Chapter 5
Performance Evaluation

The performance evaluation is of vital importance to determine the effectiveness of both the search methods and the optimization parameters. Likewise, the performance evaluation allows us to evaluate if the selected decision variables have a considerable impact on the final result of the optimization and if the search range is adequate. This performance evaluation is achieved through one or several objective functions that the different search algorithms will try to satisfy at the same time as the restrictions specified by the user.

As it is mentioned above, the objective function is an equation in which is reflected the performance of the process that is being optimized; it is achieving its maximum or its minimum value by manipulating the variables of dissolution and considering the established search restrictions.

5.1 Objective Functions

It should be noted that there are many and varied ways to calculate an objective function; this will depend on what the user seeks. Next, some of the main objective functions commonly used in optimization will be described.

5.1.1 Net Present Value

A very common way of objective function is the net present value (NPV), which is an economic measure that considers the value of money over time. It is the present value of an investment's future net cash flow (= difference between the money coming in and going out) after the cost of the original investment has been subtracted (Cambridge dictionary).

J. M. Ponce-Ortega, L. G. Hernández-Pérez, *Optimization of Process Flowsheets through Metaheuristic Techniques*,
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5.1.2 Profit

Another important objective function is the profit. The profit is money that is earned in trade or business after paying the costs of producing and selling goods and services (Cambridge dictionary).

5.1.3 Capital Cost

The capital cost is the amount of money that a company must pay out in dividends to its shareholders and in interest on bonds and other loans (Cambridge dictionary).

5.2 Capital Cost Estimation Programs

There are many tools to achieve a good estimation of the capital cost. Some of which can be programmed directly by the user in different platforms. Likewise, there are some programs that are dedicated exclusively to the estimation of the capital cost and that allow obtaining good values from the requested data. Feng and Rangaiah (2011) made an evaluation of capital cost estimation programs in which five programs were compared using a set of case studies. The most popular programs for the capital cost estimation are CapCost, EconExpert, AspenTech Process Economic Analyzer (Aspen-PEA), detailed factorial method (DFP), and capital cost estimation program (CCEP).

5.2.1 CapCost

The CapCost is based on the module costing method, written in Visual Basic, and can be used for estimating preliminary process cost. Bare module cost (CBM) is defined as the sum of the direct and indirect expenses for purchasing and installing equipment; the total module cost (CTM) is defined as the sum of the bare module cost, contingency, and fee; and the grassroots plant cost (CGR) is defined as the sum of the total module cost and the auxiliary facilities costs. To estimate the bare module cost and purchase cost of equipment, Turton et al. (2009) proposed the following:

$$C_{\mathrm{BM}} = C_p^0 \times F_{\mathrm{BM}} = C_p^0 \left(B_1 + B_2 F_{\mathrm{M}} F_{\mathrm{P}} \right) \quad (5.1)$$

$$\log C_p^0 = K_1 + K_2 \log(S) + K_3 [\log(S)]^2 \tag{5.2}$$

where S represents a parameter for the equipment size or capacity. Values for the constants B_1 and B_2, equipment-specific constants K_1, K_2, and K_3, as well as correlations and plots for F_{BM}, F_M, F_P, and Co of different equipment can be found in the appendices in Turton et al. (2009).

5.2.2 *Detailed Factorial Program (DFP)*

The detailed factorial program (DFP) is based on the detailed factorial estimates method described in Sinnott and Towler (2009). For this program, the purchase cost, C_p^0, of the major equipment items is estimated using the following:

$$C_p^0 = a + bS^n \tag{5.3}$$

Cost constants a and b, available in Sinnott and Towler (2009) for different equipment items, are mainly for carbon-steel material.

5.2.3 *Capital Cost Estimation Program (CCEP)*

Capital cost estimation program (CCEP) uses cost correlations in Seider et al. (2010) for estimation of free-on-board purchase cost of equipment. The material factor and Guthrie's bare module factor are used thereafter to estimate the installed cost of that equipment. Seider et al. (2010) developed the purchase cost correlations for common process equipment, based on available literature sources and vendor data. A list of these cost correlations can be found in Seider et al. (2010), using CEPCI = 500. The purchase cost of the major equipment items is estimated using the following:

$$C_p^0 = e\left\{A_0 + A_1 [\ln(S)] + A_2 [\ln(S)]^2 + \cdots\right\} \tag{5.4}$$

Values of constants A_0, A_1, and A_2 for various equipment items can be found in Seider et al. (2010). CCEP and DFP were developed in Microsoft Excel and Visual Basic environments, by Wong (2010) and Huang (2010), respectively, as part of research projects supervised by the second author (these programs can be obtained from the authors).

5.2.4 EconExpert

EconExpert is a Web-based interactive software for capital cost estimation (Vasudevan and Agrawal 1999). Similar to CapCost, the equipment module costing method is used to calculate bare module cost and total module cost from the purchase cost of equipment. The purchase cost data and bare module factors used can be found in Ulrich and Vasudevan (2004). In this book, the cost data are expressed in graphical form, whereas in EconExpert, the plots are represented as polynomial equations for calculation of the purchase cost. Multiple regression is used to fit the data if the purchase cost is dependent on more than one variable. The cost data and correlations in EconExpert are for a CEPCI of 400 (Ulrich and Vasudevan 2004).

5.2.5 AspenTech Process Economic Analyzer (Aspen-PEA)

AspenTech Process Economic Analyzer (Aspen-PEA) is built on Aspen Icarus technology and is designed to generate both conceptual and detailed estimates (AspenTech 2009). It takes a unique approach, representing equipment by comprehensive design-based installation models. Aspen-PEA claims to contain time-proven, field-tested, industry-standard cost modeling and scheduling methods (AspenTech 2009).

5.3 Nomenclature

A_0, A_1, and A_2	Values of constants
B_1 and B_2	Values for constants
CBM	Bare module cost
CCEP	Capital cost estimation program
CGR	Grassroots plant cost
CTM	Total module cost
DFP	Detailed factorial method
F_{BM}, F_M, F_P, and Co	Correlations for different equipment
K_1, K_2, and K_3	Equipment-specific constants
PEA	Process Economic Analyzer
S	Parameter for the equipment size or capacity