CHAPTER 1

Introduction

PURPOSE OF THIS BOOK

The purpose of this book is to enable the reader to gain fundamental knowledge of estimating the cost of projects to be constructed. Experienced estimators agree that the procedures used for estimating vary from company to company, and even among individuals within a company. Although there are variations, fundamental concepts that are universally applicable do exist. The information contained in this book presents the fundamental concepts to assist the reader in understanding the estimating process and procedures developed by others. This book can also serve as a guide to the reader in developing his or her own estimating procedures.

There are so many variations in the costs of materials, labor, and equipment from one location to another, and over time, that no book can dependably give costs that can be applied for bidding purposes. However, the estimator who learns to determine the quantities of materials, labor, and equipment for a given project and who applies proper unit costs to these items should be able to estimate the direct costs accurately.

This book focuses on basic estimating, not workbook estimating. Basic estimating involves analysis of the work to be performed, including the type and quantity of work, type and size of equipment to be used during construction, production rates of labor and equipment to install the work, and other job-site conditions that are unique to the project and that can impact the time and cost of construction. After these items are defined, both the estimated time and cost to build the project can be determined. The typical question in basic estimating is: How much time will our labor and equipment be on the job? Once that question is answered, the cost of labor and equipment can easily be calculated by multiplying the hourly or daily rates of labor and equipment times the time they will be on the job. Based on the quantity and quality of material, the cost of material can easily be obtained from a material supplier. Both the time and cost to do the work are obtained in basic estimating.

Workbook estimating involves performing a material quantity takeoff, obtaining unit costs from a nationally published cost manual, and multiplying the quantity of work times the unit cost of material and labor to determine the cost estimate. Workbook estimating is quick, simple, and easy to perform. However, unit costs can vary widely, depending on the volume of work, weather conditions, competition in pricing, variations in the skill and productivity of workers, and numerous other factors. In workbook estimating, the cost is determined directly from the material quantities, without regard to how long the workers and/or equipment will be on the job. Workbook estimating emphasizes obtaining the cost to do the work, rather than the time to do the work.

Subsequent chapters of the book present the principles and concepts of estimating construction costs. Emphasis is placed on the thought process that is required of the estimator to analyze job conditions and assess the required labor, equipment, and method of construction that will be necessary to perform the work. These are functions that can be performed only by the estimator because experience and good judgment are required to prepare reliable estimates.

To assemble a complete estimate for bid purposes, the estimator must combine his or her knowledge of construction methods and techniques into an orderly process of calculating and summarizing the cost of a project. This process requires the assembly of large amounts of information in an organized manner and numerous calculations must be performed. The computer is an ideal tool to facilitate this process by decreasing the time and increasing the accuracy of cost estimating. The computer can retrieve data and perform calculations in seconds, enabling the estimator to give more attention to alternative construction methods, to assess labor and equipment productivity, to obtain prices from subcontractors and material suppliers, and to focus on bidding strategies. Today, computers are used extensively for cost estimating.

The final chapter of this book is devoted to computer estimating. Although the computer is an effective tool for estimating, the estimator must still control the estimating process. In simple language, the computer should work for the estimator, the estimator should not work for the computer. The estimator must know the software that he or she is using, both its capabilities and its limitations. The results of a computer estimate are only as good as the estimator using the computer. The computer cannot exercise judgment; only the estimator has that capability.

ESTIMATING

Estimating is not an exact science. Knowledge of construction, common sense, and judgment are required. Estimating material costs can be accomplished with a relatively high degree of accuracy. However, accurate estimating of labor and equipment costs is considerably more difficult to accomplish.

Estimating material costs is a relatively simple and easy task. The quantity of materials for a particular job can be accurately calculated from the dimensions on the drawings for that particular job. After the quantity of material is calculated, the estimator can obtain current unit prices from the supplier and then multiply the quantity of material by the current unit price to estimate the cost of materials. Applying a percentage for material waste is the only adjustment of the material cost that may require judgment of the estimator.

Estimating labor and equipment costs is considerably more difficult than estimating material costs. The cost of labor and equipment depends on productivity rates, which can vary substantially from one job to another. The estimator and his or her team should evaluate the job conditions for each job and use their judgment and knowledge of construction operations. The skill of the laborers, job conditions, quality of supervision, and many other factors affect the productivity of labor. The wage rate of laborers can be determined with relative accuracy. Also, the quantity of work required by laborers can be determined from the plans and specifications for a job. However, the estimator must use his or her judgment and knowledge about the job to determine the expected productivity rate of laborers. Likewise, the estimator's judgment and knowledge of equipment and job conditions are required to determine the expected equipment productivity rate.

IMPORTANCE OF THE ESTIMATOR AND THE ESTIMATING TEAM

Whether using computers, or not, the estimator and his or her team play a vital role in preparing estimates. Information must be assembled, organized, and stored. Cost records from previously completed projects and cost quotes from suppliers, vendors, and subcontractors must be gathered. Assessment of job conditions and evaluation of labor and equipment and productivity rates must be performed. The estimator must review and check all parts of an estimate to ensure realistic costs. The estimator must also document the estimate so it can be used for cost control during the construction process.

The computer can assist in these activities, but the estimator must manage and control the estimating process. The estimator has to be able to work under pressure because most estimates are prepared in stringent time frames. The quality and accuracy of an estimate is highly dependent on the knowledge and skill of the estimator.

PURPOSE OF ESTIMATING

The purpose of estimating is to determine the forecast costs required to complete a project in accordance with the contract plans and specifications. For any given project, the estimator can determine with reasonable accuracy the direct costs for materials, labor, and equipment. The bid price can then be determined by adding to the direct cost the costs for overhead (indirect costs required to build the project), contingencies (costs for any potential unforeseen work), and profit (cost for compensation for performing the work). The bid price of a project should be high enough to enable the contractor to complete the project with a reasonable profit, yet low enough to be within the owner's budget.

There are two distinct tasks in estimating: determining the probable real cost and determining the probable real time to build a project. With an increased emphasis on project planning and scheduling, the estimator is often requested to provide production rates, crew sizes, equipment spreads, and the estimated time required to perform individual work items. This information, combined with costs, allows an integration of the estimating and scheduling functions of construction project management.

Because construction estimates are prepared before a project is constructed, the estimate is, at best, a close approximation of the actual costs. The true cost of the project will not be known until the project has been completed and all costs have been recorded. Thus, the estimator does not establish the cost of a project: he or she simply establishes the amount of money the contractor will receive for constructing the project.

TYPES OF ESTIMATES

There are many estimates and re-estimates for a project, based on the stage of project development. Estimates are performed throughout the life of a project, beginning with the first estimate and extending through the various phases of design and into construction, as shown in Fig. 1.1. Initial cost estimates form the basis to which all future estimates are compared. Future estimates are often expected to agree with (i.e., be equal to or less than) the initial estimates. However, too often the final project costs exceed the initial estimates.

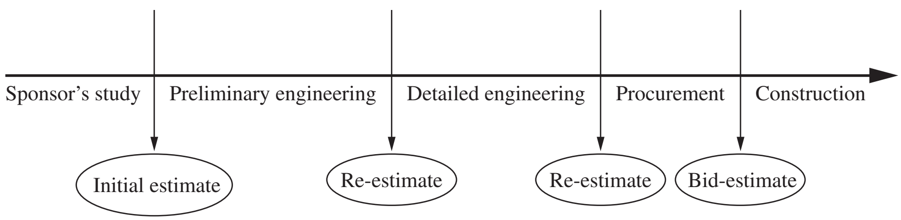

Figure 1.1 | Estimates and re-estimates through phases of project development.

Although each project is unique, generally three parties are involved: the owner, the designer, and the contractor. Each has responsibility for estimating costs during various phases of the project. Early in a project, prior to the design, the prospective owner may wish to know the approximate cost of a project before making a decision to construct it. As the design of the project progresses, the designer must determine the costs of various design alternatives to finalize the design to satisfy the owner's budget and desired use of the project. The contractor must know the cost required to perform all work in accordance with the final contract documents, and the plans and specifications.

Cost estimates can be divided into at least two different types, depending on the purposes for which they are prepared and the amount of information known when the estimates are prepared. There are approximate estimates (sometimes called feasibility, screening, authorization, preliminary, conceptual, order-of-magnitude, equipment-factored, or budget estimates) and detailed estimates (sometimes called final, bid/tender, or definitive estimates).

There is no industry standard that has been established for defining estimates. Individual companies define estimate names and percent variations that they use based on their experience with a particular type of construction and operating procedures within the company. Various organizations have also defined classifications of cost estimates. For example, Table 1.1 is the cost estimation classification by the Association for the Advancement of Cost Engineering (AACE) International. In general, an early estimate is defined as an estimate that has been prepared before completion of detailed engineering. This definition applies to Class 5, Class 4, and early Class 3 estimates of AACE International.

TABLE 1.1 | AACE International cost estimation classifications (18R-97).

Estimate class	Level of project definition	End usage— Typical purpose of estimate	Expected accuracy range
Class 5	0% to 2%	Concept screening	−50% to 100%
Class 4	1% to 5%	Study or feasibility	−30% to +50%
Class 3	10% to 40%	Budget, authorization, or control	−20% to +30%
Class 2	30% to 70%	Control or bid/tender	−15% to +20%
Class 1	50% to 100%	Check estimate or bid/tender	−10% to +15%

APPROXIMATE ESTIMATES

The prospective owner of a project establishes the budget for a project. For example, a government agency will need to know the approximate cost before holding a bond election, or it may need to know the approximate cost to ensure that the cost of a project does not exceed the funds appropriated during a fiscal year. The prospective owner of a private construction project will generally conduct a feasibility study during the developmental phase of a project. As a part of the study, an economic analysis is undertaken to compare the cost of construction with potential earnings that can be obtained upon completion of the project. Privately owned utility companies, and other types of multiple-builder owners, prepare annual construction budgets for all projects proposed during a fiscal year. An approximate estimate is sufficiently accurate for these purposes.

The designer of a project must determine the costs of various design alternatives to obtain an economical design that meets the owner's budget. An architect may reduce a building to square feet of area, or cubic feet of volume, and then multiply the number of units by the estimated cost per unit. An engineer may multiply the number of cubic yards of concrete in a structure by the estimated cost per cubic yard to determine the probable cost of the project. Considerable experience and judgment are required to obtain a dependable approximate estimate for the cost, because the estimator must adjust the unit costs resulting from the quantities of material, workmanship, location, and construction difficulties. Approximate estimates are sufficiently accurate for the evaluation of design alternatives or the presentation of preliminary construction estimates to the owner, but are not sufficiently accurate for bid purposes.

The unit cost method of estimating is commonly used to prepare approximate estimates. For building type projects, they are often referred to as square foot estimates. Other examples of unit cost estimating are cost per mile of electrical transmission line, cost per lineal foot of pipeline, cost per mile for each lane of highway pavement, cost per square yard of site grading, etc.

After the size and configuration of a project has been developed, the quantities of work can be calculated. Examples of quantity of work include square yards of site grading, number of pile foundations, cubic yards of concrete, square feet of floors, lineal feet of pipe, and number of doors in a building. After the quantity of work is defined, the cost can be calculated by simply multiplying the cost per unit of work times the quantity of work for each item. For example, if there are 900 sy of floor covering in a building and the unit cost for installed carpet is \$30/sy, then the cost of floor covering is 900 sy × \$30/sy = \$27,000. Similar calculations can be performed for other types of work.

The quantity of work is derived from the drawings for a project. Values of unit costs are sometimes obtained from a national pricing manual. Examples of national pricing manuals include: *ENR Contracting Cost Books* from McGraw-Hill Construction, *Building Construction Cost Data* from RSMeans, and *The Building Estimator's Reference Book* from Frank R. Walker Company. The cost data from national publications are averages from several cities. Therefore, it is necessary to adjust the cost information. Adjustments for location, time, and size are presented in Chapter 4 of this book.

Values of unit costs may also be obtained from company records of previously completed projects of a similar type of work. The unit costs are typically an average of the values obtained from recent jobs. It should be recognized that crew composition and production rates are unique to each individual job. Sometimes the experience, skills, and intuition of the estimator must be applied to adapt the previous cost records to the conditions of the job being estimated.

When the time for completion of a project is important, the owner may select a construction contractor before the design has been completed. A contractor may be asked to provide an approximate cost estimate based on limited information known about the project. The contractor determines the approximate costs for various work items, such as the cost per cubic yard for foundations, the cost per pound of structural steel, and the cost per square foot for finished rooms. Based on preliminary quantities of work, the contractor calculates a preliminary cost for construction of the project. The owner may then negotiate a construction contract with the contractor based on the approximate cost estimate. Construction projects of this type require owners who are knowledgeable in project management and contractors who have developed good project record keeping. Screening of design/build contractors is often based partly on the approximate estimate for a project.

DETAILED ESTIMATES

A detailed estimate of the cost of a project is prepared by determining the costs of materials, labor, equipment, subcontract work, overhead, and profit. Contractors prepare detailed estimates from a complete set of contract documents prior to submission of the bid or formal proposal to the owner. The detailed estimate is important to both the owner and the contractor because it represents the bid price—the amount of money the owner must pay for completion of the project and the amount of money the contractor will receive for building the project.

The preparation of the detailed estimate generally follows a systematic procedure that has been developed by the contractor for his or her unique construction operations. The process begins with a thorough review of the complete set of contract documents—the bidding and contract requirements, drawings, and technical specifications. It is also desirable to visit the proposed project site to observe factors that can influence the cost of construction, such as available space for storage of materials, control of traffic, security, and existing underground utilities.

The compilation of costs begins with a well-organized checklist of all work items necessary to construct the project. The estimator prepares a *material quantity takeoff* of all materials from the drawings. This involves tabulating the quantity and unit of measure of all work required during construction. Upon completion of the quantity takeoff, an extension of prices is performed. The quantity of material multiplied by the unit cost of the material yields the material cost. The quantity of work required of equipment is divided by the equipment production rate and then multiplied by the unit cost of equipment to obtain the total cost of equipment. Similarly, dividing the quantity of work required for labor by the labor production rate and then multiplying by the unit cost of labor obtains the cost of labor.

For many projects, a significant amount of work is performed by subcontractors who specialize in a particular type of work. For building type projects, examples include clearing, drywall, painting, and roofing contractors. For heavy/highway type projects, examples of subcontract work include guardrails, striping, signs, and fences. The estimator provides a set of drawings and specifications to potential subcontractors and requests a bid from them for their particular work. Subcontractors and suppliers normally quote the cost of their work by e-mail, fax, or phone just prior to final submission of the bid.

The direct cost of a project includes material, labor, equipment, and subcontractor costs. Upon completion of the estimate of direct costs, the estimator must determine the indirect costs of taxes, bonds, insurance, and overhead required to complete the project. Taxes on labor and materials vary, depending on geographic locations. Bond requirements are defined in the specifications for the project. Examples include bid bonds, material and labor payment bonds, and performance bonds. Insurance requirements are also defined in the contract bid documents. Examples include workmen's compensation, contractor's public liability and property damage, and contractor's builders risk insurance. The base estimate is the total of direct and indirect costs.

A risk analysis of uncertainties is conducted to determine an appropriate contingency to be added to the base estimate. Regardless of the effort and amount of

TABLE 1.2 | Steps for preparing a detailed estimate.

1. *Review the scope of project.* Consider the effect of location, security, traffic, available storage space, underground utilities, method of payment, etc., on costs.
2. *Determine quantities.* Perform a material quantity takeoff for all work items in the project, and record the quantity and unit of measure for each item.
3. *Obtain suppliers' bids.* Receive and tabulate the cost of each supplier on the project.
4. *Price material.* Extend material costs:

   $$\text{Material cost} = \text{Quantity} \times \text{Unit price}$$

5. *Price labor.* Based on probable labor production rates and crew sizes, determine labor costs:

   $$\text{Labor cost} = (\text{Quantity/Labor production rate}) \times \text{Labor rate}$$

6. *Price equipment.* Based on probable equipment production rates and equipment spreads, determine equipment costs:

   $$\text{Equipment cost} = (\text{Quantity/Equipment production rate}) \times \text{Equipment rate}$$

7. *Obtain specialty contractors' bids.* Receive and tabulate the cost for each specialty contractor on the project.
8. *Calculate taxes, bonds, insurance, and overhead.* Tabulate the costs of material and labor taxes, bonds, insurance, and job overhead.
9. *Contingency and markup.* Add costs for potential unforeseen work based on the amount of risk.
10. *Profit.* Add costs for compensation for performing the work in accordance with the bid documents.

detailed estimating of a project, there is almost always some unforeseen work that develops during construction. Caution must be used in assigning contingency to an estimate. A contingency that is too low might reduce the profits in a project, while a contingency that is too high may prevent the bid from being competitive.

Upon calculation of the direct and indirect costs, analysis of risk, and assignment of contingency, a profit is added to the estimate to establish the bid price. The amount of profit can vary considerably, depending on numerous factors, such as the size and complexity of the project, amount of work in progress by the contractor, accuracy and completeness of the bid documents, competition for work, availability of money, and volume of construction activity in the project area. The profit may be as low as 5 percent for large projects or as high as 30 percent for small projects that are high risks or remodels of existing projects. Table 1.2 lists the steps required to compile a detailed estimate for a project.

ORGANIZATION OF ESTIMATES

A comprehensive and well-defined organization of work items is essential to the preparation of an estimate for any project. Each contractor develops her or his own procedures to compile the cost of construction for the type of work the company performs. The contractor's system of estimating and use of forms develop over years of experience in that type of work.

Two basic approaches have evolved to organize work items for estimating. One approach is to identify work by the categories contained in the project's written specifications, such as those of the Construction Specification Institute (CSI) for building construction projects. The other approach uses a *work breakdown structure* (WBS) to identify work items by their location on the project.

BUILDING CONSTRUCTION PROJECTS

Building construction contractors usually organize their estimates in a format that closely follows the Construction Specifications Institute (CSI) numbering system, which divides work into major divisions. Each major division is subdivided into smaller items of work. The numbering system is developed for architects writing specifications that are unique to each project. However, contractors typically use CSI numbering as a checklist and guide for quantity takeoff, price extensions, and summary of cost for the final estimate.

For years the CSI used a 16 division numbering system, but recently expanded it to 50 divisions as discussed in Chapter 2 of this book. It doesn't matter which numbering system is used as long as the information that is needed to assist in the bidding process is included and can be found easily.

An illustrative example of cost summary for a building construction project is shown in Table 1.3, which follows the CSI 16 division numbering system. This table

TABLE 1.3 | Example of bid summary for a building construction project.

Item	Description	Material	Labor	Subcontract	Total
01	General requirements	$ 164,350	$ 363,550	$ 48,820	$ 576,720
02	Sitework	150,700	201,230	1,461,860	1,813,790
03	Concrete	970,176	515,240	0	1,485,416
04	Masonry	0	0	2,127,240	2,127,240
05	Metals	2,132,340	593,210	0	2,725,550
06	Wood and plastics	387,530	104,960	49,080	541,570
07	Thermal and moisture	0	0	1,380,720	1,380,720
08	Doors and windows	368,210	321,150	0	689,360
09	Finishes	1,725,870	1,879,220	0	3,605,090
10	Specialties	157,480	111,040	96,250	364,770
11	Equipment	0	0	457,290	457,290
12	Furnishing	0	0	0	0
13	Special construction	0	0	0	0
14	Conveying systems	0	0	1,283,346	1,283,346
15	Mechanical	0	0	5,133,384	5,133,384
16	Electrical	0	0	3,546,610	3,546,610
	Total for Project	$6,056,656	$4,089,600	$15,584,600	$25,730,856
Add-ons for final estimate:					
	Material tax (5%)	$302,883			$26,033,689
	Labor tax (18%)		$736,128		26,769,817
	Contingency (2%)			$ 535,397	27,305,214
	Bonds and insurance			$ 340,910	27,646,124
	Overhead and profit (15%)			$4,146,919	31,793,043
				Bid price =	$31,793,043

TABLE 1.4 | Item 2 Estimate for sitework.

Cost Code	Cost Item	Quantity	Material	Labor	Subcontract	Total
2110	Clearing	Lump sum	$ 0	$ 0	$ 36,940	$ 36,940
2222	Excavation	8,800 cy	0	118,800	94,160	212,960
2250	Compaction	960 cy	0	22,230	7,220	29,450
2294	Handwork	500 cy	0	17,500	0	17,500
2281	Termite control	Lump sum	0	0	34,750	34,750
2372	Drilled piers	1,632 ft	145,800	28,000	145,240	319,040
2411	Foundation drains	14 each	4,900	14,700	0	19,600
2480	Landscape	Lump sum	0	0	87,220	87,220
2515	Paving	4,850 sy	0	0	1,056,330	1,056,330
		Totals =	$150,700 +	$201,230 +	$1,461,860 =	$1,813,790

shows the summary costs of material, labor, and subcontract for Item 02, Sitework. Table 1.4 shows a breakdown of the sitework costs, which include clearing, excavation, compaction, handwork, termite control, drilled piers, foundation drains, landscape, and paving. Preparation of the estimate would involve further breakdown of items in Table 1.4. For example, the cost of excavation work would be broken down into the labor and equipment costs for the crew performing excavation.

HEAVY ENGINEERING CONSTRUCTION PROJECTS

Heavy engineering construction contractors generally organize their estimates in a WBS unique to the project to be constructed. An example of the WBS organization of an estimate for an electric power construction project is illustrated in Tables 1.5 to 1.7. Major areas of the project are defined by groups: switch station, transmission lines, substations, etc., as shown in Table 1.5. Each group is subdivided into divisions of work required to construct the group. For example, Table 1.6 provides a work breakdown for all the division of work required to construct group 2100, transmission line A: steel fabrication, tower foundations,

TABLE 1.5 | Example of electric power construction bid summary using the WBS organization of work group–level report for total project.

No.	Group	Material	Labor and Equipment	Subcontract	Total
1100	Switch station	$1,257,295	$ 323,521	$3,548,343	$ 5,129,159
2100	Transmission line A	3,381,625	1,259,837	0	4,641,462
2300	Transmission line B	1,744,395	0	614,740	2,359,135
3100	Substation at Spring Creek	572,874	116,403	1,860,355	2,549,632
4200	Distribution line A	403,297	54,273	215,040	672,610
4400	Distribution line B	227,599	8,675	102,387	338,661
4500	Distribution line C	398,463	21,498	113,547	533,508
	Total for project	$7,985,548 +	$1,784,207 +	$6,454,412 =	$16,224,167

TABLE 1.6 | Division-level report for transmission line A—Code 2100.

Code	Description	Material		Labor		Equipment		Total
2100	TRANSMISSION LINE A							
2210	Fabrication of steel towers	$ 692,775		$ 0		$ 0		$ 692,775
2370	Tower foundations	83,262		62,126		71,210		216,598
2570	Erection of steel towers	0		144,141		382,998		527,139
2620	Insulators and conductors	2,605,588		183,163		274,744		3,063,495
2650	Shield wire installation	0		78,164		63,291		141,455
	Total for 2100	$3,381,625	+	$467,594	+	$792,243	=	$4,641,462

TABLE 1.7 | Component-level report for tower foundations—Code 2370.

Code	Description	Quantity	Material		Labor		Equipment		Total
2370	TOWER FOUNDATIONS								
2372	Drilling foundations	4,198 lin ft	$ 0		$25,428		$44,897		$ 70,325
2374	Reinforcing steel	37.5 tons	28,951		22,050		15,376		66,377
2376	Foundation concrete	870 cy	53,306		13,831		10,143		77,280
2378	Stub angles	3,142 each	1,005		817		794		2,616
		Total for 2370	$83,262	+	$62,126	+	$71,210	=	$216,598

steel erection, etc. Each division is further broken down into components of work required to construct each division. For example, Table 1.7 provides a work breakdown for all the components of work required to construct division 2370, tower foundations: drilling, reinforcing steel, foundation concrete, and stub angles. The WBS provides a systematic organization of all the information necessary to derive an estimate for the project.

Other types of heavy engineering projects, such as highways, utilities, and petrochemical and industrial plants, are organized in a WBS that is unique to their particular types of work. The total estimate is a compilation of costs in a WBS that matches the project to be constructed.

Regardless of the system of estimating selected, either CSI or WBS, to each work item in the estimate a code number should be assigned that is reserved exclusively for that work item for all estimates within the contractor's organization. This same number should also be used in the accounting, job cost, purchasing, and scheduling functions, to enable one to track the work items during construction.

QUANTITY TAKEOFF

To prepare an estimate the estimator reviews the plans and specifications and performs a quantity takeoff to determine the type and amount of work required to build the project. Before starting the quantity takeoff, the estimator must know how the project is to be constructed and must prepare a well-organized checklist of all items required to construct the project.

The quantity of material in a project can be accurately determined from the drawings. The estimator must review each sheet of the drawings, calculate the quantity of material, and record the amount and unit of measure on the appropriate line item in the estimate. The unit costs of different materials should be obtained from material suppliers and used as the basis of estimating the costs of materials for the project. If the prices quoted for materials do not include delivery, the estimator must include appropriate costs for transporting materials to the project. The cost of taxes on materials should be added to the total cost of all materials at the end of the estimate.

Each estimator must develop a system of quantity takeoff that ensures that a quantity is not omitted or calculated twice. A common error in estimating is completely omitting an item or counting an item twice. A well-organized checklist of work will help reduce the chances of omitting an item. A careful recheck of the quantity calculations will detect those items that might be counted twice. The estimator must also add an appropriate percentage for waste for those items where waste is likely to occur during construction. For example, a 5 percent waste might be added to the volume of mortar that is calculated for bricklaying.

The material quantity takeoff is extremely important for cost estimating because it often establishes the quantity and unit of measure for the costs of labor and the contractor's equipment. For example, the quantity of concrete material for piers might be calculated as 20,000 cubic yards (cy). The labor-hours and the cost of labor required to place the concrete would also be based on 20,000 cy of material. Also the number and the cost of the contractor's equipment that would be required to install the concrete would be based on 20,000 cy of material. Therefore, the estimator must carefully and accurately calculate the quantity and unit of measure of all material in the project.

LABOR AND EQUIPMENT CREWS

Prior to preparing the quantity takeoff, an assessment of how the project will be constructed must be made. The assessment should include an analysis of the job conditions, labor and equipment crews, and appropriate subdivisions of the work. To illustrate, consider a grading and paving project. Typically, the quantity takeoff for grading is cubic yards of material. An evaluation of the job conditions considers the type of soil, including presence of rock, and the required haul distance to select the appropriate equipment to perform the work. If both soil and rock are present, the work may be subdivided into ordinary earth excavation and rock excavation. For ordinary earth excavation with long haul distances, scrapers may be used for excavating, hauling, and distributing the earth. For the rock excavation, the equipment crew may include drilling and blasting, or ripping the rock with a dozer, and a loader with a spread of trucks to haul the loosened rock. Table 1.8 is an example of a labor and equipment crew for a grading operation.

The paving work can be subdivided into three categories: main line paving, short run paving, curbs and gutters, and handwork paving. For each of these subdivisions a different crew and equipment spread would be required. Table 1.9

TABLE 1.8 | Construction crew for a grading operation.

Supervisor and pickup
Small self-loading scraper
Medium size scraper
Small dozer for assisting scraper
Dozer with ripper
Front end loader, 3 cy
Hydraulic excavator
Small tractor backhoe/box blade
Self-propelled vibrator sheepfoot roller
Self-propelled nine-wheel pneumatic roller
Motor grader
Water truck
Single axle flatbed dump truck
Tandem axle dump truck
Common laborer
Skilled laborer
Traffic flag person

TABLE 1.9 | Asphalt crew for urban work.

Labor
Supervisor
Paving machine operator
Screed operator
Steel wheel roller operator
Asphalt raker
Asphalt laborer
Asphalt distributor operator
Traffic flag person
Equipment
Supervisor's pickup
Service truck and hand tools
Asphalt paver
Asphalt roller
Asphalt distributor truck
Front-end loader/box blade tractor
Self-propelled sweeper

TABLE 1.10 | Curb and gutter crew for concrete paving.

Labor
Supervisor
Concrete finisher—three total
Concrete finisher helper
Form setter—stringline setter
Form setter—stringline setter helper
Laborer
Equipment
Supervisor's pickup
Flatbed truck and hand tools
Small tool storage van
Slipform curb and gutter machine
Miscellaneous steel forms/stringline equipment
Concrete saw/cure spray machine
Air compressor
Small tractor

shows a typical crew and equipment mix for asphalt work in an urban area, and Table 1.10 shows a typical crew and equipment mix for a curb and gutter concrete paving crew.

CHECKLIST OF OPERATIONS

To prepare an estimate, an estimator should use a checklist that includes all the operations necessary to construct the project. Before completing an estimate, one should check this list to be sure that no operations have been omitted. The CSI master format provides a uniform approach for organizing project information for building projects. Tables 1.3 and 1.4 illustrate the cost summary of an estimate following the CSI format.

It is desirable for the operations to appear, as nearly as possible, in the same order in which they will be performed during construction of the project. Other checklists, serving the same purpose, should be prepared for projects involving highways, water systems, sewerage systems, etc.

The checklist can be used to summarize the costs of a project by providing a space for entering the cost of each operation, as illustrated in Tables 1.3 to 1.7. A suitable symbol should be used to show no cost for those operations that are not required. The total cost should include the costs for material, equipment, and labor for the particular operation, as determined in the detailed estimate.

BID DOCUMENTS

The end result of the design process is the production of a set of bid documents for the project to be constructed. These documents contain all the drawings and written specifications required for preparing the estimate and submitting the bid. Written specifications can be divided into two general parts: one part addresses the legal aspects between the owner and contractor, while the other part addresses the technical requirements of the project. The legal part of the written specifications contains at least four items that are important to the estimator: procedures for receipt and opening of bids, qualifications required of bidders, owner's bid forms, and bonds and insurance required for the project. Bid documents are discussed further in Chapter 2.

ADDENDA AND CHANGE ORDERS

An addendum is a change in the contract documents during the bidding process. Sometimes the designer or owner may wish to make changes after the plans and specifications have been issued, but before the contractors have submitted their bids. Also, a contractor may detect discrepancies in the plans and specifications while preparing an estimate. When an error is detected, the contractor should notify the designer to note any discrepancies.

An addendum is issued by the designer to make changes or correct errors in the plans and specifications. An addendum may be a reissue of a drawing or pages in the written specifications. Each addendum is given a number. After it is issued, an addendum becomes a part of the contract document. Thus, it is important for the estimator to ensure that the cost of all addenda are included in the estimate before submitting a final bid.

Any change in the contract documents after the contract is signed is called a change order. For most projects, changes are necessary during the construction process. Examples include additions or modifications requested by the owner, substitution of materials, or adverse weather conditions. A change order may add or delete work in the project, increase or decrease costs, or increase or decrease the time allowed for construction. In some situations, a change order may make a change that does not include any adjustment in time or cost.

OVERHEAD

The overhead costs chargeable to a project involve many items that cannot be classified as permanent materials, construction equipment, or labor. Some firms divide overhead into two categories: job overhead and general overhead.

Job overhead includes costs that can be charged specifically to a project. These costs are the salaries of the project superintendent and other staff personnel and the costs of utilities, supplies, engineering, tests, drawings, rentals, permits, insurance, etc., that can be charged directly to the project.

General overhead is a share of the costs incurred at the general office of the company. These costs include salaries, office rent, permits, insurance, taxes, shops and yards, and other company expenses not chargeable to a specific project.

Some contractors follow the practice of multiplying the direct costs of a project, materials, equipment, and labor by an assumed percentage to determine the probable cost of overhead. Although this method gives quick results, it may not be sufficiently accurate for most estimates.

While it is possible to estimate the cost of job overhead for a given project, it is usually not possible to estimate accurately the cost of general overhead chargeable to a project. Since the cost of general overhead is incurred in operating all the projects constructed by a contractor, it is reasonable to charge a portion of this cost to each project. The actual amount charged may be based on the duration of the project, the amount of the contract, or a combination of the two.

EXAMPLE 1.1

This example illustrates a method of determining the amount of general overhead chargeable to a given project.

Average annual value of all construction = $6,000,000

Average annual cost of general overhead = 240,000

Amount of general overhead chargeable to a project:

$$= \frac{\$240{,}000 \times 100}{\$6{,}000{,}000} = 4\% \text{ of total project cost}$$

MATERIAL TAXES

After the direct costs for materials and labor have been determined, the estimator must include the applicable taxes for each. The tax rate for materials will vary depending on the location. Generally a 3 percent state tax and a 2 to 3 percent city or county tax are assessed on materials. Therefore the tax on materials will range from 3 to 6 percent. It is the responsibility of the estimator to include the appropriate amount of tax in the summary of the estimate.

Some states and cities charge a tax on the value of equipment used on the project. It is necessary for the estimator to obtain information on required taxes for the particular location where the project is to be constructed.

Some owners, such as churches and schools, are tax exempt provided the owner makes the purchase of material. Thus, the owner may wish to purchase all materials and equipment that will be permanently installed in the project by the contractor. For this situation, the contract documents will have a section that describes how the owner will issue purchase orders for payment by the owner.

LABOR TAXES

There are two basic types of taxes on labor. The federal government requires a 7.65 percent tax on all wages up to $76,000 per year. In addition, an unemployment tax of approximately 3 percent may be required. Therefore, the total tax on labor is approximately 11 percent. The estimator must determine the appropriate tax on labor and include that amount in the summary of the estimate. A discussion of labor costs is presented in Chapter 5.

WORKERS COMPENSATION INSURANCE

Contractors pay workers compensation insurance for workers who may become injured while working on the project. This insurance provides medical expenses and payment of lost wages during the period of injury.

Each state has laws and regulations that govern workers compensation insurance. The cost also varies, depending on the type of work that is performed by each worker and by geographic location within the state. The cost for this insurance can range from 10 to 30 percent of the base cost of labor.

LABOR BURDEN

The term *labor burden* refers to the combined cost of labor taxes and insurance that a contractor must pay for workers. Some contractors multiply the base cost of labor by a certain percentage to estimate the total cost of labor. The total labor burden for construction labor generally ranges from 25 to 35 percent.

BONDS

Generally bidders are required to submit bonds as qualifications for submitting a bid for a project. To provide financial and legal protection for the owner, the contractor secures bonds from a surety company on behalf of the owner. Thus, bonding is a three-party arrangement. It is issued by the security company, paid by the contractor, for the protection of the owner.

Three types of bonds are commonly required in construction contracts: bid bond, performance bond, and payment bond. The bid bond ensures the owner that the contractor will sign the contract for the bid amount. The performance bond ensures the owner that the contractor will perform all work in accordance with the contract documents. The payment bond ensures the owner that all material and labor will be paid. If the contractor defaults, the bonding company agrees to fulfill the contract agreement.

The purchase cost of bonds depends on the total bid price and the success of the contractor in completing previous jobs. Chapter 2 provides further information on bonds and the estimating process.

INSURANCE

There are many risks involved in construction. Many types of insurance are available for protection to contractors, employees, subcontractors, and the general public. The two most common types of insurance that are secured by the contractor are *basic builder's risk,* which covers the project that is being constructed, and *public liability and property damage,* which covers actions of the contractor's employees while performing their work at the jobsite.

Basic builder's risk insurance affords a contractor protection against loss resulting from fire and lightning damage during the period of construction.

Public liability and property damage insurance protects the contractor against injuries to the general public or public property due to actions of the employees while performing work during construction.

Chapter 2 provides a detailed discussion of insurance costs that should be included in preparing an estimate.

REPRESENTATIVE ESTIMATES

Numerous examples of estimates are presented in this book to illustrate the steps to follow in determining the probable cost of the project. Nominal amounts are included for overhead and profit in some instances to give examples of complete estimates for bid purposes. In other instances, only the costs of materials, construction equipment, and labor are included. The latter three costs are referred to as *direct costs.* They represent the most difficult costs to estimate, and they are our primary concern.

In preparing the sample estimate, unit prices for materials, equipment, and labor are used primarily to show how an estimate is prepared. Note that these unit costs will vary with the time and location of a project. An estimator must obtain and use unit prices that are correct for the particular project. Estimators do not establish prices; they simply use them.

Remember that estimating is not an exact science. Experience, judgment, and care should enable an estimator to prepare an estimate that will reasonably approximate the ultimate cost of the project.

INSTRUCTIONS TO THE READERS

In the examples in this book, a uniform method is used for calculating and expressing the time units for equipment and labor and the total cost. For equipment, the time is expressed in equipment-hours, and for labor it is expressed in labor-hours. A labor-hour is one person working 1 hour or two people each working $\frac{1}{2}$ hour.

If a job that requires the use of four trucks lasts 16 hours, the time units for the trucks are the product of the number of trucks and the length of the job, expressed in hours. The unit of cost is for 1 truck-hour. The calculations are as follows:

Trucks: 4 trucks × 16 hr = 64 truck-hours @ \$45.00/hr = \$2,880.00

In a similar manner, the time and cost for the truck drivers are:

Truck drivers: 4 drivers × 16 hr = 64 labor-hours @ \$28.00/hr = \$1,792.00

The terms "64 truck-hours" and "64 labor-hours" can be shortened to read 64 hr without producing ambiguity.

PRODUCTION RATES

To determine the time required to perform a given quantity of work, it is necessary to estimate the probable rates of production of the equipment or labor. These rates are subject to considerable variation, depending on the difficulty of the work, skill of the laborer, job and management conditions, and the condition of the equipment.

A production rate is the number of units of work produced by a unit of equipment or a person in a specified unit of time. The time is usually 1 hr. The rate may be determined during an interval when production is progressing at the maximum possible speed. It is obvious that such a rate cannot be maintained for a long time. There will always be interruptions and delays that reduce the average production rates to less than the ideal rates. If a machine works at full speed only 45 minutes per hour (min/hr), the average production rate will be 0.75 of the ideal rate. The figure 0.75 is defined as an efficiency factor.

A backhoe with a 1-cy bucket may be capable of handling 3 bucket-loads per minute under ideal conditions. However, on a given job the average volume per bucket may be only 0.8 cy and the backhoe may be actually operating only 45 min/hr. For these operating conditions, the average output can be calculated as follows:

The ideal output: 3 cy/min $\times$ 60 min/hr $=$ 180 cy/hr

The bucket factor: 0.8

The efficiency factor: 45/60 $=$ 0.75

The combined operating factor: 0.8 $\times$ 0.75 $=$ 0.6

The average output: 0.6 $\times$ 180 cy/hr $=$ 108 cy/hr

The average output should be used in computing the time required to complete a job.

TABLES OF PRODUCTION RATES

In this book, numerous tables give production rates for equipment and laborers. In all tables the rates are adjusted to include an operation factor, usually based on a 45- to 50-min working hour. If this factor is too high for a given job, the rates should be reduced to more appropriate values.

When preparing an estimate for a project, if access is available to production rates obtained from actual jobs constructed under similar conditions, an estimator should use them instead of rates appearing in tables that represent general industry averages.

COMPUTER APPLICATIONS

An estimator must assemble a large amount of information in an organized manner and perform numerous calculations to prepare a cost estimate. The estimator can use the computer to organize, store, and retrieve information and to perform the many calculations necessary to prepare an estimate. It can be an effective tool for decreasing preparation time and increasing the accuracy of cost estimating.

The computer is used for estimating in at least five different applications: quantity takeoff, price extensions and bid summary, historical cost database, labor and equipment productivity database, and supplier database. Each application can be subdivided and should be linked together in an overall, integrated system.

Electronic spreadsheets are widely used for preparing cost estimates. A spreadsheet program can be used to perform the numerous price extension calculations and the bid summary of an estimate. Spreadsheet programs can be easily developed by the estimator using her or his system of estimating for the particular type of construction.

Many companies have developed commercial software for estimating construction costs. The software is developed for specific types of work, such as residential, building, or infrastructure type projects. Most commercial software is supplied with cost and productivity databases that can be used by the estimator.

An electronic digitizer can be used to obtain the quantities of materials from the construction drawings of a project. The estimator can use a digitizer pin to trace the lines on the drawings to obtain information such as the square yards of paving, square feet of brick, linear feet of pipe, or number of windows. Using a digitizer to calculate the quantity takeoff automates the process and provides the information to the estimator in an organized form.

Numerous computer databases can be developed by the estimator to automate and standardize the estimating function. The estimator can develop a historical cost database from the cost records of projects that have been completed by the company. This information can be stored as unit costs in the database and organized in a CSI or WBS system with cost codes for each item. The estimator can retrieve information from the historical cost database for the preparation of estimates for future projects. As new information is obtained from current projects, the estimator can update the historical cost database.

Labor and equipment productivity databases can be developed from records of previously completed projects. For example, the labor-hours per square foot of formwork, the number of cubic yards of earth per equipment-day, etc., can be organized and stored for specific job conditions. The estimator can retrieve the labor or equipment productivity figures from the database for the preparation of a cost estimate for a prospective project. Adjustments to the stored productivity can be made by the estimator to reflect unique job conditions.

The estimator can prepare a database of information for the material suppliers and subcontractors who perform work for the company. The database can be organized by type, size, and location of the supplier. During the preparation of an estimate for a project, the estimator can retrieve supplier and subcontractor information pertinent to the project. For example, the estimator can sort and list all drywall contractors capable of performing $80,000 of work at a particular job location. The name, address, and phone number of the contact person for each potential supplier or subcontractor can be retrieved from the computer.

Different individuals access much of the information used in the operation of a construction company at different times. For example, a project is planned and scheduled based on the time and cost information prepared by the estimator. Likewise, the project budget control system is developed from the cost estimate. The computer can be used to link the information from the estimating function to the planning function and to the budget control function of a contractor's operation. Common cost codes can be used for each operation to integrate, automate, and standardize the operations of a construction firm.

Chapter 22 presents a comprehensive discussion of computer estimating. The software at the McGraw-Hill website for this book has example problems that enable the reader to gain knowledge and experience in computer methods for estimating.

FORMS FOR PREPARING ESTIMATES

Experienced estimators will readily agree that it is very important to use a good form in preparing an estimate. As previously stated, the form should treat each operation to be performed in a construction project. For each operation, there should be a systematic listing of materials, equipment, labor, and any other items, with space for all calculations, number of units, unit costs, and total cost.

Each operation should be assigned a code number, and this number should be reserved exclusively for that operation on this estimate as well as on estimates for other projects within a given construction organization. For example, Table 1.4, item 2250 refers to compaction, whereas item 2372 refers to drilled piers. The accounting department should use the same item numbers in preparing cost records.

Table 1.11 illustrates a form that might be used in preparing a detailed estimate. When a project includes several operations, the direct costs for material, equipment, labor should be estimated separately for each operation, then the indirect costs.

TABLE 1.11 | Form to estimate construction costs.

Item no.	Description	Calculations	Number of units	Unit cost	Material cost	Equipment cost	Labor cost	Total cost
2350-0	Furnish and drive 200 creosote-treated piles.							
	Drive piles to full penetration into normal soil.							
	Piles size: 50-ft length, 14-in. butt, 6-in. tip	200 × 50 ft = 10,000 lin ft	10,000 lin ft					
-10	**Materials**							
	Piles; add 5 for possible breakage	205 × 50 ft = 10,250 lin ft	10,250 lin ft	$10.80/lin.ft	$110,700			$110,700
-20	**Equipment**							
	Moving to and from the job		lump sum			$7,000		$7,000
	Crane, 12-ton	200 piles/($2\frac{1}{2}$ piles/hr) = 80 hr	80 hr	$145/hr		$11,600		$11,600
	Hammer, single-acting, 15,000 foot pound		80 hr	$15/hr		$1,200		$1,200
	Air compressor equipment		80 hr	$9/hr		$720		$720
	Leads and sundry equipment		80 hr	$5/hr		$400		$400
-30	**Labor**							
-32	(add 16 hr to set up and take							
	down equipment)	80 + 16 = 96 hr						
-32	Foreman	96 hr	96 hr	$34/hr			$3,264	$3,264
-34	Crane operator	96 hr	96 hr	$28/hr			$2,688	$2,688
-36	Laborer (1 total)	96 hr	96 hr	$21/hr			$2,016	$2,016
-38	Workers on hammer (2 total)	96 hr × 2 = 192 hr	192 hr	$23/hr			$4,416	$4,416
-39	Helpers (2 total)	96 hr × 2 = 192 hr	192 hr	$19/hr			$3,648	$3,648
-40	**Subtotal direct costs**				$110,700	$20,920	$16,032	$147,652
-50	**Indirect costs**							
-51	Material taxes							
-511	State sales tax	5% × $110,700						$5,535
-512	County sales tax	1% × $110,700						$1,107
-520	Labor taxes							
-521	FICA (social security tax)	7.65% × $16,032						$1,226
-522	Unemployment tax	3% × $16,032						$481
-530	Insurance							
-531	Workers' compensation insurance	9% × $16,032						$1,443
-532	Contractor's liability insurance	4% × $16,032						$641
-540	Overhead							
-541	Job overhead	8% × $147,652						$11,812
-542	Office overhead	2% × $147,652						$2,953
-60	**Subtotal indirect costs**							$25,198
-70	**Total direct and indirect costs**							$172,850
-80	**Add-ons**							
-811	Contingency	5% × $172,850						$8,643
-812	Profit	10% × $172,850						$17,285
	Subtotal of add-ons							$25,928
-90	Performance bond	1% × ($172,850 + $25,928)						$1,988
-91	**Total cost,** amount of bid	$172,850 + $25,928 + $1,988						$200,766
-92	Cost per lin ft	$200,766/10,000 lin ft						$20.08 per lin ft