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Construction Estimating

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1.1 Introduction

The preparation of estimates represents one of the most important functions performed in any business enterprise. In the construction industry, the quality of performance of this function is paramount to the success of the parties engaged in the overall management of capital expenditures for construction projects. The estimating process, in some form, is used as soon as the idea for a project is conceived. Estimates are prepared and updated continually as the project scope and definition develops and, in many cases, throughout construction of the project or facility.

The parties engaged in delivering the project continually ask themselves "What will it cost?" To answer this question, some type of estimate must be developed. Obviously, the precise answer to this question cannot be determined until the project is completed. Posing this type of question elicits a finite answer from the estimator. This answer, or estimate, represents only an approximation or expected value for the cost. The eventual accuracy of this approximation depends on how closely the actual conditions and specific details of the project match the expectations of the estimator.

Extreme care must be exercised by the estimator in the preparation of the estimate to subjectively weigh the potential variations in future conditions. The estimate should convey an assessment of the accuracy and risks.

1.2 Estimating Defined

Estimating is a complex process involving collection of available and pertinent information relating to the scope of a project, expected resource consumption, and future changes in resource costs. The process involves synthesis of this information through a mental process of visualization of the constructing process for the project. This visualization is mentally translated into an approximation of the final cost.

At the outset of a project, the estimate cannot be expected to carry a high degree of accuracy, because little information is known. As the design progresses, more information is known, and accuracy should improve.

Estimating at any stage of the project cycle involves considerable effort to gather information. The estimator must collect and review all of the detailed plans, specifications, available site data, available resource data (labor, materials, and equipment), contract documents, resource cost information, pertinent government regulations, and applicable owner requirements. Information gathering is a continual process by estimators due to the uniqueness of each project and constant changes in the industry environment.

Unlike the production from a manufacturing facility, each product of a construction firm represents a prototype. Considerable effort in planning is required before a cost estimate can be established. Most of the effort in establishing the estimate revolves around determining the approximation of the cost to produce the one-time product.

The estimator must systematically convert information into a forecast of the component and collective costs that will be incurred in delivering the project or facility. This synthesis of information is accomplished by mentally building the project from the ground up. Each step of the building process should be accounted for along with the necessary support activities and embedded temporary work items required for completion.

The estimator must have some form of systematic approach to ensure that all cost items have been incorporated and that none have been duplicated. Later in this chapter is a discussion of alternate systematic approaches that are used.

The quality of an estimate depends on the qualifications and abilities of the estimator. In general, an estimator must demonstrate the following capabilities and qualifications:

- Extensive knowledge of construction
- Knowledge of construction materials and methods
- Knowledge of construction practices and contracts
- Ability to read and write construction documents
- Ability to sketch construction details
- Ability to communicate graphically and verbally
- Strong background in business and economics
- Ability to visualize work items
- Broad background in design and code requirements

Obviously, from the qualifications cited, estimators are not born but are developed through years of formal or informal education and experience in the industry. The breadth and depth of the requirements for an estimator lend testimony to the importance and value of the individual in the firm.

1.3 Estimating Terminology

There are a number of terms used in the estimating process that should be understood. AACE International (formerly the American Association of Cost Engineers) developed a glossary of terms and definitions in order to have a uniform technical vocabulary. Several of the more common terms and definitions are given below.

1.4 Types of Estimates

There are two broad categories for estimates: conceptual (or approximate) estimates and detailed estimates. Classification of an estimate into one of these types depends on the available information, the extent of effort dedicated to preparation, and the use for the estimate. The classification of an estimate into one of these two categories is an expression of the relative confidence in the accuracy of the estimate.

Conceptual Estimates

At the outset of the project, when the scope and definition are in the early stages of development, little information is available, yet there is often a need for some assessment of the potential cost. The owner needs to have a rough or approximate value for the project's cost for purposes of determining the economic desirability of proceeding with design and construction. Special quick techniques are usually employed, utilizing minimal available information at this point to prepare a conceptual estimate. Little effort is expended to prepare this type of estimate, which often utilizes only a single project parameter, such as square feet of floor area, span length of a bridge, or barrels per day of output. Using available, historical cost information and applying like parameters, a quick and simple estimate can be prepared. These types of estimates are valuable in determining the order of magnitude of the cost for very rough comparisons and analysis but are not appropriate for critical decision making and commitment.

Many situations exist that do not warrant or allow expenditure of the time and effort required to produce a detailed estimate. Feasibility studies involve elimination of many alternatives prior to any detailed design work. Obviously, if detailed design were pursued prior to estimating, the cost of the feasibility study would be enormous. Time constraints may also limit the level of detail that can be employed. If an answer is required in a few minutes or a few hours, then the method must be a conceptual one, even if detailed design information is available.

Conceptual estimates have value, but they have many limitations as well. Care must be exercised to choose the appropriate method for conceptual estimating based on the available information. The estimator must be aware of the limitations of his estimate and communicate these limitations so that the estimate is not misused. Conceptual estimating relies heavily on past cost data, which is adjusted to reflect current trends and actual project economic conditions.

The accuracy of an estimate is a function of time spent in its preparation, the quantity of design data utilized in the evaluation, and the accuracy of the information used. In general, more effort and more money produce a better estimate, one in which the estimator has more confidence regarding the accuracy of his or her prediction. To achieve significant improvement in accuracy requires a larger-than-proportional increase in effort. Each of the three conceptual levels of estimating has several methods that are utilized, depending on the project type and the availability of time and information.

Order of Magnitude

The order-of-magnitude estimate is by far the most uncertain estimate level used. As the name implies, the objective is to establish the order of magnitude of the cost, or more precisely, the cost within a range of +30 to –50%.

Various techniques can be employed to develop an order-of-magnitude estimate for a project or portion of a project. Presented below are some examples and explanations of various methods used.

Rough Weight Check

When the object of the estimate is a single criterion, such as a piece of equipment, the order-of-magnitude cost can be estimated quickly based on the weight of the object. For the cost determination, equipment can be grouped into three broad categories:

1. Precision/computerized/electronic
2. Mechanical/electrical
3. Functional

Precision equipment includes electronic or optical equipment such as computers and surveying instruments. Mechanical/electrical equipment includes pumps and motors. Functional equipment might include heavy construction equipment, automobiles, and large power tools. Precision equipment tends to cost ten times more per pound than mechanical/electrical equipment, which in turn costs ten times per pound more than functional equipment. Obviously, if you know the average cost per pound for a particular class of equipment (e.g., pumps), this information is more useful than a broad category estimate. In any case, the estimator should have a feel for the approximate cost per pound for the three categories so that quick checks can be made and order-of-magnitude estimates performed with minimal information available. Similar approaches using the capacity of equipment, such as flow rate, can be used for order-of-magnitude estimates.

Cost Capacity Factor

This quick method is tailored to the process industry. It represents a quick shortcut to establish an order-of-magnitude estimate of the cost. Application of the method involves four basic steps:

1. Obtain information concerning the cost (C_1 or C_2) and the input/output/throughput or holding capacity (Q_1 or Q_2) for a project similar in design or characteristics to the one being estimated.
2. Define the relative size of the two projects in the most appropriate common units of input, output, throughput, or holding capacity. As an example, a power plant is usually rated in kilowatts of output, a refinery in barrels per day of output, a sewage treatment plant in tons per day of input, and a storage tank in gallons or barrels of holding capacity.
3. Using the three known quantities (the sizes of the two similar plants in common units and the cost of the previously constructed plant), the following relationship can be developed:

$$C_1/C_2 = \left(Q_1/Q_2\right)^x$$

   where x is the appropriate cost capacity factor. With this relationship, the estimate of the cost of the new plant can be determined.
4. The cost determined in the third step is adjusted for time and location by applying the appropriate construction cost indices. (The use of indices is discussed later in this chapter.)

The cost capacity factor approach is also called the *six-tenths rule*, because in the original application of the exponential relationship, x was determined to be equal to about 0.6. In reality, the factors for various processes vary from 0.33 to 1.02 with the bulk of the values for x around 0.6.

Example 1

Assume that we have information on an old process plant that has the capacity to produce 10,000 gallons per day of a particular chemical. The cost today to build the plant would be $1,000,000. The appropriate cost factor for this type of plant is 0.6. An order-of-magnitude estimate of the cost is required for a plant with a capacity of 30,000 gallons per day.

$$C = \$1,000,000\left(30,000/10,000\right)^{0.6} = \$1,930,000$$

Comparative Cost of Structure

This method is readily adaptable to virtually every type of structure, including bridges, stadiums, schools, hospitals, and offices. Very little information is required about the planned structure except that the following general characteristics should be known:

1. Use — school, office, hospital, and so on
2. Kind of construction — wood, steel, concrete, and so on
3. Quality of construction — cheap, moderate, top grade
4. Locality — labor and material supply market area
5. Time of construction — year

By identifying a similar completed structure with nearly the same characteristics, an order-of-magnitude estimate can be determined by proportioning cost according to the appropriate unit for the structure. These units might be as follows:

1. Bridges — span in feet (adjustment for number of lands)
2. Schools — pupils

3. Stadium — seats
4. Hospital — beds
5. Offices — square feet
6. Warehouses — cubic feet

Example 2

Assume that the current cost for a 120-pupil school constructed of wood frame for a city is $1,800,000. We are asked to develop an order-of-magnitude estimate for a 90-pupil school.

Solution. The first step is to separate the per-pupil cost.

$$\$1{,}800{,}000/120 = \$15{,}000/\text{pupil}$$

Apply the unit cost to the new school.

$$\$15{,}000/\text{pupil} \text{ ¥ } 90 \text{ pupils} = \$1{,}350{,}000$$

Feasibility Estimates

This level of conceptual estimate is more refined than the order-of-magnitude estimate and should provide a narrower range for the estimate. These estimates, if performed carefully, should be within ±20 to 30%. To achieve this increase in accuracy over the order-of-magnitude estimate requires substantially more effort and more knowledge about the project.

Plant Cost Ratio

This method utilizes the concept that the equipment proportion of the total cost of a process facility is about the same, regardless of the size or capacity of the plant, for the same basic process. Therefore, if the major fixed equipment cost can be estimated, the total plant cost can be determined by factor multiplication. The plant cost factor or multiplier is sometimes called the Lang factor (after the man who developed the concept for process plants).

Example 3

Assume that a historical plant with the same process cost $2.5 million, with the equipment portion of the plant costing $1 million. Determine the cost of a new plant if the equipment has been determined to cost $2.4 million.

$$C = 2.4/\left(1.0/2.5\right)$$

$$C = 6 \text{ million dollars}$$

Floor Area

This method is most appropriate for hospitals, stores, shopping centers, and residences. Floor area must be the dominant attribute of cost (or at least it is assumed to be by the estimator). There are several variations of this method, a few of which are explained below.

Total Horizontal Area

For this variation, it is assumed that cost is directly proportional to the development of horizontal surfaces. It is assumed that the cost of developing a square foot of ground-floor space will be the same as a square foot of third-floor space or a square foot of roof space. From historical data, a cost per square foot is determined and applied uniformly to the horizontal area that must be developed to arrive at the total cost.

Example 4

Assume that a historical file contains a warehouse building that cost $2.4 million that was 50 ft ¥ 80 ft with a basement, three floors, and an attic. Determine the cost for a 60 ft ¥ 30 ft warehouse building with no basement, two floors, and an attic.

Solution. Determine the historical cost per square foot.

Basement area	4000
1st floor	4000
2nd floor	4000
3rd floor	4000
Attic	4000
Roof	4000
TOTAL	24,000

$$\$2,400,000/24,000 = \$100/\text{ft}^2$$

Next, calculate the total cost for the new project.

1st floor	1800
2nd floor	1800
Attic	1800
Roof	1800
TOTAL	7200

$$7200\ \text{ft}^2\ \text{¥}\ \$100/\text{ft}^2 = \$720,000$$

Finished Floor Area

This method is by far the most widely used approach for buildings. With this approach, only those floors that are finished are counted when developing the historical base cost and when applying the historical data to the new project area. With this method, the estimator must exercise extreme care to have the same relative proportions of area to height to avoid large errors.

Example 5

Same as the preceding example.

Solution. Determine historical base cost.

1st floor	4000
2nd floor	4000
3rd floor	4000
TOTAL	12,000 ft^2fa

$$\$2,400,000/12,000 = \$200/\text{ft}^2\text{fa}$$

where ft^2fa is square feet of finished floor area.

Next, determine the total cost for the new project.

1st floor	1800
2nd floor	1800
TOTAL	3600 ft^2fa

$$3600\ \text{ft}^2\text{fa}\ \text{¥}\ \$200/\text{ft}^2\text{fa} = \$720,000$$

As can be seen, little difference exists between the finished floor area and total horizontal area methods; however, if a gross variation in overall dimensions had existed between the historical structure and the new project, a wider discrepancy between the methods would have appeared.

Cubic Foot of Volume Method

This method accounts for an additional parameter that affects cost: floor-to-ceiling height.

Example 6

The same as the preceding two examples, except that the following ceiling heights are given:

	Old Structure	New Structure
1st floor	14	12
2nd floor	10	12
3rd floor	10	—

Solution. Determine the historical base cost.

$$\begin{aligned} 14 \text{ ¥ } 4000 &= 56{,}000 \text{ ft}^3 \\ 10 \text{ ¥ } 4000 &= 40{,}000 \text{ ft}^3 \\ 10 \text{ ¥ } 4000 &= 40{,}000 \text{ ft}^3 \\ \text{TOTAL} &= 136{,}000 \text{ ft}^3 \end{aligned}$$

$$\$2{,}400{,}000/136{,}000 \text{ ft}^3 = \$17.65/\text{ft}^3$$

Next, determine the total cost for the new warehouse structure.

$$\begin{aligned} &\text{1st floor} \quad 1800 \text{ ft}^2 \text{ ¥ } 12 \text{ ft} = 21{,}600 \text{ ft}^3 \\ &\text{2nd floor} \quad 1800 \text{ ft}^2 \text{ ¥ } 12 \text{ ft} = 21{,}600 \text{ ft}^3 \\ &\text{TOTAL} \qquad\qquad\qquad\quad = 43{,}200 \text{ ft}^3 \end{aligned}$$

$$43{,}200 \text{ ft}^3 \text{ ¥ } \$17.65/\text{ft}^3 = \$762{,}500$$

Appropriation Estimates

As a project scope is developed and refined, it progresses to a point where it is budgeted into a corporate capital building program budget. Assuming the potential benefits are greater than the estimated costs, a sum of money is set aside to cover the project expenses. From this process of appropriation comes the name of the most refined level of conceptual estimate. This level of estimate requires more knowledge and effort than the previously discussed estimates.

These estimating methods reflect a greater degree of accuracy. Appropriation estimates should be between ±10 to 20%. As with the other forms of conceptual estimates, several methods are available for preparing appropriation estimates.

Parametric Estimating/Panel Method

This method employs a database in which key project parameters, project systems, or panels (as in the case of buildings) that are priced from past projects using appropriate units are recorded. The costs of each parameter or panel are computed separately and multiplied by the number of panels of each kind. Major unique features are priced separately and included as separate line items. Numerous parametric systems exist for different types of projects. For process plants, the process systems and piping are the parameters. For buildings, various approaches have been used, but one approach to illustrate the method is as follows:

Parameter	Unit of Measure
Site work	Square feet of site area
Foundations and columns	Building square feet
Floor system	Building square feet
Structural system	Building square feet
Roof system	Roof square feet
Exterior walls	Wall square feet minus exterior windows
Interior walls	Wall square feet (interior)
HVAC	Tons or Btu
Electrical	Building square feet
Conveying systems	Number of floor stops
Plumbing	Number of fixture units
Finishes	Building square feet

Each of these items would be estimated separately by applying the historical cost for the appropriate unit for similar construction and multiplying by the number of units for the current project. This same approach is used on projects such as roads. The units or parameters used are often the same as the bid items, and the historical prices are the average of the low-bid unit prices received in the last few contracts.

Bay Method

This method is appropriate for buildings or projects that consist of a number of repetitive or similar units. In the plan view of a warehouse building shown in Fig. 1.1, the building is made up of three types of bays. The only difference between them is the number of outside walls. By performing a definitive estimate of the cost of each of these bay types, an appropriation estimate can be made by multiplying this bay cost times the number of similar bays and totaling for the three bay types.

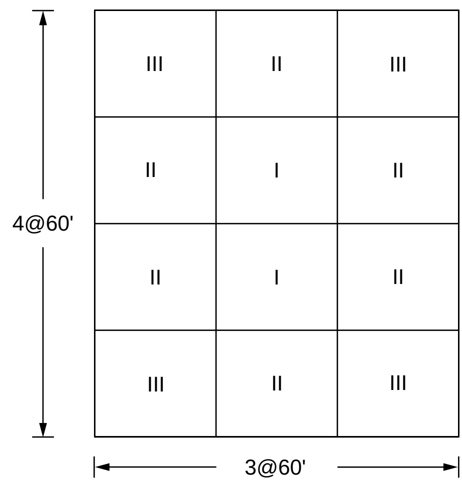

FIGURE 1.1 Plan view — warehouse building.

Example 7

We know from a definitive estimate that the cost of the three bay types is as follows:

Type I = $90,000
Type II = $120,000
Type III = $150,000

Determine the cost for the building structure and skin (outer surface).

Solution.

2 Type I @ 90,000	=	$180,000
6 Type II @ 120,000	=	$720,000
4 Type III @ 150,000	=	$600,000
TOTAL	=	$1,500,000

After applying the bay method for the overall project, the estimate is modified by making special allowances (add-ons) for end walls, entrances, stairs, elevators, and mechanical and electrical equipment.

Plant Component Ratio

This method requires a great deal more information than other methods used in the process industry. Definitive costs of the major pieces of equipment are needed. These can be determined from historical records or published data sources. Historical records also provide the data that identifies the relative percentage of all other items. The total project cost is then estimated as follows:

$$TPC = \frac{ET}{1 - PT}$$

where TPC = total plant cost
ET = total estimated equipment cost
PT = sum of percentages of other items or phases (major account divisions).

Example 8

The total equipment cost for a plant is estimated to be \$500,000. The following percentages represent the average expenditures in other cost phases:

Engineering, overhead, and fees	22%
Warehousing	5%
Services	2%
Utilities	6%
Piping	20%
Instrumentation	5%
Electrical	6%
Buildings	4%
TOTAL	70% = PT

$$\frac{500{,}000}{(1.0 - 0.70)} = \$1{,}670{,}000$$

While the solution here appears simple, in fact, the majority of time and effort is spent collecting the equipment cost and choosing the appropriate percentages for application.

Time and Location Adjustments

It is often desirable when preparing conceptual estimates to utilize cost data from a different period of time or from a different location. Costs vary with time and location, and it is, therefore, necessary to adjust the conceptual estimate for the differences of time and location from the historical base. A construction cost-indexing system is used to identify the relative differences and permit adjustment.

Cost Indexing

A cost index is a dimensionless number associated with a point in time and/or location that illustrates the cost at that time or location relative to a base point in time or base location. The cost index provides a comparison of cost or cost change from year to year and/or location to location for a fixed quantity of services and commodities. The concept is to establish cost indices to avoid having to estimate all of the unique features of every project, when it is reasonable to assume that the application of relative quantities of resources is constant or will follow the use of historical data on a proportional basis without knowledge of all of the design details. If the cost index is developed correctly, the following simple relationship will exist:

$$\text{New cost/New index} = \text{Historical cost/Historical index}$$

An example of the way in which a cost index might be computed is given below. The cost elements used for developing a cost index for concrete in 1982 are as follows:

$$\begin{array}{lcr} C_1 = \text{four hours for a carpenter} & = & \$240 \\ C_2 = \text{one cubic yard concrete} & = & \$60 \\ C_3 = \text{three hours for laborer} & = & \$66 \\ C_4 = \text{100 fbm lumber (2 ¥ 10)} & = & \$49 \\ C_5 = \text{100 \# rebar} & = & \$35 \\ C_6 = \text{one hour from an ironworker} & = & \$50 \end{array}$$

$$C_a = 240 + 60 + 66 + 49 + 35 + 50 = 500$$

Calculating C_b similarly for another time or location involves the following steps:

$$\begin{array}{lcr} C_1 = \text{four hours for a carpenter} & = & \$200 \\ C_2 = \text{one cubic yard concrete} & = & \$58 \\ C_3 = \text{three hours for laborer} & = & \$90 \\ C_4 = \text{100 fbm lumber (2 ¥ 10)} & = & \$42 \\ C_5 = \text{100 \# rebar} & = & \$36 \\ C_6 = \text{one hour from an ironworker} & = & \$44 \end{array}$$

$$C_a = 200 + 58 + 90 + 42 + 36 + 44 = 470$$

Using the CI_a as the base with an index equal to 100, the CI_b index can be calculated as follows:

$$CI_b = \left(C_b / C_a\right) \text{ ¥ } 100 = \left(470/500\right) \text{ ¥ } 100 = 94$$

The key to creating an accurate and valid cost index is not the computational approach but the correct selection of the cost elements. If the index will be used for highway estimating, the cost elements should include items such as asphalt, fuel oil, paving equipment, and equipment operators. Appropriately, a housing cost index would include timber, concrete, carpenters, shingles, and other materials common to residential construction.

Most of the cost indices are normalized periodically to a base of 100. This is done by setting the base calculation of the cost for a location or time equal to 100 and converting all other indices to this base with the same divisor or multiplier.

While it is possible to develop specialized indices for special purposes, numerous indices have been published. These include several popular indices, such as the *Engineering News Record* building cost index and construction cost index and the *Means Building Construction Cost Data* construction cost index and historical cost index. These indices are developed using a wide range of cost elements. For example, the Means' construction cost index is composed of 84 construction materials, 24 building crafts' labor hours, and 9 different equipment rental charges that correspond to the labor and material items. These cost indices are tabulated for the major metropolitan areas four times each year and for the 16 major UCI construction divisions. Additionally, indices dating back to 1913 can be found to adjust costs from different periods of time. These are referred to as historical cost indices.

Application of Cost Indices

These cost indices can have several uses:

- Comparing costs from city to city (construction cost indices)
- Comparing costs from time to time (historical cost indices)

- Modifying costs for various cities and times (both)
- Estimating replacement costs (both)
- Forecasting construction costs (historical cost indices)

The cost index is only a tool and must be applied with sound judgment and common sense.

Comparing Costs from City to City

The construction cost indices can be used to compare costs between cities, because the index is developed identically for each city. The index is an indicator of the relative difference. The cost difference between cities for identical buildings or projects in a different city can be found by using the appropriate construction cost indices (CCI). The procedure is as follows:

$$\text{Cost, city A} = \frac{\text{CCI for city A}}{\text{CCI for city B}}\left(\text{Known cost, city B}\right)$$

$$\left(\text{Known cost, city B}\right) - \left(\text{Cost, city A}\right) = \text{Cost difference}$$

Comparing Costs from Time to Time

The cost indices can be used to compare costs for the same facility at different points in time. Using the historical cost indices of two points in time, one can calculate the difference in costs between the two points in time. It is necessary to know the cost and the historical index for time B and the historical cost index for time A.

$$\text{Cost, time A} = \frac{\text{HCI for time A}}{\text{HCI for time B}}\left(\text{Cost, time B}\right)$$

$$\left(\text{Known cost, time B}\right) - \left(\text{Cost, time A}\right) = \text{Cost difference}$$

Modifying Costs for Various Cities and Times

The two prior uses can be accomplished simultaneously, when it is desired to use cost information from another city and time for a second city and time estimate. Care must be exercised to establish the correct relationships. The following example illustrates the principle.

Example 9

A building cost $2,000,000 in 2000 in South Bend. How much will it cost to build in Boston in 2002?

Given: HCI, 2002 = 114.3
HCI, 2000 = 102.2
CCI, S. Bend = 123.4
CCI, Boston = 134.3

$$\frac{\left(\text{HCI, 2002}\right)\left(\text{CCI, Boston}\right)}{\left(\text{HCI, 2000}\right)\left(\text{CCI, S. Bend}\right)}\left(\text{Cost, S. Bend}\right) = \left(\text{Cost, Boston}\right)$$

$$\frac{\left(114.3\right)\left(134.3\right)}{\left(102.2\right)\left(123.4\right)}\left(2{,}000{,}000\right) = \$2,430,000$$

Estimating Replacement Costs

The historical cost index can be used to determine replacement cost for a facility built a number of years ago or one that was constructed in stages.

Example 10

A building was constructed in stages over the last 25 years. It is desired to know the 2002 replacement cost for insurance purposes. The building has had two additions since the original 1981, $300,000 portion was built. The first addition was in 1990 at a cost of $200,000, and the second addition came in 1994 at a cost of $300,000. The historical cost indices are as follows:

2002	100.0 = HCl
1994	49.8 = HCl
1990	34.6 = HCl
1981	23.9 = HCl

Solution. The cost of the original building is

$$\frac{100}{23.9}\,\$300,000 = \$1,255,000$$

The cost of addition A is

$$\frac{100}{34.6}\,\$200,000 = \$578,000$$

The cost of addition B is

$$\frac{100}{49.8}\,\$300,000 = \$602,000$$

So,

$$\text{Total replacement cost} = \$2,435,000$$

Construction Cost Forecasting

If it is assumed that the future changes in cost will be similar to the past changes, the indices can be used to predict future construction costs. By using these past indices, future indices can be forecast and, in turn, used to predict future costs. Several approaches are available for developing the future index. Only one will be presented here.

The simplest method is to examine the change in the last several historical cost indices and use an average value for the annual change in the future. This averaging process can be accomplished by determining the difference between historical indices each year and finding the average change by dividing by the number of years.

Detailed Estimates

Estimates classified as detailed estimates are prepared after the scope and definition of a project are essentially complete. To prepare a detailed estimate requires considerable effort in gathering information and systematically forecasting costs. These estimates are usually prepared for bid purposes or definitive budgeting. Because of the information available and the effort expended, detailed estimates are usually fairly accurate projections of the costs of construction. A much higher level of confidence in the accuracy of the estimate is gained through this increased effort and knowledge. These types of estimates are used for decision making and commitment.

The Estimating Process

Estimating to produce a detailed construction cost estimate follows a rigorous process made up of several key steps. These key steps are explained below.

Familiarization with Project Characteristics

The estimator must be familiar with the project and evaluate the project from three primary avenues: scope, constructibility, and risk. Having evaluated these three areas in a general way, the estimator will decide whether the effort to estimate and bid the work has a potential profit or other corporate goal potential (long-term business objective or client relations). In many cases, investigation of these three areas may lead to the conclusion that the project is not right for the contractor. The contractor must be convinced that the firm's competitive advantage will provide the needed margin to secure the work away from competitors.

Scope — Just because a project is available for bidding does not mean that the contractor should invest the time and expense required for the preparation of an estimate. The contractor must carefully scrutinize several issues of scope for the project in relation to the company's ability to perform. These scope issues include the following:

1. Technological requirements of the project
2. Stated milestone deadlines for the project
3. Required material and equipment availability
4. Staffing requirements
5. Stated contract terms and associated risk transfer
6. Nature of the competition and likelihood of an acceptable rate-of-return

The contractor must honestly assess the technological requirements of the project to be competitive and the internal or subcontractor technological capabilities that can be employed. This is especially true on projects requiring fleets of sophisticated or specialized equipment or on projects with duration times that dictate employment of particular techniques such as slipforming. On these types of projects, the contractor must have access to the fleet, as in the case of an interstate highway project, or access to a knowledgeable subcontractor, as in the case of high-rise slipforming.

The contractor must examine closely the completion date for the project as well as any intermediate contractual milestone dates for portions of the project. The contractor must feel comfortable that these dates are achievable and that there exists some degree of time allowance for contingencies that might arise. Failure to complete a project on time can seriously damage the reputation of a contractor and has the potential to inhibit future bidding opportunities with the client. If the contract time requirements are not reasonable in the contractor's mind after having estimated the required time by mentally sequencing the controlling work activities, two choices exist. The obvious first choice is to not bid the project. Alternatively, the contractor may choose to reexamine the project for other methods or sequences which will allow earlier completion. The contractor should not proceed with the estimate without a plan for timely completion of the project.

A third issue that must be examined in relation to the project's scope is availability to satisfy the requirements for major material commodities and equipment to support the project plan. Problems in obtaining structural steel, timber, quality concrete, or other materials can have pronounced effects on both the cost and schedule of a project. If these problems can be foreseen, solutions should be sought, or the project should not be considered for bidding.

Staffing requirements, including staffing qualifications as well as required numbers, must be evaluated to determine if sufficient levels of qualified manpower will be available when required to support project needs. This staffing evaluation must include supervisory and professional support and the various crafts that will be required. While the internal staffing (supervisory and professional support) is relatively simple to analyze, the craft availability is extremely uncertain and to some degree uncontrollable. With the craft labor in much of the construction industry (union sector) having no direct tie to any one construction company, it is difficult to predict how many workers of a particular craft will be available during a particular month or week. The ability to predict craft labor availability today is a function of construction economy prediction. When there is a booming construction market, some shortfalls in craft labor supply can be expected with a result of higher labor costs or longer project durations.

Constructibility — A knowledgeable contractor, having made a preliminary review of the project documents, can assess the constructibility of the project. Constructibility evaluations include examination of construction quality requirements, allowable tolerances, and the overall complexity of the project. The construction industry has general norms of quality requirements and tolerances for the various types of projects. Contractors tend to avoid bidding for projects for which the quality or tolerances specified are outside those norms. The alternative for the contractor is to overcompensate for the risk associated with achieving the requirements by increasing their expectation of cost.

Complexity of a project is viewed in terms of the relative technology requirement for the project execution compared with the technology in common practice in the given area. Where the project documents indicate an unusual method to the contractor, the contractor must choose to either accept the new technology or not bid. The complexity may also come about because of dictated logistical or scheduling requirements that must be met. Where the schedule does not allow flexibility in sequence or pace, the contractor may deem the project unsuitable to pursue through bidding.

The flexibility left to the contractor in choosing methods creates interest in bidding the project. The means and methods of work are the primary ways that contractors achieve competitive advantage. This flexibility challenges the contractor to develop a plan and estimate for the work that will be different and cheaper than the competition's.

Risk — The contractor must also evaluate the myriad of potential problems that might be encountered on the project. These risks can include the following:

- Material and workmanship requirements not specified
- Contradictory clauses interpreted incorrectly
- Impossible specifications
- Unknown or undiscovered site conditions
- Judgment error during the bidding process
- Assumption of timely performance of approvals and decisions by the owners
- Interpretation and compliance requirements with the contract documents
- Changes in cost
- Changes in sequence
- Subcontractor failure
- Suspension of work
- Weather variations
- Environmental issues
- Labor and craft availability
- Strikes and labor disputes
- Utility availability

This list represents a sample of the risks, rather than an inclusive listing. In general, a construction firm faces business risks, project risks, and operational risks, which must be offset in some way. Contract terms that transfer unmanageable risk or categories of risk that are not easily estimated discourage participation in bidding.

Contractors assess the likelihood of success in the bidding process by the number of potential competitors. Typically, more competition means lower markups. Lower markup reduces the probability for earning acceptable margins and rates of return associated with the project risks.

Examine the Project Design

Another aspect of the information important to the individual preparing the estimate is the specific design information that has been prepared. The estimator must be able to read, interpret, and understand the technical specifications, the referenced standards and any project drawings, and documents. The estimator must closely examine material specifications so that an appropriate price for the quality and characteristics specified can be obtained. The estimator must use sound judgment when pricing substitute materials for providing an assumption of "or-equal" quality for a material to be used. A thorough familiarity and technical understanding is required for this judgment. The same is also true for equipment and furnishings that will be purchased. The estimator must have an understanding of referenced documents that are commonly identified in specifications. Standards of testing and performance are made a part of the specifications by a simple reference. These standards may be client standards or more universal standards, such as State Highway Specifications or ASTM (American Society for Testing and Materials) documents. If a specification is referenced that the estimator is not familiar with, he or she must make the effort to locate and examine it prior to bid submittal.

In some cases, the specifications will identify prescribed practices to be followed. The estimator must assess the degree to which these will be rigidly enforced and where allowances will be made or performance criteria will be substituted. Use of prescriptive specifications can choke innovation by the contractor but may also protect the contractor from performance risks. Where rigid enforcement can be expected, the estimator should follow the prescription precisely.

The drawings contain the physical elements, their location, and their relative orientation. These items and the specifications communicate the designer's concept. The estimator must be able to examine the drawings and mentally visualize the project as it will be constructed to completion. The estimator relies heavily on the information provided in the drawings for determination of the quantity of work required. The drawings provide the dimensions so that lengths, widths, heights, areas, volumes, and numbers of items can be developed for pricing the work. The drawings show the physical features that will be part of the completed project, but they do not show the items that may be required to achieve completion (such as formwork). It is also common that certain details are not shown on the drawings for the contractor but are developed by shop fabricators at a later time as shop drawings.

The estimator must keep a watchful eye for errors and omissions in the specifications and drawings. Discrepancies are often identified between drawings, between specifications, or between drawings and specifications. The discrepancies must be resolved either by acceptance of a risk or through communication with the designer. The best choice of solution depends on the specifics of the discrepancy and the process or the method for award of contract.

Structuring the Estimate

The estimator either reviews a plan or develops a plan for completing the project. This plan must be visualized during the estimating process; it provides the logical flow of the project from raw materials to a completed facility. Together with the technical specifications, the plan provides a structure for the preparation of the detailed estimate. Most estimators develop the estimate around the structure of the technical specifications. This increases the likelihood that items of work are covered without duplication in the estimate.

Determine the Elements of Cost

This step involves the development of the quantities of work (a quantity survey) to be performed and their translation into expected costs. Translating a design on paper into a functioning, completed project involves the transformation and consumption of a multitude of resources. These basic ingredients or resources utilized and incorporated in a project during construction can be classified into one of the following categories:

1. Labor
2. Material
3. Equipment
4. Capital
5. Time

Associated with the use or consumption of each of these resources is a cost. It is the objective of the estimator performing a detailed estimate to identify the specific types of resources that will be used, the quantity of such resources, and the cost of the resources. Every cost item within an estimate is either one or a combination of these five basic resources. The common unit used to measure the different types of resources is dollars. Although overhead costs may not be broken down into the component resource costs, overhead items are a combination of several of these basic resources.

Labor Resources

Labor resources refer to the various human craft or skill resources that actually build a project. Through the years, large numbers of crafts have evolved to perform specialized functions and tasks in the construction industry. The specialties or crafts have been defined through a combination of collective bargaining agreements, negotiation and labor relations, and accepted extensions of trade practices. In most cases, the evolutionary process of definition of work jurisdiction has followed a logical progression; however, there are limited examples of bizarre craftwork assignment. In all, there are over 30 different crafts in the construction industry. Each group or craft is trained to perform a relatively narrow range of construction work differentiated by material type, construction process, or type of construction project. Where union construction is dominant, the assignment of work to a particular craft can become a significant issue with the potential for stopping or impeding progress. Usually in nonunion construction, jurisdictional disputes are nonexistent, and much more flexibility exists in the assignments of workers to tasks. In union construction, it is vital that the estimator acknowledge the proper craft for a task because labor wage rates can vary substantially between crafts. In nonunion construction, more managerial flexibility exists, and the critical concern to the estimator must be that a sufficient wage rate be used that will attract the more productive craftsworkers without hindering the chances of competitive award of the construction contract.

The source of construction labor varies between localities. In some cities, the only way of performing construction is through union construction. This, however, has been changing, and will most likely continue to change over the next few years. Open-shop or nonunion construction is the predominant form in many parts of the United States.

With union construction, the labor source is the hiring hall. The usual practice is for the superintendent to call the craft hiring hall for the type of labor needed and request the number of craftsworkers needed for the project. The craftsworkers are then assigned to projects in the order in which they became available for work (were released from other projects). This process, while fair to all craftsworkers, has some drawbacks for the contractor because the personnel cannot be selected based on particular past performance.

These union craftsworkers in construction have their primary affiliation with the union, and only temporarily are affiliated with a particular company, usually for the duration of a particular project. Training and qualifications for these craftsworkers must, therefore, be a responsibility of the union. This training effort provided through the union is financed through a training fund established in the collective bargaining agreement. Apprenticeship programs are conducted by union personnel to develop the skills needed by the particular craft. A second avenue for control is through admission into the union and acceptance after a trial period by the employer. The training for the craftsworker for this approach may have been in another vocational program, on-the-job experience, or a military training experience. The supply of craftsworkers in relation to the demands is thus controlled partially through admissions into the training or apprenticeship programs.

Open-shop or nonunion construction has some well-established training programs. The open-shop contractor may also rely on other training sources (union apprenticeship, vocational schools, and military training) for preparation of the craftsworker. The contractor must exercise considerable effort in screening and hiring qualified labor. Typically, craftsworkers are hired for primary skill areas but can be utilized on a much broader range of tasks. A trial period for new employees is used to screen craftsworkers for the desired level of skill required for the project. Considerably more effort is required for recruiting and maintaining a productive workforce in the open-shop mode, but the lower wage and greater flexibility in work assignments are advantages.

Cost of Labor

For a detailed estimate, it is imperative that the cost of labor resources be determined with precision. This is accomplished through a three-part process from data in the construction bidding documents that identify the nature of work and the physical quantity of work. The first step in the process involves identifying the craft that will be assigned the work and determining the hourly cost for that labor resource. This is termed the *labor rate*. The second part of the process involves estimation of the expected rate of work accomplishment by the chosen labor resource. This is termed the labor productivity. The third step involves combining this information by dividing the labor rate by the labor productivity to determine the labor resource cost per physical unit of work. The labor cost can be determined by multiplying the quantity of work by the unit labor resource cost. This entire process will be illustrated later in this chapter; however, an understanding of labor rate and labor productivity measurement must first be developed.

Labor Rate — The labor rate is the total hourly expense or cost to the contractor for providing the particular craft or labor resource for the project. This labor rate includes direct costs and indirect costs. Direct labor costs include all payments made directly to the craftsworkers. The following is a brief listing of direct labor cost components:

1. Wage rate
2. Overtime premium
3. Travel time allowance
4. Subsistence allowance
5. Show-up time allowance
6. Other work or performance premiums

The sum of these direct labor costs is sometimes referred to as the *effective wage rate*. Indirect labor costs include those costs incurred as a result of use of labor resources but which are not paid directly to the craftsworker. The components of indirect labor cost include the following:

1. Vacation fund contributions
2. Pension fund contributions
3. Group insurance premiums
4. Health and welfare contributions
5. Apprenticeship and training programs
6. Workers' compensation premiums
7. Unemployment insurance premiums
8. Social security contribution
9. Other voluntary contribution or payroll tax

It is the summation of direct and indirect labor costs that is termed the labor rate — the total hourly cost of providing a particular craft labor resource. Where a collective bargaining agreement is in force, most of these items can be readily determined on an hourly basis. Others are readily available from insurance companies or from local, state, and federal statutes. Several of the direct cost components must be estimated based on past records to determine the appropriate allowance to be included. These more difficult items include overtime, show-up time, and performance premiums. A percentage allowance is usually used to estimate the expected cost impact of such items.

Labor Productivity — Of all the cost elements that contribute to the total project construction cost, labor productivity ranks at the top for variability. Because labor costs represent a significant proportion of the total cost of construction, it is vital that good estimates of productivity be made relative to the productivity that will be experienced on the project. Productivity assessment is a complex process and not yet fully understood for the construction industry.

The following example illustrates the calculation of a unit price from productivity data.

Example 11

To form 100 square feet of wall requires 6 hours of carpenter time and 5 hours of common laborer time. This assumption is based on standards calculated as averages from historical data. The wage rate with burdens for carpenters is $60.00/h. The wage rate with burdens for common laborers is $22.00/h.

Solution. The unit cost may be calculated as follows:

Carpenter — 6 h at $60.00/h	= $360.00
Laborer — 5 h at $22.00/h	= $110.00
Total labor cost for 100 ft²	= $470.00

$$\text{Labor cost per ft}^2 = \$470.00/100\ \text{ft}^2 = \$4.70/\text{ft}^2$$

This labor cost is adjusted for the following conditions:

Weather adjustment	1.05
Job complexity	1.04
Crew experience	0.95
Management	1.00

$$\text{Adjusted unit cost} = 4.70 ¥ 1.05 ¥ 1.04 ¥ 0.95 ¥ 1.00 = \$4.88/\text{ft}^2$$

Equipment Resources

One of the most important decisions a contractor makes involves the selection of construction equipment. Beyond simple construction projects, a significant number of the activities require some utilization of major pieces of equipment. This equipment may either be purchased by the contractor or leased for the particular project at hand. The decision for selection of a particular type of equipment may be the result of an optimization process or may be based solely on the fact that the contractor already owns a particular piece of equipment that should be put to use. This decision must be anticipated or made by the estimator, in most cases, to forecast the expected costs for equipment on a project being estimated.

Equipment Selection Criteria

It is important for the estimator to have a solid background in and understanding of various types of construction equipment. This understanding is most important when making decisions about equipment. The estimator, having recognized the work to be performed, must identify the most economical choice for equipment. There are four important criteria that must be examined to arrive at the best choice:

1. Functional performance
2. Project flexibility
3. Companywide operations
4. Economics

Functional performance is only one criterion, but an important one, for the selection of construction equipment. For each activity, there is usually a clear choice based on the most appropriate piece of equipment to perform the task. Functional performance is usually examined solely from the perspective of functional performance. The usual measures are capacity and speed. These two parameters also give rise to the calculation of production rates.

A second criterion that must be used is project flexibility. Although each task has an associated, appropriate piece of equipment based on functional performance, it would not be prudent to mobilize a different piece of equipment for each activity. Equipment selection decisions should consider the multiple uses the item of equipment possesses for the particular project. The trade-off between mobilization expense and duration versus efficiency of the operation must be explored to select the best fleet of equipment for the project.

Companywide usage of equipment becomes an important factor when determining whether to purchase a particular piece of equipment for a project application. If the investment in the equipment cannot be fully justified for the particular project, then an assessment of future or concurrent usage of the equipment is necessary. This whole process necessarily influences selection decisions by the estimator because the project cost impacts must be evaluated. Equipment that can be utilized on many of the company projects will be favored over highly specialized single-project oriented equipment.

The fourth, and probably most important, criterion the estimator considers is the pure economics of the equipment selection choices. Production or hourly costs of the various equipment alternatives should be compared to determine the most economical choice for the major work tasks involving equipment. A later section in this chapter explains and illustrates the process of determining equipment costs that the estimator should follow.

Production Rates

Equipment production rates can be determined in a relatively simple fashion for the purposes of the estimator. Most manufacturers produce handbooks for their equipment that provide production rates for tasks under stated conditions.

Equipment Costs

Equipment costs represent a large percentage of the total cost for many construction projects. Equipment represents a major investment for contractors, and it is necessary that the investment generate a return to the contractor. The contractor must not only pay for the equipment purchased but also pay the many costs associated with the operation and maintenance of the equipment. Beyond the initial purchase price, taxes, and setup costs, the contractor has costs for fuel, lubricants, repairs, and so on, which must be properly estimated when preparing an estimate. A system must be established to measure equipment costs of various types to provide the estimator with a data source to use when establishing equipment costs.

The cost associated with equipment can be broadly classified as direct equipment costs and indirect equipment costs. Direct equipment costs include the ownership costs and operating expenses, while indirect equipment costs are the costs that occur in support of the overall fleet of equipment but which cannot be specifically assigned to a particular piece of equipment. Each of the broad cost categories will be discussed in greater detail in the following sections.

Direct Equipment Costs

Direct equipment expenses are costs that can be assigned to a particular piece of equipment and are usually divided into ownership and operating expenses for accounting and estimating. The concept behind this separation is that the ownership costs occur regardless of whether the equipment is used on a project.

Ownership Costs

Ownership costs include depreciation, interest, insurance, taxes, setup costs, and equipment enhancements. There are several views taken of ownership costs relating to loss in value or depreciation. One view is that income must be generated to build a sufficient reserve to replace the equipment at the new price, when it becomes obsolete or worn out. A second view is that ownership of a piece of equipment is an investment, and, as such, must generate a monetary return on that investment equal to or larger than the investment made. A third view is that the equipment ownership charge should represent the loss in value of the equipment from the original value due purely to ownership, assuming some arbitrary standard loss in value due to use. These three views can lead to substantially different ownership costs for the same piece of equipment, depending on the circumstances. For simplicity, ownership will be viewed as in the third view. The depreciation component of ownership cost will be discussed separately in the following section.

Depreciation Costs

Depreciation is the loss in value of the equipment due to use and/or obsolescence. There are several different approaches for calculating depreciation, based on hours of operation or on real-time years of ownership. In both cases, some arbitrary useful life is assumed for the particular piece of equipment based on experience with similar equipment under similar use conditions. The simplest approach for calculating depreciation is the straight-line method. Using the useful life, either hours of operation or years, the equipment is assumed to lose value uniformly over the useful life from its original value down to its salvage value. The salvage value is the expected market value of the equipment at the end of its useful life.

Operating Expenses

Operating costs are items of cost directly attributable to the use of the equipment. Operating costs include such items as fuel, lubricants, filters, repairs, tires, and sometimes operator's wages. Obviously, the specific project conditions will greatly influence the magnitude of the operating costs. It is, therefore, important that on projects where the equipment is a significant cost item, such as large civil works projects like dams or new highway projects, attention must be given to the job conditions and operating characteristics of the major pieces of equipment.

Equipment Rates

The equipment rates used in an estimate represent an attempt to combine the elements of equipment cost that have been explained above. The pricing of equipment in an estimate is also influenced by market conditions. On very competitive projects, the contractor will often discount the actual costs to win the project. In other cases, even though the equipment has been fully depreciated, a contractor may still include an ownership charge in the estimate, because the market conditions will allow the cost to be included in the estimate.

Materials Costs

Materials costs can represent the major portion of a construction estimate. The estimator must be able to read and interpret the drawings and specifications and develop a complete list of the materials required for the project. With this quantity takeoff, the estimator then identifies the cost of these materials. The materials costs include several components: the purchase price, shipping and packaging, handling, and taxes.

There are two types of materials: bulk materials and engineered materials. Bulk materials are materials that have been processed or manufactured to industry standards. Engineered materials have been processed or manufactured to project standards. Examples of bulk materials are sand backfill, pipe, and concrete. Examples of engineered materials are compressors, handrailing, and structural steel framing. The estimator must get unit price quotes on bulk materials and must get quotes on the engineered materials that include design costs as well as processing and other materials costs.

Subcontractor Costs

The construction industry continues to become more specialized. The building sector relies almost entirely on the use of specialty contractors to perform different trade work. The heavy/highway construction industry subcontracts a smaller percentage of work. The estimator must communicate clearly with the various subcontractors to define the scope of intended work. Each subcontractor furnishes the estimator with a quote for the defined scope of work with exceptions noted. The estimator must then adjust the numbers received for items that must be added in and items that will be deleted from their scope. The knowledge of the subcontractor and any associated risk on performance by the subcontractor must also be assessed by the estimator. The estimator often receives the subcontractor's best estimate only a few minutes before the overall bid is due. The estimator must have an organized method of adjusting the overall bid up to the last minute for changes in the subcontractor's prices.

Example 12

For use as structural fill, 15,000 cubic yards of material must be hauled onto a job site. As the material is excavated, it is expected to swell. The swell factor is 0.85. The material will be hauled by four 12-yd^3 capacity trucks. The trucks will be loaded by a 1.5-yd^3 excavator. Each cycle of the excavator will take about 30 sec. The hauling time will be 9 min, the dumping time 2 min, the return time 7 min, and the spotting time 1 min. The whole operation can be expected to operate 50 min out of every hour. The cost of the trucks is \$66/h and the excavator will cost about \$75/h. What is the cost per cubic yard for this operation?

Solution.

$$\text{Excavator capacity} = 1.5\ yd^3\ \text{¥}\ 0.85 = 1.28\ yd^3/\text{cycle}$$

$$\text{Hauler capacity} = 12\ \text{¥}\ 0.85 = 10.2\ yd^3/\text{cycle}$$

$$\text{Number of loading cycles} = 10.2/1.28 = 8\ \text{cycle}$$

Truck cycle time:

Load 8 cycles ¥ 0.5 min =	4 min
Haul	9 min
Dump	2 min
Return	7 min
Spot	1 min
TOTAL	23 min

Fleet production:

$$4\ \text{¥}\ (50/23)\ \text{¥}\ 10.2 = 89.75\ yd^3/h$$

$$15{,}000/89.75 = 168\ h$$

Cost:

168 ¥ 66 ¥ 4 =	\$44,352
168 ¥ 75 =	\$12,600
TOTAL	\$56,952

$$56{,}952/15{,}000 = \$3.80/yd^3$$

Example 13

It is necessary to place 90 cubic yards of concrete. Site conditions dictate that the safest and best method of placement is to use a crane and a 2-cubic-yard bucket. It is determined that to perform the task efficiently, five laborers are needed — one at the concrete truck, three at the point of placement, and one on the vibrator. It is assumed that supervision is done by the superintendent.

The wage rate for laborers is \$22.00/h.

Time needed:	
Setup	30 min
Cycle:	
Load	3 min
Swing, dump, and return	6 min
TOTAL	9 min

No. of cycles	90/2 = 45 cycles
Total cycle time	45 ¥ 9 = 405 min
Disassembly subtotal	= 15 min
Inefficiency (labor, delays, etc.) 10% of cycle time	= 41 min
Total operation time	405 + 15 + 41 = 461 min
Amount of time needed (adjusted to workday)	= 8 h
Laborers — five for 8 hours at $22.00/h	= $880.00
Cost per 90 yd^3	= $880.00
Cost per cubic yard	$880/90 yd^3 = $9.78/$yd^3$

Example 14

A small steel-frame structure is to be erected, and you are to prepare an estimate of the cost based on the data given below and the assumptions provided. The unloading, erection, temporary bolting, and plumbing will be done by a crew of 1 foreman, 1 crane operator, and 4 structural steel workers with a 55-ton crawler crane. The bolting will be done by two structural-steel workers using power tools. The painting will be done by a crew of three painters (structural-steel) with spray equipment. For unloading at site, erection, temporary bolting, and plumbing, allow 7 labor-hours per ton for the roof trusses, and allow 5.6 labor-hours per ton for the remaining steel. Assume 60 crew hours will be required for bolting. Allow 1.11 labor-hours per ton for painting.

Materials:		
A 36 structural	Steel trusses	15 tons
	Columns, etc.	50 tons
Costs:		
Structural steel supply:		44¢/lb
Fabrication:		$800/ton — trusses
		$410/ton — other steel
Freight cost:		$2.65/100 lb
Field bolts:		250 @ $1.10 each
Paint:		41 gallons @ $30.00/gallon
Labor costs:	Assume payroll taxes and insurance are 80% of labor wage; use the following wages:	
	Foreman	$24.10
	Crane Operator	$21.20
	Structural steel worker	$22.10
	Painter	$20.20
Equipment costs:	Crane	$915.00/day
	Power tools	$23.40/day
	Paint equipment	$68.00/day
Move in/out:		$300.00
Overhead:		40% of field labor cost
Profit:		12% of all costs

Solution.

Materials:		
Structural steel: 65 ¥ 2000 ¥.44	=	$57,200
Freight: 65 ¥ 2000/100 ¥ 2.65	=	3445
Field bolts: 250 ¥ $1.10	=	275
Paint: 41 ¥ 30	=	1230
		$62,150

Fabrication:

Truss: 15 ¥ 800	=	$12,000
Frame: 50 ¥ 410	=	20,500
		$32,500

Labor crew costs:

Erection:	
1 foreman:	$24.10
1 crane operator:	21.20
4 structural steel workers:	88.40
	$133.70
Paint:	
3 painters:	$60.60
Bolting:	
2 structural steel workers:	$44.20

Erection:

Frame:	
(50 ¥ 5.6)/6	= 46.7 crew hours — 6 days
	46.7 ¥ $133.40 = $6239
Trusses:	
(15 ¥ 7)/6	= 17.5 crew hours — 2 days
	17.5 ¥ 133.40 = $2340

Paint:	
(65 ¥ 1.11)/3	= 24 crew hours — 3 days
	24 ¥ 60.60 = $1455
Bolting:	60 ¥ 44.20 = $2652
	Total labor = $12,686

Equipment:

Crane: 8 days ¥ 915/day	=	$7320
Power tools: 8 days ¥ 23.40/day	=	187
Paint equipment: 3 days ¥ 68/day	=	204
Move in/out	=	300
TOTAL		$8011

Summary

Materials:	$62,150
Fabrication:	32,500
Labor:	12,686
Equipment:	8011
Payroll taxes and insurance:	
80% of 12,686	10,149
Overhead:	
40% of (12,686 + 10,149)	9134
TOTAL	$134,630
Profit:	
12% of 90,781	16,156
Bid	= $150,786

Project Overhead

Each project requires certain items of cost that cannot be identified with a single item of work. These items are referred to as project overhead and are normally described in the general conditions of the contract. The items that are part of the project overhead include but are not limited to the following:

- Bonds
- Permits
- Mobilization
- Professional services (such as scheduling)
- Safety equipment
- Small tools
- Supervision
- Temporary facilities
- Travel and lodging
- Miscellaneous costs (e.g., cleanup, punch list)
- Demobilization

Each of these types of items should be estimated and included in the cost breakdown for a project.

Markup

Once the direct project costs are known, the estimator adds a sum of money to cover a portion of the general overhead for the firm and an allowance for the risk and investment made in the project — the profit. Each of these elements of markup is in large part determined by the competitive environment for bidding the project. The more competition, the less the markup.

General Overhead

Each business has certain expenses that are not variable with the amount of work they have under contract. These expenses must be spread across the projects. The typical method for spreading general overhead is to assign it proportionally according to the size of the project in relation to the expected total volume of work for the year. General overhead costs typically include the following:

- Salaries (home office)
- Employee benefits
- Professional fees
- Insurance
- Office lease or rent
- Office stationery and supplies
- Maintenance
- Job procurement and marketing
- Home office travel and entertainment
- Advertising

The only restriction on the items of general overhead is that they must have a legitimate business purpose. The estimator typically will start with the proportional amount and then add a percentage for profit.

Profit

The profit assigned to a project should recognize the nature of risk that the company is facing in the project and an appropriate return on the investment being made in the project. The reality is that the profit is limited by the competition. A larger number of bidders requires that a smaller profit be assigned to have a chance at having the low bid. This process of assigning profit is usually performed at the last minute by the senior management for the company submitting the bid.

1.5 Contracts

The estimator prepares the estimate in accordance with the instructions to bidders. There are numerous approaches for buying construction services that the estimator must respond to. These various approaches can be classified by three characteristics: the method of award, the method of bidding/payment, and incentives/disincentives that may be attached.

Method of Award

There are three ways in which construction contracts are awarded: competitive awards, negotiated awards, and combination competitive-negotiated awards. With a purely competitive award, the decision is made solely on the basis of price. The lowest bidder will be awarded the project. Usually, public work is awarded in this manner, and all who meet the minimum qualifications (financial) are allowed to compete. In private work, the competitive method of award is used extensively; however, more care is taken to screen potential selective bidders.

The term *selective bid process* describes this method of competitive award. At the opposite extreme from competitive awards are the negotiated awards. In a purely negotiated contract, the contractor is the only party asked to perform the work. Where a price is required prior to initiating work, this price is negotiated between the contractor and the client. Obviously, this lack of competition relieves some of the tension developed in the estimator through the competitive bid process because there is no need to be concerned with the price another contractor might submit. The contractor must still, if asked, provide a firm price that is acceptable to the client and may have to submit evidence of cost or allow an audit. As the purely competitive and purely negotiated method of contract awards represent the extremes, the combination competitive-negotiated award may fall anywhere in between. A common practice for relatively large jobs is to competitively evaluate the qualifications of several potential constructors and then select and negotiate with a single contractor a price for the work.

Method of Bidding/Payment

Several methods of payment are used to reimburse contractors for the construction services they provide. These methods of payment include lump sum or firm price, unit-price, and cost-plus. Each of these methods of payment requires an appropriate form of bidding that recognizes the unique incentive and risk associated with the method. The requirements for completeness of design and scope definition vary for the various types. The lump-sum or firm-price contract is widely used for well-defined projects with completed designs. This method allows purely competitive bidding. The contractor assumes nearly all of the risk, for quantity and quality. The comparison for bidding is based entirely on the total price submitted by the contractors, and payment for the work is limited to the agreed-upon contract price with some allowance for negotiated changes. The lump sum is the predominant form used for most building projects.

The unit-price contract is employed on highway projects, civil works projects, and pipelines. For these projects, the quality of the work is defined, but the exact quantity is not known at the time of bidding. The price per unit is agreed upon at the time of bidding, but the quantity is determined as work progresses and is completed. The contractor, therefore, assumes a risk for quality performance, but the quantity risk is borne by the owner. There is a strong tendency, by contractors, to overprice or front-load those bid items that will be accomplished first and compensate with lower pricing on items of work that will be performed later. This allows contractors to improve their cash flow and match their income closer to their expenses. Each unit-price given must include a portion of the indirect costs and profits that are part of the job. Usually, quantities are specified for bidding purposes so that the prices can be compared for competitive analysis. If contractors "unbalance" or front-load certain bid items to an extreme, they risk being excluded from consideration. The unit-price approach is appropriate for projects where the quantity of work is not known, yet where competitive bidding is desirable.

A third method, with many variations, is the cost-plus method of bidding/payment. With this method, the contractor is assured of being reimbursed for the costs involved with the project plus an additional amount to cover the cost of doing business and an allowance for profit. This additional amount may be calculated as a fixed fee, a percent of specified reimbursable costs, or a sliding-scale amount. The cost to the owner with this method of bidding/payment is open-ended; thus, the risks lie predominantly with the owner. This method is used in instances where it is desired to get the construction work underway prior to completion of design, or where it is desired to protect a proprietary process or production technology and design. Many of the major power plant projects, process facilities, and other long-term megaprojects have used this method in an attempt to shorten the overall design/construct time frame and realize earlier income from the project.

Of the several variations used, most relate to the method of compensation for the "plus" portion of the cost and the ceiling placed on the expenditures by the owner. One of the variations is the cost plus a fixed fee. With this approach, it is in the contractor's best interest to complete the project in the least time with the minimum nonreimbursable costs so that his profits during a given time period will be maximized. Where the scope, although not defined specifically, is generally understood, this method works well. The owner must still control and closely monitor actual direct costs. A second variation is the cost plus a percentage. This method offers little protection for the owner on the cost of the project or the length of performance. This method, in fact, may tempt the contractor to prolong project completion to continue a revenue stream at a set return. The sliding-scale approach is a third approach. This method of compensation is a combination of the two approaches described above. With this approach, a target amount for the project cost is identified. As costs exceed this amount, the fee portion decreases as a percentage of the reimbursable portion. If the costs are less than this target figure, there may be a sliding scale that offers the contractor an increased fee for good cost containment and management.

In addition to the method of calculations of the plus portion for a cost-plus method, there may be a number of incentives attached to the method. These typically take the form of bonuses and penalties for better time or cost performance. These incentives may be related to the calendar or working day allowed for completion in the form of an amount per day for early completion. Similarly, there may be a penalty for late completion. The owner may also impose or require submittal of a guaranteed maximum figure for a contract to protect the owner from excessive costs.

1.6 Computer-Assisted Estimating

The process of estimating has not changed, but the tools of the estimator are constantly evolving. The computer has become an important tool for estimators, allowing them to produce more estimates in the same amount of time and with improved accuracy.

Today, the computer is functioning as an aid to the estimator by using software and digitizers to read the architect/engineer's plans, by retrieving and sorting historical cost databases, by analyzing information and developing comparisons, and by performing numerous calculations without error and presenting the information in a variety of graphical and tabular ways.

The microcomputer is only as good as the programmer and data entry person. The estimator must still use imagination to create a competitive plan for accomplishing the work. The computer estimating tools assist and speed the estimator in accomplishing many of the more routine tasks.

Many commercially available programs and spreadsheets are used by estimators for developing their final estimates of cost. These are tools that calculate, sort, factor, and present data and information. The selection of a software program or system is a function of the approach used by the contractor and the particular work processes and cost elements encountered. The most widely used tool is still the spreadsheet because it gives the estimator a tool for flexible organization of data and information and the capacity to make quick and accurate calculations.

Defining Terms[1]

Bid — To submit a price for services; a proposition either verbal or written, for doing work and for supplying materials and/or equipment.

Bulk materials — Material bought in lots. These items can be purchased from a standard catalog description and are bought in quantity for distribution as required.

Cost — The amount measured in money, cash expended, or liability incurred, in consideration of goods and/or services received.

Direct cost — The cost of installed equipment, material, and labor directly involved in the physical construction of the permanent facility.

Indirect cost — All costs that do not become part of the final installation but which are required for the orderly completion of the installation.

Markup — Includes the percentage applications, such as general overhead, profit, and other indirect costs.

Productivity — Relative measure of labor efficiency, either good or bad, when compared to an established base or norm.

Quantity survey — Using standard methods to measure all labor and material required for a specific building or structure and itemizing these detailed quantities in a book or bill of quantities.

Scope — Defines the materials and equipment to be provided and the work to be done.

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[1]Source: American Association of Cost Engineers (AACE, Inc.), *AACE Recommended Practices and Standards,* November 1991.

Further Information

For more information on the subject of cost estimating, one should contact the following professional organizations that have additional information and recommended practices.

AACE, International (formerly the American Association of Cost Engineers), 209 Prairie Ave., Suite 100, Morgantown, WV 26507, 800–858-COST.

American Society of Professional Estimators, 11141 Georgia Ave., Suite 412, Wheaton, MD 20902, 301–929–8848.

There are numerous textbooks on the subject of cost estimating and construction cost estimating. Cost engineering texts usually have a large portion devoted to both conceptual estimating and detailed estimating. The following reference materials are recommended:

Process Plant Construction Estimating Standards. Richardson Engineering Services, Mesa, AZ.

Contractor's Equipment Cost Guide. Data quest — The Associated General Contractors of America (AGC).

The Building Estimator's Reference Book. Frank R. Walker, Lisle, IL.

Means Building Construction Cost Data. R.S. Means, Duxbury, MA.

Estimating Earthwork Quantities. Norseman Publishing, Lubbock, TX.

Caterpillar Performance Handbook, 24th ed. Caterpillar, Peoria, IL.

Means Man-Hour Standards. R.S. Means, Duxbury, MA.

Rental Rates and Specifications. Associated Equipment Distributors.

Rental Rate Blue Book. Data quest — The Dun & Bradstreet Corporation, New York.

Historical Local Cost Indexes. AACE — Cost Engineers Notebook, Vol. 1.

Engineering News Record. McGraw-Hill, New York.

U.S. Army Engineer's Contract Unit Price Index. U.S. Army Corps of Engineers.

Chemical Engineering Plant Cost Index. McGraw-Hill, New York.

Bureau of Labor Statistics. U.S. Department of Labor.