Process Equipment Cost Estimating by Ratio and Proportion

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Course Overview

Students of this one-hour course will be provided with two simple methods to arrive at approximate equipment costs during preliminary estimate preparation.

Learning Objective

At the conclusion of this course the student will:

- Understand the applicability of ratio and proportion estimating methods;
- Learn the technique to factor costs to correspond to varying equipment sizes and capacities;
- Learn the technique to escalate or otherwise adjust historical costs.

Intended Audience

This course is intended for anyone involved with cost estimate generation.

Benefits for Attendees

This course will provide new methods of estimating for some and refresher information for others. The course material can be used as a reference source for actual future situations.

The course includes a true-false test at the end.

Introduction

This course provides the student with an understanding of the estimating technique known as *The Rule of Six-tenths* and when appropriate, use of this rule in combination with cost indices. The various types of estimates are discussed as prerequisite background. Equations are provided to enable the student to escalate or otherwise adjust historical equipment cost data.

Content

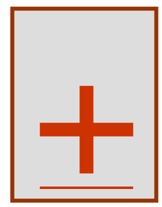
Cost Estimate Types and Accuracy

Regardless of accuracy, capital cost estimates are typically made-up of direct and indirect costs. Indirect costs consist of project services, such as overhead and profit, and engineering and administrative fees. Direct costs are construction items for the project and include property, equipment, and materials. This course deals with the equipment component of direct cost.

In order for the student to fully understand the applicability of ratio and proportion estimating, it will be helpful to list the types of estimates that exist. Cost estimates fall into the following categories and generally accepted accuracy:

- Order of Magnitude (OME) estimate ± 50%
- Study estimate ± 30%
- Preliminary (budget, scope) estimate ± 20%
- Definitive estimate ± 10%
- Detailed estimate ± 5%

As the names imply, the main difference between these types of estimates is their accuracy. The first three types serve as a cost indicator at a very early stage of the project design stage. They are developed with a minimum amount of detailed engineering and advise a client or a management group of that first look at project cost. The preparation of a preliminary estimate is done by an estimator based on his assessment of the design, past cost estimates, in-house estimating information, and previous contracts and purchase orders. It is not normal to obtain formal quotations from equipment manufactures in support of a preliminary estimate. Informal telephone *budget* quotations on identified major equipment such as vessels, filters, *etc.* are acceptable. However, even these types of "expedient" quotations can prove to be time restrictive to obtain sometimes. Even with the advent of sophisticated estimating software it is sometimes simply easier to manually approximate an equipment cost. That is the subject of this course.



Definitive and detailed cost estimates are full-blown exercises that are undertaken to produce a competitive bid submission or otherwise produce an accurate (plus or minus 10% or better) cost estimate, for say, a corporation's management approval for appropriation of funds. The ratio and proportion methods presented in this course would not be normally suitable for inclusion in a definitive estimate.

The equipment cost estimating methods that will be outlined in this course are suitable for use with the first three types of estimates; definitive and detail estimates require formal, firm equipment cost quotations from equipment manufacturers and suppliers.

Ratio and proportion estimating

A ratio indicates the relationship between two (or more) things in quantity, amount, or size. Proportion implies that two (or more) items are similar, differing only in magnitude. Using these well-known mathematical tools is a simple process.

When preparing preliminary estimates, two methods for estimating the cost of equipment are the *Rule of Six-tenths* and the use of cost indices to adjust historic costs to current prices. Each will be discussed and a single example will be offered to demonstrate the use of both.

The Rule of Six-tenths

Approximate costs can be obtained if the cost of a similar item of different size or capacity is known. A rule of thumb developed over the years known as the *rule of six-tenths* gives very satisfactory results when only an approximate cost within plus or minus 20% is required. An exhaustive search in conjunction with the development of this course left this author with no indication of any single individual who developed this concept. One is forced to assume that the relationship naturally evolved in the public domain after large quantities of actual cost data were analyzed retrospectively. The earliest mention of this concept was found in a reference accredited to a December 1947 *Chemical Engineering* magazine article by Roger Williams, Jr. entitled “Six-tenths Factor Aids in Approximating Costs”.

$$(ratio)^{0.6}$$

At any rate, the following equation expresses the *rule of six-tenths*:

$$C_B = C_A \left(\frac{S_B}{S_A} \right)^{0.6}$$

Where C_B = the approximate cost ($) of equipment having size S_B (cfm, Hp, ft^2, or whatever)
C_A = is the known cost ($) of equipment having corresponding size S_A (same units as S_B),
and S_B/S_A is the ratio known as the *size factor*, dimensionless.

The "N" exponent

An analysis of the cost of individual pieces of equipment shows that the size factor's exponent will vary from 0.3 to unity, but the average is very near to 0.6, thus the name for the rule of thumb. If a higher degree of sophistication is sought, Table 1 below can be used. It lists the value of a *size exponent* for various types of process equipment. The Table 1 values have been condensed from a vast, comprehensive tabulation of estimating cost data presented in the March 24, 1969 issue of *Chemical Engineering* magazine. This article by K.M. Guthrie is entitled "Data and Techniques for Preliminary Capital Cost Estimating". While the source for the concept and the presented exponential data is somewhat dated, *i.e.*1947 and 1969 respectively, there is indication that this material is still relevant and valid.

Using Table 1 size exponents transforms the previously presented formula into,

$$C_B = C_A \left(\frac{S_B}{S_A} \right)^N$$

Where the symbols are identical to those already described and *N* is the *size exponent*, dimensionless, from Table 1:

PROCESS EQUIPMENT SIZE EXPONENT (N) - TABLE 1		
EQUIPMENT NAME	UNIT	SIZE EXPONENT (N)
Agitator, propeller	Hp	0.50
Agitator, turbine	Hp	0.30
Air compressor, single stage	cfm	0.67
Air compressor, multiple stage	cfm	0.75
Air dryer	cfm	0.56
Boiler, industrial, all sizes	lb/hr	0.50
Boiler, package	lb/hr	0.72
Centrifuge, horizontal basket	dia (inches)	1.72
Centrifuge, solid bowl	dia (inches)	1.00
Conveyor, belt	feet	0.65
Conveyor, bucket	feet	0.77
Conveyor, screw	feet	0.76
Conveyor, vibrating	feet	0.87
Crystallizer, growth	ton/day	0.65
Crystallizer, forced circulation	ton/day	0.55
Crystallizer, batch	gallons	0.70

PROCESS EQUIPMENT SIZE EXPONENT (N) - TABLE 1		
EQUIPMENT NAME	UNIT	SIZE EXPONENT (N)
Dryer, drum and rotatory	sq. ft.	0.45
Dust collector, cyclone	cfm	0.80
Dust collector, cloth filter	cfm	0.68
Dust collector, precipitator	cfm	0.75
Evaporator, forced circulation	sq. ft.	0.70
Evaporator, vertical and horizontal tube	sq. ft.	0.53
Fan	Hp	0.66
Filter, plate and press	sq. ft.	0.58
Filter, pressure leaf	sq. ft.	0.55
Heat exchanger, fixed tube	sq. ft.	0.62
Heat exchanger, U-tube	sq. ft.	0.53
Mill, ball and roller	ton/hr	0.65
Mill, hammer	ton/hr	0.85
Pump, centrifugal carbon steel	Hp	0.67
Pump, centrifugal stainless steel	Hp	0.70
Tanks and vessels, pressure, carbon steel	gallons	0.60
Tanks and vessels, horizontal, carbon steel	gallons	0.50
Tanks and vessels, stainless steel	gallons	0.68

Cost Indices

The names and purpose of today's cost indices are too numerous to mention. Probably the most widely known cost index to the general public is the Consumer Price Index (CPI) generated by the U.S. Department of Labor, Bureau of Labor Statistics. While the CPI could probably serve our needs, more specific data is available for use in engineering and technical applications.

Cost indices are useful when basing the approximated cost on other than current prices. If the known cost of a piece of equipment is based on, for instance 1998 prices, this cost must be multiplied by the ratio of the present day index to the 1998 base index in order to proportion the value to present day dollars. (Incidentally, the inverse of this operation can be performed to estimate what a given piece of equipment would have cost in some prior time). Mathematically, this looks like,

$$C = C_O \left(\frac{I}{I_O} \right)$$

Where C = current cost, dollars
C_O = base cost, dollars
I = current index, dimensionless
I_O = base index, dimensionless

Many sources exist for technical indices but two of the more popular ones which are readily available are those published monthly in *Chemical Engineering* magazine under "Economic Indicators, Chemical Engineering Plant Cost Index (CEPCI)" and weekly in *Engineering News Record* magazine under "Market Trends". Both work equally well but as with other indices, they cannot be used interchangeably. Incidentally, current *Engineering New Record* cost information is accessible on the Internet at www.enr.com. Click on the ECONOMICS file tab and select either "Current Costs" or "Historical Indices". Unfortunately no free cost index information is offered at the *Chemical Engineering* magazine website.

About the CEPCI number

Since we will be using the CEPCI value in an example, let's examine its makeup. The index was established in the early 1960s using the period of 1957-1959 as a base of 100. According to Couper[1] the value of the CEPCI index number is weighted approximately 61% toward equipment and machinery. Of that portion, fully 85% of the value comprises process equipment. These heavily weighted component values bode well for escalating chemical process equipment costs.

The U.S. Department of Energy published the summary table of historical CEPCI data[2] show here:

HISTORICAL CECPI TABLE 2[2]

YEAR	ANNUAL AVERAGE
1957-59	100
1964	103
1965	104
1970	126
1975	182
1980	261
1985	325
1990	357.6
1995	381.1
1996	381.8
1997	386.5
1998	389.5
1999	390.6
2000	394.1
2001	394.3

Let us take an illustrative example:

The following example illustrates a combined use of both of these ratio and proportion methods to produce an approximate cost. Please note that the costs presented here are purely hypothetical and should not be used as a basis for anything other than an illustration.

Let us assume that a rough estimate is being prepared for a project in which a 5,000-gallon capacity stainless steel pressure vessel is involved. Let us further assume that our past project purchasing data shows that a 2,000-gallon stainless steel pressure vessel, very similar to that currently required, was purchased in 2001 for $15,000.

We now have all of the necessary components to approximate the present day cost (C_B) of a 5,000-gallon vessel. We have, two dates, past and of course current; two known capacities (S_B and S_A); and one historical cost (C_O) (that of the 2001 purchased vessel).

The first step is to determine the cost index for our two dates. Referring to Table 2, the CECPI index for 2001 is found to be 394.3 (our base index for this example). Consulting a recent issue of *Chemical Engineering* magazine, the CECPI index for 2006 is found to be 499.6 (the current index for this example). The student may be interested to know that the CECPI base of 1959 = 100 provides an astonishing indication of the amount of inflation that has taken place.

This complied data allows us to substitute,

$$C = C_O \left(\frac{I}{I_O} \right) = (\$15{,}000)\left(\frac{499.6}{394.3} \right) = \$19{,}005$$

Therefore, the 2006 cost of the 2,000-gallon capacity vessel is estimated to be $19,005.

Now, having determined the current estimated cost of the smaller capacity vessel, we need to adjust this amount to correspond to the larger volume (5,000 gallons). Referring to Table 1, we find a size exponent corresponding to stainless steel vessels equal to 0.68. Substituting in the equation presented earlier results in,

$$C_B = C_A \left(\frac{S_B}{S_A} \right)^N = (\$19{,}005)\left(\frac{5{,}000}{2{,}000} \right)^{0.68} = \$35{,}438$$

The unit, ten, and hundred places in this figure are irrelevant. A "rough" estimate of $35,438 is ridiculous and implies a degree of accuracy that has no basis in this case; $35,000 is more sensible and just as likely to be correct in the context of a plus or minus 20% estimate.

Therefore, the approximate 2006 cost of the 5,000-gallon capacity vessel is $35,000.

Summary

While there may be sophisticated software available to generate accurate cost estimates, we should never lose sight of the importance of understanding the basis for costs. Never let computer output cloud simple estimating judgment.

It is novel to be armed with simple, quick, easy to understand techniques to arrive at approximate equipment costs. The Rule of Six-tenths and the use of cost indices are two readily available and easy to use ratio and proportion methods to quickly estimate equipment costs.

References

1. Couper, J.R., *Process Engineering Economics*, Chapter 4, page 70, CRC Press, Boca Raton, FL, 2002.
2. Loh, H.P., U.S. Department of Energy National Energy Technology Center, *Final Report-Process Equipment Cost Estimation*, DOE/NETL-2002/1169, Table 9, page 49, January 2002.