raw materials. The amount of raw materials is calculates by the program as part of the simulation.

Facility-Dependent
This accounts for the depreciation of the fixed capital investment, equipment maintenance, insurance, local (property) taxes and possibly other overhead-type of expenses. By default it is estimated as the sum of the above cost items. Alternatively, the user may select (at a section level) a lumped estimate method based on either a Facility Usage Rate (in $/facility hour) or an Equipment Rate (in $/equipment hour) for all equipment belonging to the section. In the latter case, the facility-dependent cost is estimated by multiplying the equipment rate times the hours that the corresponding equipment is actually used by this section (usage basis) or is reserved for that section (availability basis). The lumped-estimate approach is usually more convenient for existing multi-product facilities. The Facility Usage Rate and the Equipment Rate are estimated based on historical cost data and can also be deposited in the Sites and Equipment database respectively. An allocated section can use the database value for the Facility Usage Rate, which, depending on the user's choice, will be distributed to all site-sharing sections in the flowsheet or will be applied as is to every allocated section.

In terms of depreciation, three different models are available: straight-line, declining balance, and sum-of-the-years-digit. The method of depreciation can be selected through the **Edit/Flowsheet Options/Economic Evaluation Parameters...** menu item. Pro-Designer depreciates the entire DFC of a section minus its salvage value at the end of the project lifetime. The annual equipment maintenance cost is estimated as a percentage of the equipment's purchase cost (usually 10%). Insurance rates depend to a considerable extent upon the maintenance of a safe plant in good repair condition. The processing of flammable, explosive, or dangerously toxic materials usually results in higher insurance rates. The cost of insurance is estimated as a fraction of DFC. The local (property) taxes and other factory expenses are also estimated as a fraction of DFC. The factory expense represents overhead cost incurred by the operation of non-process-oriented facilities and organizations, such as accounting, payroll, fire protection, security, cafeteria, etc.

Labor
This is estimated based on a unit-specific ratio of labor hours (for every labor type used) required for each hour of equipment operation. Default values for this ratio are available for every operation. On top of the itemized estimate, the user has the option to specify labor hours per batch, per campaign, per year or per kg of main product, needed to carry out services or jobs not accounted by the processes themselves. Each labor type or staff used in the process has its own labor cost parameters that are used to calculate the total labor cost.

Laboratory / QC / QA
This accounts for the cost of off-line analysis and quality control costs. Chemical analysis and physical property characterization, from raw materials to final product, is

a vital part of chemical operations. By default, it is estimated by multiplying the operating labor by a factor. In addition, the user may specify detailed information about the number and unit cost of the various assays along with a fixed cost for QA activities.

Consumables
This includes the cost of periodically replacing membranes, chromatography resins, activated carbon, and other materials in equipment/procedures that use up such items.

Waste Treatment/Disposal
The cost of treating and/or disposing of certain process outputs, such as undesirable by-products, solvents, etc. Wastes can be classified as solid, liquid, or gaseous (emissions.) Depending on the phase, the complexity of the facility, and the nature of the waste, the treatment cost can vary substantially. You can specify the waste treatment/disposal cost of a stream on a per-kg of total mass basis, or allow the system to estimate the treatment/disposal cost of a waste stream using the component's property information and the stream's composition (see Section 4.1).

Utilities
The sum off all utilities costs. There are two kinds of utilities:
a. heating/cooling and
b. power.

There are two kinds of heating/cooling requirements for each process step:
a. the heating/cooling which is part of an operation model (like the heating/cooling required to achieve a temperature specification of an exiting stream) and
b. the heating/cooling which is specified as an auxiliary utility (through the Labor, etc. tab of an operation's dialog window).

Power requirements are specified or calculated for each operation that requires a power input (like a pump, for instance) and for the entire flowsheet for support operations (like night lighting, etc.) or other purposes that are not directly associated with the execution of any specific process step. Just like heating/cooling , there are two kinds of power requirements associated with an operation:
a. the power which is part of the model for those models that require such parameter (such as power for agitation in reaction operations), and
b. the auxiliary power (all operations).

There are also three additional power requirements specified for the entire flowsheet:
a. the cost of electricity not accounted by the operations themselves, which can be defined on a per year or per batch basis,
b. the cost of the general power load, which is estimated as a percentage of the total process power requirement
c. the cost of power for unlisted equipment, which is also estimated as a percentage of the total process power requirement.

Transportation
This accounts for the cost of long-distance transportation by sea, land, and air.

Miscellaneous
This accounts for on-going R&D, process validation and other overhead-type of expenses. By default this cost item is zero. Its parameters can be modified through the **Misc** tab of a section's **Operating Cost Adjustments** dialog.

Running Royalties
If the process, any part of the process, or any equipment used in the process are covered by a patent not assigned to the corporation undertaking the new project, permission to use the teachings of the patent must be negotiated, and some form of royalties is usually required. The licensing agreement usually calls for a flat charge per unit of product or else a percentage on the sales dollar. The default parameters for this expense (which is zero by default) can be accessed and modified through the **Misc** tab of the **Economic Evaluation Parameters...** dialog of a process.

Advertising and Selling
Cost associated with the activities of the sales department. The economic evaluation, by default, assumes this cost is zero. You may decide to take it into account by modifying the zero multiplier value or setting an absolute dollar value through the **Misc** tab of the **Economic Evaluation Parameters...** dialog of a process.

Failed Product Disposal Cost
Cost associated with the disposal/recycling of scrapped product. The default parameters for this expense (which is zero by default) can be accessed and modified through the **Production Level** tab of the **Economic Evaluation Parameters...** dialog of a process.

Profitability Analysis

Working Capital
It is the investment in temporary or consumable materials. It represents tied-up funds required to operate the business. In Pro-Designer, the value of the working capital can either be set by the user or calculated based on contributions from the following cost items: labor, raw materials, utilities, waste treatment / disposal, and miscellaneous.

Startup and Validation Cost
Cost associated with the startup and validation of the process. It is either set by the user or calculated as a percentage of DFC. The process validation cost can be substantial for pharmaceutical plants.

Gross Margin
Cost associated with the startup of the process site. It includes labor, and raw materials.

Cash Flow Analysis

Definitions and detailed explanations of the Cash Flow Analysis variables appear in section 8.6 (Calculations).

8.2 Initialization

Economic information can be classified into the following four categories (default values are provided for all economic variables related to the last three categories):

Accessing Stream-Related Information
Through the **Tasks/Stream Classification...** option of the main menu.

Accessing Operation-Related Information
Through the **Labor, etc. tab** of the operation's i/o simulation dialog.

Accessing Equipment-Related Information
Through the **Edit / Procedure Options / Equipment Data...** of the main menu, or the **Equipment Data...** option of any procedure (hosted by the equipment) context menu.

Accessing Capital and Operating Cost Related Data for the Entire Flowsheet
Through the **Edit/Flowsheet Options/ Section /Capital Cost Adjustments...** and the **Edit/ Flowsheet Options / Section /Operating Cost Factors...** menu items;
Or from the sections' toolbar:

Accessing Project Venture Information
Through the **Edit/ Flowsheet Options /Economic Evaluation Parameters...** menu item.

8.2.1 Economic Data for Raw Material, Revenue and Waste Streams

The information which appears in this section, is specified through the **Tasks/Stream Classification...** menu item. A related discussion with more details can be found in Section 4.1.

Essentially, *an input stream* can be classified as:

a. raw material or
b. revenue,

whereas *an output stream* could be classified as:

a. revenue,
b. solid waste,
c. aqueous waste
d. organic waste, or
e. emission

Furthermore, an output stream could also be tagged as hazardous, but this tagging does not affect the economic evaluation. It only affects the environmental impact report.

Revenue Stream
Any stream (input or output) that contributes to the revenues of the project. For each revenue stream, you can either let the corresponding selling price (processing fee) be calculated based on the selling price (processing fee) of each component present in that stream and the stream composition, or you can simply set a value. Even though for most manufacturing processes revenue streams are typically output streams (products), for waste treatment facilities revenue streams could be considered input streams, as the proceeds from the operation of the plant are based on the amount of waste treated (process input).

Main Revenue Stream
One of the revenue streams which is used to calculate the throughput (or production rate) of the plant. The production rate could be based on the entire flowrate of the designated main revenue stream, or it could be calculated based on the flowrate of a selected component in that stream.

Raw Material Stream
A process input stream that costs money. The unit cost of such streams can either be calculated by the program based on the purchase cost of each component and the composition of the raw material stream, or it can be set by the user in $/kg of total stream mass.

Waste Streams
A stream with no selling value with deleterious effects on the environment. Typically such streams are further classified into solid wastes, liquid (aqueous / organic) wastes and emissions as they find their way to the environment through different pathways and are regulated differently. Each waste stream can have a treatment/disposal cost associated with it and it will show on the expense side of the project evaluation. Depending on the nature of a manufacturing process, waste treatment costs can be the dominant item of the operating cost. The waste treatment/disposal cost of a waste stream can either be calculated by the system based on the composition of a waste stream and the waste treatment/disposal cost associated with each component, or it can be simply set explicitly by the user (in $/kg treated or disposed).

8.2.2 Economic Data for Each Operation

The information that appears in this section can be accessed through the **Labor, etc.** tab of the operation's i/o simulation dialog.

Two items can be specified:

a. Labor: you can specify the labor hours required for each hour of equipment operation (when the operation is being executed) for multiple labor types. Generic labor cost factors can be modified through the dialog that appears when you select the **Edit/Flowsheet Options/Labor...** menu item. Site labor cost factors should be set inside the sites databank (accessed through the **Databanks/Sites and Resources...** menu item.)

b. Auxiliary Utilities: you can specify the need for auxiliary heating, cooling, and power. For heating and cooling, you must specify the agent for carrying out the heat transfer. Generic heating and cooling agent unit prices can be modified through the dialog that appears when you select the **Edit/Flowsheet Options/Heat Transfer Agents...** menu item. Site agent cost factors should be set inside the sites databank (accessed through the **Databanks/Sites and Resources...** menu item.)

The unit cost of power can be modified on a section basis through the **Utilities** tab in the **Section Operating Cost Adjustments** dialog accessed through the section toolbar. Auxiliary heating, cooling, and power do not affect the energy balance of the unit.

8.2.3 Economic Data for Each Procedure / Equipment

All unit procedures have two common dialog tabs through which the user can provide information that affects the capital investment and certain items of the operating cost of that particular step.

Purchase Cost
Information about equipment purchase costs can be provided through the Purchase Cost tab of the Equipment Data dialog (right click on a unit procedure and select **Equipment Data**). By default SuperPro uses a built-in model to estimate purchase costs for each piece of equipment. However, you can override this estimate by either using your own model (click on User-Defined Model) or specifying an exact purchase cost (from a vendor quote, for instance) as a fixed value or for a specific purchase year (see sections 5.3.2, 5.3.3 of the manual for more information). For allocated equipment the purchase cost is set according to the databank and is not editable.

Cost Adjustments
Information about various cost adjustments can be provided through the Adjustaments tab of the Equipment Data dialog (right click on a unit procedure and select **Equipment Data.** You can specify the number of Standby Units, the Capital Cost Adjustments, and the Operating Cost Adjustments. For more information see section 5.3.4 of the manual.

8.2.4 Economic Data for Each Section

You may set parameters that affect both the capital as well as the operating cost of each section. For sections allocated to databank sites you have the option to use the site data for some of the economic parameters. To use this option, click on the 'Use Site Data' check box whenever it appears in a section tab. Parameters tied to site data though this option are not editable at the section level. In addition to setting them one by one, you can set in a global way which parameters to get from the site for a particular section by visiting the **Economic Flags** tab in the **Section Resources** dialog accessed through **Edit/Flowsheet Options/Section/Resources…** menu item or the **Edit Section Resources** button in the section toolbar.

Capital Cost Adjustments

The parameters that affect the capital investment of a process section can be accessed through **Edit/Flowsheet Options/Section/Capital Cost Adjustments…** or through the **Capital Cost Adjustments** button of the section toolbar (the button with the large dollar sign on it). Please note that the parameters edited through this dialog affect the currently selected section.

You can modify factors for determining the following costs: unlisted equipment, piping, instrumentation, insulation, electrical facilities, buildings, yard improvement, auxiliary facilities, engineering, construction, contractor's fee, and contingency. Also, you can modify the fraction of the equipment purchase cost that is to be assigned to the project (this is useful in situations of multi-product facilities). This cost allocation can be made either on a section-wide basis or a unit-by-unit basis. Finally, some other miscellaneous items, such as the Working Capital, the Start-up and Validation Cost, the Up-Front R&D expenses, and the Up-Front Royalties can also be specified.

Operating Cost Adjustments

The parameters that affect the operating cost of a process section can be accessed through **Edit/Flowsheet Options/Section/Operating Cost Adjustments… …** or through the **Operating Cost Adjustments** button of the section toolbar (the button with the small dollar sign and the runner).

You can modify factors determining the operating costs: equipment-dependent, labor, laboratory/QC/QA, electricity and miscellaneous

8.2.5 Economic Data for the Entire Process

The information which appears in this section, can be accessed through **Edit / Flowsheet Options / Economic Evaluation Parameters**. It can also be accessed by right-clicking on a blank area of the flowsheet and selecting the **Economic Evaluation Parameters...** option.

You can modify the following parameters: the year of analysis (the year that the economic evaluation is carried out), the starting year of construction, the construction duration, the expected lifetime of the project, the inflation (to update equipment purchase cost for years for which the Chemical Engineering Cost Index is not available), the fixed capital cost outlay schedule, the method of depreciation, the salvage value, the depreciation period, the income tax rate, the discount interest for calculating the net present value of the project, and information for calculating the start-up and validation cost. You can specify the production level (as a percentage of the nominal capacity), the product failure rate, and the unit cost of disposal/recycling for the scrapped product. Last, you can modify the parameters that determine the financing of the product (debt fraction, loan period, and loan interest for DFC, working capital, up front R&D, and up front royalties).

8.3 Calculations

8.3.1 Equipment Purchase Cost (PC)

For each processing step, the purchase cost is either

a. set by the user, or
b. based on an internal model, or
c. based on a user-defined power law model.

The program by default uses its internal model to calculate the purchase cost of the unit(s) involved. If a step requires multiple units (of equal size) operating in parallel, then the purchase cost displayed is the cost of a single unit. The purchase cost of the step is that of a single unit times the number of units required to carry out the operation.

The form of the user-modifiable power law is the following:

$$PC = C_o\left(\frac{Q}{Q_o}\right)^a$$

C_o is the base cost, Q_o is the base capacity, and a is the exponent of the power law. You may break the whole capacity range into any number of intervals and specify a set of power low data for each interval. To account for the time value of money, you must also specify the year for which the PC is valid.

The total purchase cost is the sum of the purchase costs over all processing steps.

Direct Fixed Capital (DFC)
The Direct Fixed Capital Cost is the sum of various cost elements. Their definitions can be found in section 8.1. The calculations are explained best by presenting the corresponding table from the program's economic evaluation report:

3. FIXED CAPITAL ESTIMATE SUMMARY (2000 prices in $)

3A. Total Plant Direct Cost (TPDC) (physical cost)	
1. Equipment Purchase Cost	2,212,000
2. Installation	1,766,000
3. Process Piping	774,000
4. Instrumentation	885,000
5. Insulation	66,000
6. Electrical	221,000
7. Buildings	996,000
8. Yard Improvement	332,000
9. Auxiliary Facilities	885,000
TPDC	8,138,000
3B. Total Plant Indirect Cost (TPIC)	
10. Engineering	2,034,000
11. Construction	2,848,000
TPIC	4,883,000
3C. Total Plant Cost (TPC = TPDC+TPIC)	
TPC	13,020,000
3D. Contractor's Fee & Contingency (CFC)	
12. Contractor's Fee	651,000
13. Contingency	1,302,000
CFC = 12+13	1,953,000
3E. Direct Fixed Capital Cost (DFC = TPC+CFC)	
DFC	14,973,000

All multipliers (except the installation factors) that appear in this table are modifiable through **Edit/Flowsheet Options/Section/Capital Cost Adjustments…** or through the corresponding section toolbar button (the button with the large dollar sign on it). The

installation factors can be specified through the right-click (context) menu of a process step (by selecting the **Purchase Cost**... option).

8.3.2 Operating Cost (OC)

The operating cost calculations are described in good detail in the definitions section 8.1 (under **Operating Cost Estimation**).

8.3.3 Profitability Analysis

The profitability analysis calculations are best explained by presenting the corresponding table from the economic evaluation report as shown in Table10. The following terms are used:

$$\text{Gross Margin} = \frac{\text{Gross Profit}}{\text{Revenues}}$$

$$\text{Return on Investment (ROI)} = \frac{\text{Net Profit}}{\text{Total Investment}} \times 100\ \%$$

$$\text{Payback Time (in years)} = \frac{\text{Total Investment}}{\text{Net Profit}}$$

10. PROFITABILITY ANALYSIS (2000 prices)

A.	Direct Fixed Capital	14,973,000	$
B.	Working Capital	296,000	$
C.	Startup Cost	749,000	$
D.	Up-Front R&D	0	$
E.	Up-Front Royalties	0	$
F.	Total Investment (A+B+C+D+E)	16,018,000	$
G.	Investment Charged to This	16,018,000	$
H.	**Revenue Stream Flowrates**		
	Total flow in Final Product	18,221	kg/yr
I.	**Production Unit Cost**		
	Final Product	345.03	$/kg
J.	**Selling / Processing Price**		
	Total flow in Final Product	500.00	$/kg
K.	**Revenues**		
	Final Product	9,111,000	$/yr

L.	Annual Operating Cost	6,287,000	$/yr
M.	Gross Profit (K-L)	2,824,000	$/yr
N.	Taxes (40%)	1,130,000	$/yr
O.	Net Profit (M-N + Depreciation)	3,117,000	$/yr
	Gross Margin	30.99	%
	Return On Investment	19.46	%
	Payback Time	5.14	years

8.3.4 Cash Flow Analysis

For each year during the expected lifetime of the project, the system calculates the net cash flow using the following rules:

a. Calculate the capital expenses term: During the first n years of construction, include any DFC-related expenditures (only the fractions that come from equity financing) according to the time schedule as specified in the **Edit/Flowsheet Options/Economic Evaluation Parameters...** dialog. Include as capital expense for the first year of the project the fraction of up-front R&D that comes from equity financing. Include as capital expenses for the first year of operation, the fractions of working capital and up-front royalties that come from equity financing.

b. For each year of operation, calculate the revenues (sales) based on the annual production rate (capacity profile) and the prices of the products (or the processing fee of revenue streams for waste management plants).

c. For each year of operation, calculate the total operating expenses (variable and fixed).

d. For each year of operation, calculate the gross profit as:
gross profit = revenues - operating expenses

e. For each year of operation, calculate all loan payments made against the fractions of DFC, working capital, up-front royalties, and up-front R&D that come from borrowed money. A detailed breakdown of loan payment is provided in the last table of the economic evaluation report.

f. For each year of operation calculate the amount of depreciation. Three methods of depreciation calculations are available, straight line, declining balance, and sum of the years digit. In the operating cost and profitability analysis tables, the depreciation term is calculated using the straight line method. All three depreciation methods are available for the cash flow analysis calculations. The user specifies the salvage value, f, as a fraction of DFC, and the depreciation period, n. The book value of DFC (amount of DFC that has not been depreciated) at the end of year j is denoted by V_j (V_o = DFC). Based on these quantities, the annual depreciation for year j, D_j, can be calculated based on one of the following three options:

1. Straight Line:

$$D_j = \frac{V_o(1-f)}{n}$$

2. Declining Balance: For the first years,

$$D_j = \frac{2}{n} V_{j-1},\ V_j = V_{j-1} - D_j$$

For the last year, $D_n = V_{n-1} - V_o f$

3. Sum of the Years Digit:

$$D_j = V_o (1 - f) \frac{2\,(n + 1 - j)}{n\,(n + 1)}$$

g. For each year of operation, calculate the taxable income as:
taxable income = gross profit - (loan payments + depreciation).

h. For each year of operation calculate the net profit as:
net profit = taxable income - taxes + depreciation.

i. Finally, for each year of the project, the net cash flow is calculated as:
net cash flow = net profit + capital expenditures.

The *net present value* (NPV) of the project is calculated for three different interest rates using the following formula:

$$NPV = \sum_{k=1}^{n} \frac{CF_k}{(1+i)^k}$$

where i is the interest rate, CF_k is the net cash flow in year k, and n is the project lifetime (in number of years).

The *internal rate of return* (IRR) which is also known as *discounted cash rate of return* (DCRR) is calculated based on cash flows before and after income taxes. The method is analogous to the NPV method, but instead of asking what the NPV is for a prescribed interest rate, we seek a value of the interest rate which will make the NPV of all the cash flows just equal to zero.

NOTES: **a.** The time schedule used to describe the DFC outlay can span up to five years.

b. Taxes are calculated based on the taxable income for the year and the tax coefficient as supplied in the **Edit/Flowsheet Options/Economic Evaluation Parameters...** dialog. No tax is assessed for years where the cumulative net profit is negative.

c. The positive capital expenditure in the final year of the project is due to the salvage value of equipment and the return of the working capital.

8.4 References

Valle-Riestra, J. F. *Project Evaluation in the Chemical Process Industries*. McGraw-Hill, NY, 1983.

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