8

Cost Estimation and Budgeting

Chapter Outline

Chapter Objectives

After completing this chapter, you should be able to:

1. Understand the various types of common project costs.
2. Recognize the difference between various forms of project costs.
3. Apply common forms of cost estimation for project work, including ballpark estimates and definitive estimates.
4. Understand the advantages of parametric cost estimation and the application of learning curve models in cost estimation.
5. Discern the various reasons why project cost estimation is often done poorly.
6. Apply both top-down and bottom-up budgeting procedures for cost management.
7. Understand the uses of activity-based budgeting and time-phased budgets for cost estimation and control.
8. Recognize the appropriateness of applying contingency funds for cost estimation.

PROJECT MANAGEMENT BODY OF KNOWLEDGE CORE CONCEPTS COVERED IN THIS CHAPTER

1. Plan Cost Management (PMBoK sec. 7.1)
2. Estimate Costs (PMBoK sec. 7.2)
3. Determine Budget (PMBoK sec. 7.3)
4. Control Costs (PMBoK sec. 7.4)

PROJECT PROFILE

Sochi Olympics—What's the Cost of National Prestige?

The Olympics happen every two years and the focus is usually centered mostly on the athletes, but 2012 proved to be different. Instead, topics of overspending, terroristic threats, graft and corruption in high places, and criminal activities took center stage during these winter games. With an initial budget set at $12 billion, the final price tag on the Sochi Olympics is estimated to have surpassed $51 billion, leaving many people scratching their heads. How could the Winter Games become so expensive and where did all the money go?

Previously, the most expensive games were the 2008 Beijing Summer Olympics. However, at an estimated price tag of $40 billion, that total was still far less than the Sochi Olympics. Summer Olympics are also generally more expensive than the Winter Games due to more events being conducted, the need for venue construction, and the higher housing costs for larger teams. When it comes to hosting the Olympics, it seems that preliminary budgets are quickly abandoned, with higher and higher price tags accruing. Countries view hosting the Olympics as an opportunity to showcase their national achievements, so little effort is made to spare expenses. Even by these standards, the Sochi Olympics set a new standard for profligate spending. Historically, the average budget overspending for Olympics between 1960 and 2012 is 179% in real terms and 324% in nominal terms. The final bill for the Sochi games is far worse than these historical averages.

In 2007, when Russia won the bid to host the Winter Olympics against fellow finalists from South Korea and Austria, it promised to spend $12 billion. Although this figure was reasonable (and perhaps even excessive) at the time, it was quickly overtaken by events involved in developing the Sochi site. The key question: How did the original budget of $12 billion become a final price tag of $51 billion? There are several reasons for the escalating cost of the Sochi Games, including:

1. Although host to the Winter Games, Sochi is actually a subtropical climate. Temperatures average 52 degrees in the winter and 75 degrees in the summer. There are even palm trees in this location. So the majority of the skiing events had to be held in the mountains of Krasnaya Polyana, a distance of about 25 miles from Sochi. The cost of constructing the roadway and infrastructure used to transport athletes and spectators back and forth came to a mind-boggling $9.4 billion. At a price of $220 million per kilometer, the roadway was more expensive than the entire budget of the 2010 Vancouver Winter Olympics.
2. Vladimir Putin, President of Russia, had the goal of developing Sochi as a world-class ski resort in an effort to attract winter tourism to the country. As a result, he was a highly visible spectator throughout the project's development, offering suggestions and criticisms of the work being done. Rework on several of the venues and facilities added to the final bill.
3. Fears of terrorism and other disruptions led to an unprecedented level of security around the Sochi site. For example, troops from Russia's Interior Ministry cordoned off the Olympic area to a depth of nearly 20 kilometers to enforce a safe-zone around the Games. The costs of heightened security added significantly to Sochi's costs.
4. Projects needed to be rebuilt several times due to difficulties with terrain or resource management. For example, state planners did not account for streams that ran beneath the location of the venues. This oversight caused an embankment near Olympic Park to collapse repeatedly due to constant flooding, each time having to be rebuilt. Likewise, construction of the ski jump was budgeted for $40 million. However, because of the complex terrain, the placement had to be adjusted many times. It was also alleged that the necessary geological tests were not conducted before construction started. Trees were removed as needed, leaving several structures constructed on fragile soil that was prone to reoccurring landslides, which caused more rebuilding. In the end, the ski jump was completed, but for $265 million, rather than the initial $40 million estimate.
5. Kickbacks and graft were rumored to be rampant during the years of development, with insiders getting "sweetheart" deals from the government, and cronyism running rampant.

How bad was the corruption? As journalist Brett Forrest noted: "The Sochi Internal Affairs department has conducted numerous investigations into Olympstroy [the Russian Olympic organizing commission] and filed criminal complaints, alleging that the Olympic agency and its contractors operated a kickback scheme related to the construction of the Olympic stadium, the main hockey rink, and various other properties. The total in stolen funds, according to prosecutors, approaches $800 million."

(*continued*)

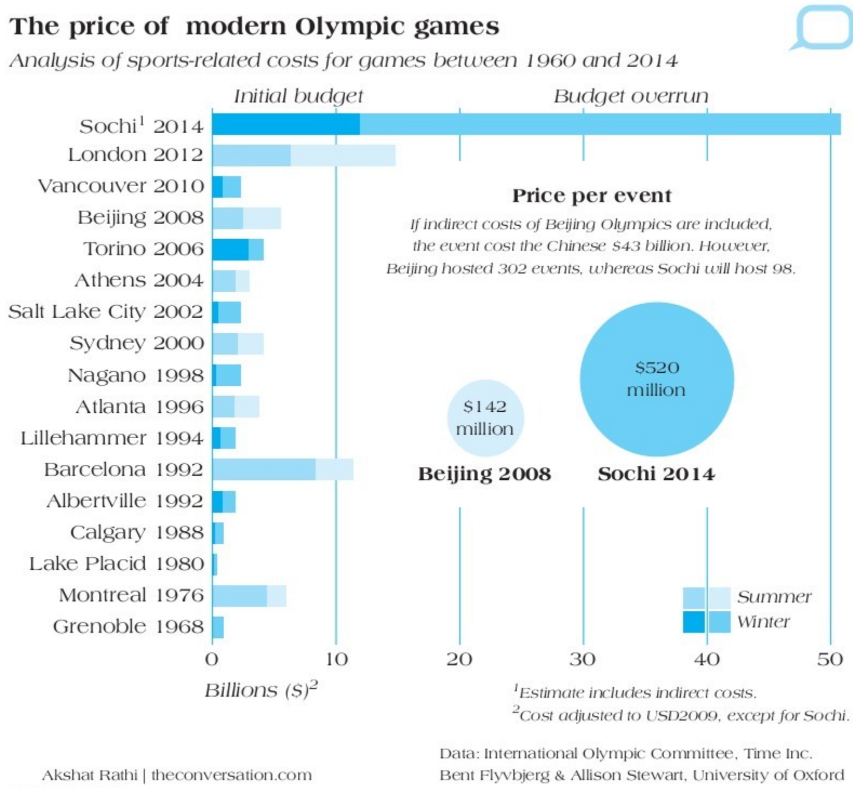

FIGURE 8.1 **Sochi Winter Olympics Costs**

Source: B. Flyvbjerg and A Stewart. (2012). "Olympic proportions: Cost and cost overrun at the Olympics 1960–2012." Said Business School Working Papers, Oxford: University of Oxford.

This may have been only the tip of the iceberg. Besides the speculated kickbacks, a green light was given to all development schemes around Sochi. Contractors sought to have their projects labeled "Olympic," knowing that way they would receive generous funding, including easements in zoning and building code regulations. There were also widespread allegations of cronyism, as friends and business associates of high-ranking Kremlin officials, including Vladimir Putin, received the choicest contracts. One opposition politician, Boris Nemtsov, criticized the substantial overspending, stating that the total amount embezzled or acquired by Putin's friends was in the range of $25–$30 billion, or more than half of the total budget for the Olympic Games. Construction companies that won contracts would have to inflate their projected costs in order to make the kickback payments to Russian State managers who had originally awarded the contracts. According to Nemtsov, it did not matter if the construction company had sufficient resources and skills for the project. What mattered was the company's willingness to return a percentage to the corrupt officials.

Many issues contribute to the reasons why these Olympics became so expensive. Russia had a concept that was budgeted at $12 billion when it started its preparations. History shows most nations exceed their budgets, though not to the excessive degree experienced by Russia in 2014. Ultimately, though, time is a relentless enemy of Olympic venue preparation; there is no possibility of extensions to the schedule. As a result, with the time moving closer to the opening of the Games, no expense could be (or was) spared in getting Sochi ready. Without question, enormous (and probably unknowable) sums disappeared to corruption and mismanagement. Nevertheless, the Sochi Games came on time and delivered a smoothly running experience to all who participated or came to watch. And yet, at a final price tag of $51 billion, one can still wonder about the costs of maintaining and enhancing national prestige.[1]

8.1 COST MANAGEMENT

Cost management is extremely important for running successful projects. The management of costs, in many ways, reflects the project organization's strategic goals, mission statement, and business plan. *Cost management* has been defined to encompass data collection, cost accounting, and cost control,[2] and it involves taking financial-report information and applying it to projects at finite levels of accountability in order to maintain a clear sense of money management for the project.[3] Cost accounting and cost control serve as the chief mechanisms for identifying and maintaining control over project costs.

Cost estimation is a natural first step in determining whether or not a project is viable; that is, can the project be done profitably? **Cost estimation** processes create a reasonable budget baseline for the project and identify project resources (human and material) as well, creating a time-phased budget for their involvement in the project. In this way, cost estimation and project budgeting are linked hand in hand: The estimates of costs for various components of the project are developed into a comprehensive project budgeting document that allows for ongoing project tracking and cost control.

During the development stage of the proposal, the project contractor begins cost estimation by identifying all possible costs associated with the project and building them into the initial proposal. While a simplified model of cost estimation might only require a bottom-line final figure, most customers will wish to see a higher level of detail in how the project has been priced out, that is, an itemization of all relevant costs. For example, a builder could simply submit to a potential home buyer a price sheet that lists only the total cost of building the house, but it is likely that the buyer will ask for some breakdown of the price to identify what costs will be incurred where. Some of the more common sources of project costs include:

1. ***Labor***—Labor costs are those associated with hiring and paying the various personnel involved in developing the project. These costs can become complex, as a project requires the services of various classifications of workers (skilled, semiskilled, laborers) over time. At a minimum, a project cost estimation must consider the personnel to be employed, salary and hourly rates, and any overhead issues such as pension or health benefits. A preliminary estimate of workers' exposure to the project in terms of hours committed is also needed for a reasonable initial estimate of personnel costs.
2. ***Materials***—Materials costs apply to the specific equipment and supplies the project team will require in order to complete project tasks. For building projects, materials costs are quite large and run the gamut from wood, siding, insulation, and paint to shrubbery and paving. For many other projects, the actual materials costs may be relatively small, for example, the purchase of a software package that allows rapid compiling of computer code. Likewise, many projects in the service industries may involve little or no materials costs whatsoever. Some materials costs can be charged against general company overhead; for example, the use of the firm's mainframe computer may be charged to the project on an "as used" basis.
3. ***Subcontractors***—When subcontractors provide resources (and in the case of consultants, expertise) for the project, their costs must be factored into the preliminary cost estimate for the project and be reflected in its budget. One subcontractor cost, for example, could be a charge to hire a marketing communications professional to design the project's promotional material; another might be costs for an industrial designer to create attractive product packaging.
4. ***Equipment and facilities***—Projects may be developed away from the firm's home office, requiring members of the project team to work "off site." Firms commonly include rental of equipment or office facilities as a charge against the cost of the project. For example, oil companies routinely send four- or five-person site teams to work at the headquarters of major subcontractors for extended periods. The rental of any equipment or facility space becomes a cost against the project.
5. ***Travel***—If necessary, expenses that are related to business travel (car rentals, airfare, hotels, and meals) can be applied to the project as an up-front charge.

Another way to examine project costs is to investigate the nature of the costs themselves. Among the various forms of project costs are those related to type (direct or indirect), frequency of occurrence (recurring or nonrecurring), opportunity to be adjusted (fixed or variable), and schedule (normal or expected) We will examine each of these types of project costs in turn this chapter

Direct Versus Indirect Costs

Direct costs are those clearly assigned to the aspect of the project that generated the cost. Labor and materials may be the best examples. All labor costs associated with the workers who actually build a house are considered direct costs. Some labor costs, however, might not be viewed as direct costs for the project. For example, the costs of support personnel, such as the project's cost accountant or other project management resources, may not be allocated directly, particularly when their duties consist of servicing or overseeing multiple, simultaneous projects. In a nonproject setting such as manufacturing, it is common for workers to be assigned to specific machinery that operates on certain aspects of the fabrication or production process. In this case, labor costs are directly charged against work orders for specific parts or activities.

The formula for determining total direct labor costs for a project is straightforward:

$$\text{Total direct labor costs} = (\text{Direct labor rate})\ (\text{Total labor hours})$$

The direct costs of materials are likewise relatively easy to calculate, as long as there is a clear understanding of what materials are necessary to complete the project. For example, the direct costs of building a bridge or hosting a conference dinner for 300 guests can be estimated with fair accuracy. These costs can be applied directly to the project in a systematic way; for example, all project purchase orders (POs) can be recorded upon receipt of bills of materials or sales and applied to the project as a direct cost.

Indirect costs, on the other hand, generally are linked to two features: overhead, and selling and general administration. Overhead costs are perhaps the most common form of indirect costs and can be one of the more complex forms in estimating. Overhead costs include all sources of indirect materials, utilities, taxes, insurance, property and repairs, depreciation on equipment, and health and retirement benefits for the labor force. Common costs that fall into the selling and general administration category include advertising, shipping, salaries, sales and secretarial support, sales commissions, and similar costs. Tracing and linking these costs to projects is not nearly as straightforward as applying direct costs, and the procedures used vary by organization. Some organizations charge a flat rate for all overhead costs, relative to the direct costs of the project. For example, some universities that conduct research projects for the federal government use a percentage multiplier to add administrative and overhead indirect costs to the proposal. The most common range for such indirect multiplier rates is from 20% to over 50% on top of direct costs. Other firms allocate indirect costs project by project, based on individual analysis. Whichever approach is preferred, it is important to emphasize that all project cost estimates include both direct and indirect cost allocations.

EXAMPLE 8.1 Developing Fully Loaded Labor Costs

Suppose that we are attempting to develop reasonable cost estimation for the use of a senior programmer for a software project. The programmer is paid an annual salary of $75,000, which translates to an hourly rate of approximately $37.50/hour. The programmer's involvement in the new project is expected to be 80 hours over the project's life. Remember, however, that we also need to consider overhead charges. For example, the company pays comprehensive health benefits and retirement, charges the use of plant and equipment against the project, and so forth. In order to cover these indirect costs, the firm uses an overhead multiplier of 65%. Employing an overhead multiplier is sometimes referred to as the *fully loaded* rate for direct labor costs. Thus, the most accurate calculation of the programmer's charge against the project would look like this:

$$\underset{(\$37.50)}{\text{Hourly rate}} \times \underset{(80)}{\text{Hours needed}} \times \underset{(1.65)}{\text{Overhead charge}} = \underset{\$4{,}950}{\text{Fully loaded labor cost}}$$

Some have argued that a more realistic estimate of fully loaded labor costs for each person assigned to the project would reflect the fact that no one truly works a full 8-hour day as part of the job. An allowance for a reasonable degree of personal time during the workday is simply recognition of the need to make personal calls, have coffee breaks, walk the hallways to the restroom, and so forth. Meredith and Mantel (2003) have argued that if such personal time is not included in the original total labor cost estimate, a multiplier of 1.12 should be used to reflect this charge, increasing the fully loaded labor cost of our senior programmer to:[4]

Hourly rate	×	Hours needed	×	Overhead charge	×	Personal Time	=	Fully loaded labor cost
($37.50)		(80)		(1.65)		(1.12)		$5,544

One other point to consider regarding the use of overhead (indirect costs) involves the manner in which overhead may be differentially applied across job categories. In some firms, for example, a distinction is made between salaried and nonsalaried employees. Thus, two or more levels of overhead percentage may be used, depending upon the category of personnel to which they are applied. Suppose that a company applied a lower overhead rate (35%) to hourly workers, reflecting the lesser need for contributions to retirement or health insurance. The calculated fully loaded labor cost for these personnel (even assuming a charge for personal time) would resemble the following:

Hourly rate	×	Hours needed	×	Overhead charge	×	Personal Times	=	Fully loaded labor cost
($12.00)		(80)		(1.35)		(1.12)		$1,451.52

The decision to include personal time requires input from the project's client. Whichever approach is taken, a preliminary total labor cost budget table can be constructed when the process is completed, as shown in Table 8.1. This table assumes a small project with only five project team personnel, whose direct labor costs are to be charged against the project without a personal time charge included.

Recurring Versus Nonrecurring Costs

Costs can also be examined in terms of the frequency with which they occur; they can be recurring or nonrecurring. **Nonrecurring costs** might be those associated with charges applied once at the beginning or end of the project, such as preliminary marketing analysis, personnel training, or outplacement services. **Recurring costs** are those that typically continue to operate over the project's life cycle. Most labor, material, logistics, and sales costs are considered recurring because some budgetary charge is applied against them throughout significant portions of the project development cycle. In budget management and cost estimation, it is necessary to highlight recurring versus nonrecurring charges. As we will see, this becomes particularly important as we begin to develop time-phased budgets—those budgets that apply the project's baseline schedule to projected project expenditures.

Fixed Versus Variable Costs

An alternative designation for applying project costs is to identify fixed and variable costs in the project budget. **Fixed costs**, as their title suggests, do not vary with respect to their usage.[5] For example, when leasing capital equipment or other project hardware, the leasing price is likely not

TABLE 8.1 Preliminary Cost Estimation for Fully Loaded Labor

Personnel	Title	Salary (Hourly)	Hours Needed	Overhead Rate Applied	Fully Loaded Labor Cost
Linda	Lead Architect	$35/hr	250	1.60	$14,000.00
Alex	Drafter—Junior	$20/hr	100	1.60	3,200.00
Jessica	Designer—Intern	$8.50/hr	80	1.30	884.00
Todd	Engineer—Senior	$27.50/hr	160	1.60	7,040.00
Thomas	Foreman	$18.50/hr	150	1.30	3,607.50
Total					$28,731.50

TABLE 8.2 Cost Classifications

	Type		Frequency		Adjustment		Schedule	
Costs	**Direct**	**Indirect**	**Recurring**	**Nonrecurring**	**Fixed**	**Variable**	**Normal**	**Expedited**
Direct Labor	X		X		X		X	
Building Lease		X	X		X		X	
Expediting Costs	X			X		X		X
Material	X		X			X	X	

to go up or down with the amount of usage the equipment receives. Whether a machine is used for 5 hours or 50, the cost of its rental is the same. When entering fixed-rate contracts for equipment, a common decision point for managers is whether the equipment will be used sufficiently to justify its cost. **Variable costs** are those that accelerate or increase through usage; that is, the cost is in direct proportion to the usage level. Suppose, for example, we used an expensive piece of drilling equipment for a mining operation. The equipment degrades significantly as a result of use in a particularly difficult geographical location. In this case, the variable costs of the machinery are in direct proportion to its use. It is common, in many cases, for projects to have a number of costs that are based on fixed rates and others that are variable and subject to significant fluctuations either upward or downward.

Normal Versus Expedited Costs

Normal costs refer to those incurred in the routine process of working to complete the project according to the original, planned schedule agreed to by all project stakeholders at the beginning of the project. Certainly, this planned schedule may be very aggressive, involving extensive overtime charges in order to meet the accelerated schedule; nevertheless, these costs are based on the baseline project plan. **Expedited costs** are unplanned costs incurred when steps are taken to speed up the project's completion. For example, suppose the project has fallen behind schedule and the decision is made to "crash" certain project activities in the hopes of regaining lost time. Among the **crashing** costs could be expanded use of overtime, hiring additional temporary workers, contracting with external resources or organizations for support, and incurring higher costs for transportation or logistics in speeding up materials deliveries.

All of the above methods for classifying costs are linked together in Table 8.2.[6] Across the top rows are the various classification schemes, based on cost type, frequency, adjustment, and schedule. The left-side column indicates some examples of costs incurred in developing a project. Here we see how costs typically relate to multiple classification schemes; for example, direct labor is seen as a direct cost, which is also recurring, fixed, and normal. A building lease, on the other hand, may be classified as an indirect (or overhead) cost, which is recurring, fixed, and normal. In this way, it is possible to apply most project costs to multiple classifications.

8.2 COST ESTIMATION

Estimating project costs is a challenging process that can resemble an art form as much as a science. Two important project principles that can almost be called laws are at work in cost estimation. First, the more clearly you define the project's various costs in the beginning, the less chance there is of making estimating errors. Second, the more accurate your initial cost estimations, the greater the likelihood of preparing a project budget that accurately reflects reality for the project and the greater your chances of completing the project within budget estimates.

One key for developing project cost estimates is to first recognize the need to cost out the project on a disaggregated basis; that is, to break the project down by deliverable and work package as a method for estimating task-level costs. For example, rather than attempt to create a cost estimate for completing a deliverable of four work packages, it is typically more accurate to first identify the costs for completing each work package individually and then create a deliverable cost estimate, as Table 8.3 illustrates.

TABLE 8.3 Disaggregating Project Activities to Create Reasonable Cost Estimates

Project Activities	Estimated Cost
Deliverable 1040—Site Preparation	
Work Package 1041—Surveying	$ 3,000
Work Package 1042—Utility line installation	15,000
Work Package 1043—Site clearing	8,000
Work Package 1044—Debris removal	3,500
Total cost for Deliverable 1040	$29,500

Companies use a number of methods to estimate project costs, ranging from the highly technical and quantitative to the more qualitative approaches. Among the more common cost estimation methods are the following:[7]

1. **Ballpark estimates**—Sometimes referred to as *order of magnitude* estimates, ballpark estimates are typically used when either information or time is scarce. Companies often use them as preliminary estimates for resource requirements or to determine if a competitive bid can be attempted for a project contract. For example, a client may file an RFQ (request for quote) for competitive bids on a project, stating a very short deadline. Managers would have little time to make a completely accurate assessment of the firm's qualifications or requirements, but they could still request ballpark estimates from their personnel to determine if they should even attempt to bid the proposal through a more detailed analysis. The unofficial rule of thumb for ballpark estimates is to aim for an accuracy of ±30%. With such a wide variance plus or minus, it should be clear that ballpark estimates are not intended to substitute for more informed and detailed cost estimation.
2. **Comparative estimates**—Comparative estimates are based on the assumption that historical data can be used as a frame of reference for current estimates on similar projects. For example, Boeing Corporation routinely employs a process known as **parametric estimation**, in which managers develop detailed estimates of current projects by taking older work and inserting a multiplier to account for the impact of inflation, labor and materials increases, and other reasonable direct costs. This parametric estimate, when carefully performed, allows Boeing to create highly accurate estimates when costing out the work and preparing detailed budgets for new aircraft development projects. Even in cases where the technology is new or represents a significant upgrade over old technologies, it is often possible to gain valuable insight into the probable costs of development, based on historical examples.

   Boeing is not the only firm that has successfully employed parametric cost estimation. Figure 8.2 shows a data graph of the parametric estimation relating to development of the Concorde aircraft in the 1960s. The Concorde represented such a unique and innovative airframe design that it was difficult to estimate the amount of design time required to complete the schematics for the airplane. However, using parametric estimation and based on experiences with other recently developed aircraft, a linear relationship was discovered between the number of fully staffed weeks (Concorde referred to this time as "manweeks") needed to design the aircraft and its projected cruising speed. That is, the figure demonstrated a direct relationship between the cruising speed of the aircraft and the amount of design time necessary to complete the schematics. Using these values, it was possible to make a reasonably accurate cost projection of the expected budget for design, demonstrating that in spite of significant changes in airplane design over the past decades, the relationship between cruising speed and design effort had held remarkably steady.

   Effective comparative estimates depend upon some important supplementary sources including a history of similar projects and a detailed archive of project data that includes the technical, budgetary, and other cost information. Adjusting costs to account for inflation simply becomes a necessary step in the process. The key to making comparative estimates meaningful lies in the comparability to previous project work. It makes little sense to compare direct labor costs for two projects when the original was done in a foreign country with different wage rates, overhead requirements, and so forth. Although some argue that comparative cost estimation cannot achieve a degree of accuracy closer

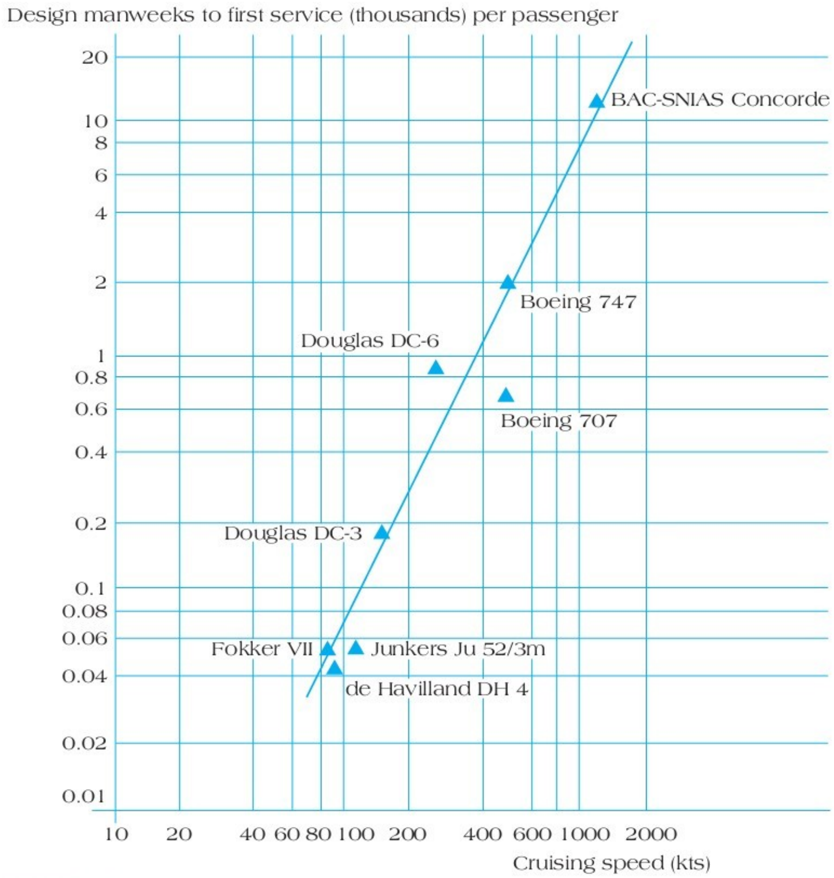

FIGURE 8.2 **Parametric Estimate for Design Costs for Concorde**

Note: Plot of design effort versus cruising speed for significant commercial aircraft types.

than ±15%, in some circumstances the estimate may be much more accurate and useful than that figure indicates.

3. **Feasibility estimates**—These estimates are based as a guideline on real numbers, or figures derived after the completion of the preliminary project design work. Following initial scope development, it is possible to request quotes from suppliers and other subcontractors with a greater degree of confidence, particularly as it is common to engage in some general scheduling processes to begin to determine the working project baseline. Feasibility estimates are routinely used for construction projects, where there are published materials cost tables that can give reasonably accurate cost estimates for a wide range of project activities based on an estimate of the quantities involved. Because they are developed farther down the life cycle, feasibility estimates are often expressed in terms of a degree of accuracy of ±10%.
4. **Definitive estimates**—These estimates can be given only upon the completion of most design work, at a point when the scope and capabilities of the project are quite well understood. At this point all major purchase orders have been submitted based on known prices and availabilities, there is little or no wiggle room in the project's specifications, and the steps to project completion have been identified and a comprehensive project plan is in place. Because it is understood that cost estimation should naturally improve with time, as more information becomes available and fewer project unknowns remain unresolved, definitive estimates should accurately reflect the expected cost of the project, barring unforeseen circumstances, at completion. Hence, definitive estimates can be expected to have an accuracy of ±5%. We saw in previous chapters that some projects may offer very thin profit margins; for example, in the case of fixed-cost contracts, the project organization assumes almost all risk for completing the project according to originally agreed-on contract terms. As a result, the better the job we do in estimating costs, the more likely we will be to maintain the profit margin contracted.

Which cost estimation approach should a project organization employ? The answer to this question presupposes knowledge of the firm's industry (e.g., software development vs. construction), ability to account for and manage most project cost variables, the firm's history of successful project management, the number of similar projects the firm has completed in the past, the knowledge and resourcefulness of project managers, and the company's budgeting requirements. In some instances (e.g., extremely innovative research and development projects), it may be impossible to create cost estimates with more than a ±20% degree of accuracy. On the other hand, in some projects such as events management (e.g., managing a conference and banquet), it may be reasonable to prepare definitive budgets quite early in the project. For example, while cost estimation can involve significant calculations and some amount of guesswork for certain types of projects, in other cases, project managers and cost estimators are able to calculate project costs with a much greater degree of accuracy. Many construction projects, particularly in standard residential and commercial building, employ estimates based on relatively stable historical data that makes it much easier to determine costs with good accuracy. To illustrate, Internet sites such as RSMeans.com, developed by Reed Construction Data, or CostDataOnLine.com include building cost calculators that are able to predict construction costs (including assumptions about labor rates, cost of living adjustments for location, square footage, type of building) with a reasonable degree of accuracy (see Figure 8.3).

RSMeans QuickCost Estimator

Project Title:	Sample Project
Model:	Apartment, 1-3 Story
Construction:	Face Brick with Concrete Block Back-up/Wood Joists
Location:	VANCOUVER, BC
Stories:	3
Story Height (l.f.):	10
Floor Area (s.f.):	2,500
Data Release:	Year 2012 Quarter 3
Wage Rate:	Union
Basement:	Not included

Costs are derived from a building model with basic components. Scope differences and market conditions can cause costs to vary significantly.

Cost Ranges	Low	Med	High
Total:	$826,650	$918,500	$1,148,125
Contractor's Overhead & Profit:	$206,550	$229,500	$286,875
Architectural Fees:	$82,800	$92,000	$115,000
Total Building Cost:	$1,116,000	$1,240,000	$1,550,000

Do You Need a More Comprehensive Estimate With Current Cost Data and Your Own Detailed Project Specifications?

Access the Custom Cost Estimator, a paid subscription service, to reference a comprehensive library of square foot models updated and localized for the United States to create a customized online estimate specific to your individual project! - All from RSMeans, *The Industry Source!*

(click here to view a sample report)

Important note: *These costs are not exact and are intended only as a preliminary guide to possible project cost. Actual project cost may vary greatly depending on many factors. RSMeans uses diligence in preparing the information contained here. RSMeans does not make any warranty or guarantee as to the accuracy, correctness, value, sufficiency or completeness of the data or resulting project cost estimates. RSMeans shall have no liability for any loss, expense or damage arising out of or in connection with the information contained herein.*

FIGURE 8.3 Sample Cost Estimator Using RSMeans.com Web Site

Source: Copyright RSMeans 2014- RSMeans Square Foot Models www.rsmeans.com/estimator/qce/qce_result.asp

ESTIMATE AND QUOTATION SHEET				
Project No.	Description:		Type No.	
Work Package No.	Task No.		Estimate No.	
Work Package Description:		Task Description:		
Internal Labor				
Skill	Category	Rate	Hours	Cost
Senior Test Engineer	TE4	18.50	40	$ 740.00
Test Engineer	TE3	14.00	80	1,120.00
Fitter	PF4	13.30	30	399.00
Drafter	DR2	15.00	15	225.00
Drawing Checker	DR3	16.50	3	49.50
Subtotal, Hours and Costs			168	$2,533.50
Labor Contingency (10%)			17	254.00
Total Labor, Hours and Costs			185	$2,787.50
Overhead (80%)				2,230.00
Gross Labor Cost				$5,017.50
Bought-Out Costs				
Materials (Specify): Bolts plus cleating material				$ 20.00
Finished Goods (Specify): N/A				
Services and Facilities: Hire test house; instrumentation plus report				12,300.00
Subcontract Manufacture (Specify): Fixture and bolt modification				250.00
Subtotal				$12,570.00
Contingency (15%)				1,885.50
Total Bought-Out Costs				$14,455.50
Expenses				
Specify: On-site accommodation plus traveling				$ 340.00
Total Bought-Out Costs and Expenses				$14,795.50
Profit %: N/A				
Total Quoted Sum: Gross Labor plus Bought-Out Costs and Expenses				$19,813.00
Compiled by:				
Approved:			Date	

FIGURE 8.4 **Sample Project Activity Cost Estimating Sheet**

The key to cost estimation lies in a realistic appraisal of the type of project one is undertaking, the speed with which various cost estimates must be created, and the comfort level top management has with cost estimation error. If the information is available, it is reasonable to expect the project team to provide as accurate a cost estimate as possible, as early in the project as possible. Figure 8.4 shows a sample project cost estimation form.

Learning Curves in Cost Estimation

Cost estimation, particularly for labor hours, often takes as its assumption a steady or uniform rate at which work is done. In the case of having to perform multiple activities, the amount of time necessary to complete the first activity is not significantly different from the time necessary to complete the *n*th activity. For example, in software development, it may be considered standard practice to estimate each activity cost independently of other, related activities with which the programmer is involved. Therefore, in the case of a programmer required to complete four work assignments, each involving similar but different coding activities, many cost estimators will simply apply a direct, multiplicative rule-of-thumb estimate:

$$\underset{(\$8{,}000)}{\text{Cost of activity}} \times \underset{(4)}{\begin{array}{c}\text{Number of times}\\ \text{activity is repeated}\end{array}} = \underset{\$32{,}000}{\text{Total cost estimate}}$$

When we calculate that each actual coding sequence is likely to take approximately 40 hours of work, we can create the more formal direct cost budget line for this resource. Assuming an overhead rate of .60 and a cost per hour for the programmer's services of $35/hour, we can come up with a direct billing charge of:

$$\begin{array}{c}\text{Wage}\\ (\$35/\text{hr})\end{array} \times \begin{array}{c}\text{Unit}\\ (4\text{ iterations})\end{array} \times \begin{array}{c}\text{Overhead Rate}\\ (1.60)\end{array} \times \begin{array}{c}\text{Hours/Unit}\\ (40\text{ hours})\end{array} = \$8{,}960$$

Although this rule of thumb is simple, it may also be simplistic. For example, is it reasonable to suppose that in performing similar activities, the time necessary to do a coding routine the fourth time will take as long as it took to do it the first time? Or is it more reasonable to suppose that the time needed (and hence, cost) of the fourth iteration should be somewhat shorter than the earlier times?

These questions go to the heart of a discussion of how **learning curves** affect project cost estimation.[8] In short, experience and common sense teach us that repetition of activities often leads to reduction in the time necessary to complete the activity over time. Some research, in fact, supports the idea that performance improves by a fixed percentage each time production doubles.[9]

Let us assume, for example, that the time necessary to code a particular software routine is estimated at 20 hours of work for the first iteration. Doing the coding work a second time requires only 15 hours. The difference between the first and second iteration suggests a learning rate of .75 (15/20). We can now apply that figure to estimates of cost for additional coding iterations. When output is doubled from the first two routines to the required four, the time needed to complete the fourth unit is now estimated to take:

$$15\text{ hrs. }(.75) = 11.25\text{ hours}$$

These time and cost estimates follow a well-defined formula,[10] which is the time required to produce the steady state unit of output, and is represented as:

$$Y_x = aX^b$$

where

Y_x = the time required for the steady state, x, unit of output
a = the time required for the initial unit of output
X = the number of units to be produced to reach the steady state
b = the slope of the learning curve, represented as: log decimal learning rate/log 2

Assume the need to conduct a project cost estimation in the case of construction, where one resource will be tasked to perform multiple iterations of a similar nature (e.g., fitting, riveting, and squaring). The worker must do a total of 15 of these activities to reach the steady state. Also assume that the time estimated to perform the last iteration (the steady state) is 1 hour, and we know from past experience the learning rate for this highly repetitive activity is .60. In calculating the time necessary to complete the first activity, we would apply these values to the formula to determine the value of a, the time needed to complete the task the first time:

$$\begin{aligned} b &= \log 0.60/\log 2 \\ &= -0.2219/0.31 \\ &= -0.737 \\ 1\text{ hr.} &= a(15)^{-0.737} \\ a &= 7.358\text{ hours} \end{aligned}$$

Note that the difference between the first and fifteenth iteration of this activity represents a change in duration estimation (and therefore, cost) from over 7 hours for the first time the task is performed to 1 hour for the steady state. The difference this learning curve factor makes in project cost estimates can be significant, particularly when a project involves many instances of repetitive work or large "production runs" of similar activities.

EXAMPLE 8.2 Learning Curve Estimates

Let's return to the earlier example where we are trying to determine the true cost for the senior programmer's time. Recall that the first, linear estimate, in which no allowance was made for the learning curve effect, was found to be:

$$(\$35/\text{hr})\ (4\text{ iterations})\ (1.60)\ (40\text{ hours}) = \$8{,}960$$

Now we can apply some additional information to this cost estimate in the form of better knowledge of learning-rate effects. Suppose, for example, that the programmer's learning rate for coding is found to be .90. The steady state time to code the sequence is 40 hours. Our estimate of the time needed for the first coding iteration is:

$$\begin{aligned} b &= \log 0.90/\log 2 \\ &= -0.0458/0.301 \\ &= -0.1521 \\ 40\text{ hrs.} &= a(4)^{-0.1521} \\ a &= 49.39\text{ hours} \end{aligned}$$

Thus, the first unit would take 9.39 hours longer than the steady state 40 hours. For this programming example, we can determine the appropriate unit and total time multipliers for the calculated initial unit time by consulting tables of learning curve coefficients (multipliers) derived from the formula with $a = 1$. We can also calculate unit and total time multipliers by identifying the unit time multipliers from 1 to 3 units of production (coding sequences) with a learning rate of .90. We use the units 1 to 3 because we assume that by the fourth iteration, the programmer has reached the steady state time of 40 hours. Based on $a = 1$, the unit time learning curve coefficients are $1^{-0.5121} = 1$, $2^{-0.1521} = 0.90$, and $3^{-0.1521} = .846$, for a total time multiplier of 2.746. Therefore, the time needed to code the first three sequences is:

$$\begin{array}{ccccc} \text{Total time} & & \text{Time required} & & \text{Total time to program} \\ \text{multiplier} & \times & \text{for initial unit} & = & \text{first three sequences} \\ (2.746) & & (49.39) & & 135.62\text{ hours} \end{array}$$

Because the steady state time of 40 hours occurs for the final coding iteration, total coding time required for all four sequences is given as:

$$135.62 + 40 = 175.62$$

The more accurate direct labor cost for the coding activities is:

$$\begin{matrix}\text{Wage} \\ (\$35/\text{hr})\end{matrix} \times \begin{matrix}\text{Overhead Rate} \\ (1.60)\end{matrix} \times \begin{matrix}\text{Total Hours} \\ (175.62\text{ hours})\end{matrix} = \$9{,}834.72$$

Compare this figure to the original value of $8,960 we had calculated the first time, which understated the programming cost by $874.72. The second figure, which includes an allowance for learning curve effects, represents a more realistic estimate of the time and cost required for the programmer to complete the project activities.

In some industries it is actually possible to chart the cost of repetitive activities to accurately adjust cost estimation for learning curves. Note the curve relating time (or cost) against activity repetition shown in Figure 8.5.[11] The learning curve effect here shows savings in time as a function of the sheer repetition of activities found in many projects. Some operations management books offer tables that show the total time multiplier, based on the learning rate values multiplied by the number of repetitive iterations of an activity.[12] Using these multipliers, the savings in revising cost estimates downward to account for learning curve effects can be significant. However, there is one important caveat: Learning curve effects may occur differentially across projects; projects with redundant work may allow for the use of learning curve multipliers while other projects with more varied work will not. Likewise, it may be more likely to see learning curve effects apply in greater proportion to projects in some industries (say, for example, construction) than in others (such as research and development). Ultimately, project budgets must be adjusted for activities in which learning curve effects are likely to occur, and these effects must be factored into activity cost estimates.

Increasingly, project contracts are coming to reflect the impact of learning curves for repetitive operations. For example, in the automotive industry, the manufacturer of hydraulic cylinders may be given a contract for the first year to provide cylinders at a price of $24 each. Each year after, the cost of the cylinder sold to the automobile maker is priced at $1 less per year, under the assumption that learning curves will allow the cylinder manufacturer to produce the product at a steadily lower cost. Thus, learning curves are factored into the value of long-term contracts.[13]

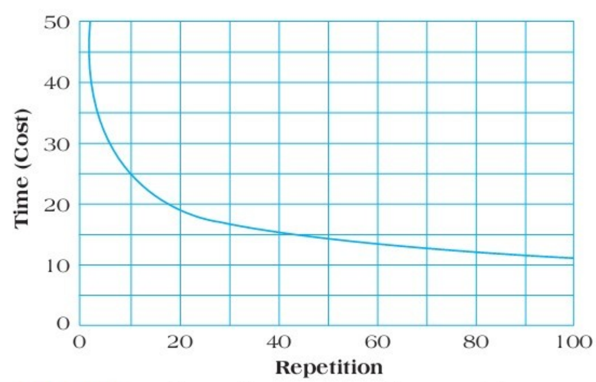

FIGURE 8.5 **Unit Learning Curve Log-Linear Model**

Source: J. P. Amor and C. J. Teplitz. (1998). "An efficient approximation for project composite learning curves," *Project Management Journal, 29*(3), pp. 28–42, figure on page 36.

Note: Graph on arithmetic coordinates.

Software Project Estimation—Function Points

Evidence from Chapter 1 and Box 8.1 (Software Cost Estimation) highlights the difficulties in developing realistic estimates for large-scale software projects. The track record is not encouraging: More and more software projects are overshooting their schedule and cost estimates, often by significant amounts. One of the reasons is simply due to the nature of uncertainty in these projects. We can make estimates of cost, but without a clear sense of the nature of the software,

BOX 8.1

Project Management Research in Brief

Software Cost Estimation

The software project industry has developed a notorious reputation when it comes to project performance. Past research by the Standish Group[14] found that for large companies, less than 9% of IT projects are completed on schedule and at budget. Over 50% of these projects will cost 189% of their original budget, while the average schedule overrun is 202%. A recent study of 5,400 IT projects conducted by McKinsey and Company and Oxford University found that on average, large IT projects run 45% over budget and 7% over time while delivering 56% less value than predicted. In fact, 17% of IT projects are such a disaster that they can threaten the very existence of the company.[15] Clearly, from both cost and schedule estimation perspectives, the industry is frustrated by unrealistic expectations. In spite of recent improvements in software development cost, schedule, and effort estimation, using Constructive Cost Estimating models (COCOMO II), required by several branches of the federal government when bidding software contracts, our lack of ability to accurately predict software project costs remains a serious concern.[16]

A book by Steven McConnell, president of Construx Software,[17] sheds light on some of the key reasons why software projects suffer from such a poor track record. Among his findings is the common failure to budget adequate time and funding for project activities that are likely to vary dramatically, depending upon the size of the project. He distinguished among six software project activities: (1) architecture, (2) detailed design, (3) coding and debugging, (4) developer testing, (5) integration, and (6) system testing. McConnell determined that for small IT projects of 2,000 lines of code or less, 80% of the project work consisted of just three activities: detailed design, coding and debugging, and unit testing (see Figure 8.6). However, as the complexity of the software projects increased, the proportion of these activities to the overall project cost dropped dramatically. Projects of over 128,000 lines of code required significantly more attention to be paid to the other three activities: architecture, integration, and system testing (about 60% of total effort).

The implications of this research suggest that IT project budgets must consider the size of the project as they calculate the costs of each component (work package). Larger projects resulting in hundreds of thousands of lines of code require that a higher proportion of the budget be allocated to software architecture and testing, relative to the actual cost of construction (design, coding, and unit testing).

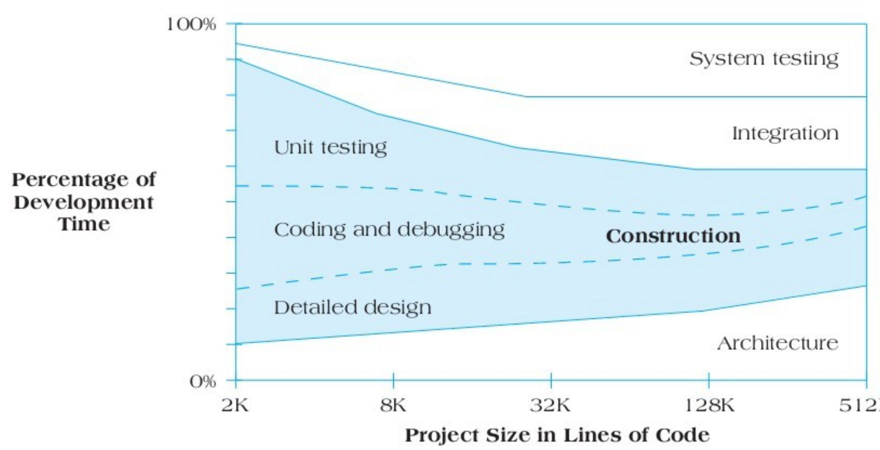

FIGURE 8.6 Software Project Development Activities as a Function of Size

Source: From *Code Complete,* 2d ed. (Microsoft Press, 2004), by Steve McConnell. Used with permission of the author.

the size of the program, and its functionality, these are often just best guesses and are quickly found to be inadequate.

Function point analysis is a system for estimating the size of software projects based on what the software does. To build any system, you need time to create files that hold information and interfaces to other screens (files and interfaces). You also need to create input screens (inputs), enquiry screens (queries), and reports (outputs). If you count all the files, interfaces, inputs, queries, and outputs, you can begin estimating the amount of work to be undertaken. The measure then relates directly to the business requirements that the software is intended to address. It can therefore be readily applied across a wide range of development environments and throughout the life of a development project, from early requirements definition to full operational use.

Simply stated, **function points** are a standard unit of measure that represents the functional size of a software application. In the same way that a house is measured by the square feet it provides, the size of an application can be measured by the number of function points it delivers to the users of the application. As part of that explanation, it is critically important to recognize that the size of the application being measured is based on the *user's view* of the system. It is based on what the user asked for, not what is delivered. Further, it is based on the way the user interacts with the system, including the screens that the user accesses to enter input, and the reports the user receives as output.

We know that it takes different amounts of time to build different functions; for example, it may take twice as long to build an interface table as an input table. Once we have a general sense of the relative times for each of the functions of the system, we have to consider additional factors to weight these estimates. These factor weightings are based on "technical complexity" and "environmental complexity." Technical complexity assesses the sophistication of the application to be built. Are we developing a complex model to determine the multiple paths of geosynchronous orbiting satellites or are we simply creating a database of customer names and addresses? Environmental complexity considers the nature of the setting in which the system is designed to work. Will it support a single user on one PC or a wide-area network? What computer language will the application be written in? A relatively streamlined and commonplace language such as Visual Basic requires less work than a more complex language and, consequently, we would assume that programmers could be more productive (generate more function points). These function points are adjusted for such complexity factors and then summed to determine a reasonable cost estimate for developing the software system.

Let's take a simple example: Suppose a local restaurant commissioned our firm to develop a replenishment and ordering system to ensure that minimum levels of foods and beverages are maintained at all times. The restaurant wants the application to have a reasonable number of input screens, output screens, a small number of query options and interfaces, but large and detailed report generation capabilities. Further, we know from past experience that one programmer working for one month (a "person-month") at our firm can generate an average of 10 function points. Finally, based on our company's past history, we have a set of average system technical and environmental complexity weightings that we can apply across all functions (see Table 8.4). For example, we know that in building an input function for the application, a system with high complexity is approximately three times more complicated (and requires more effort) than one with low complexity.

TABLE 8.4 Complexity Weighting Table for Function Point Analysis

	Complexity Weighting			
Function	**Low**	**Medium**	**High**	**Total**
Number of Inputs	2 × ____ =	4 × ____ =	6 × ____ =	
Number of Outputs	4 × ____ =	6 × ____ =	10 × ____ =	
Number of Interfaces	3 × ____ =	7 × ____ =	12 × ____ =	
Number of Queries	5 × ____ =	10 × ____ =	15 × ____ =	
Number of Files	2 × ____ =	4 × ____ =	8 × ____ =	

TABLE 8.5 Function Point Calculations for Restaurant Reorder System

	Complexity Weighting			
Function	**Low**	**Medium**	**High**	**Total**
Number of Inputs		$4 \times 15 =$		60
Number of Outputs			$10 \times 20 =$	200
Number of Interfaces	$3 \times 3 =$			9
Number of Queries		$10 \times 6 =$		60
Number of Files	$2 \times 40 =$			80
Total				409

With this information, we can apply the specific system requirements from the client to construct a function point estimate for the project. Suppose we determined (from our interviews with the restaurant owners) that the estimate for relative complexity was inputs (medium), outputs (high), interfaces (low), queries (medium), and files (low). Further, we know that the clients require the following number of each function: input screens (15), output screens (20), interfaces (3), queries (6), and report files (40). We can combine this information with our historic weightings for complexity to create Table 8.5.

Table 8.5 shows the results of combining our estimates for complexity of various programming functions with the requirements of the client for system features, including numbers of screens and other elements for each function. The result is our estimate that the project will require approximately 409 function points. We know that our organization estimates that each resource can perform 10 function points each "person-month." Therefore, we calculate the expected number of person-months to complete this job as $409/10 = 40.1$. If we assigned only four programmers to this job, it would take approximately 10 months to complete. On the other hand, by assigning our entire staff of 10 programmers, we would expect to complete the job in just over four months. Cost estimation using this information is straightforward: If our average resource cost per programmer is $5,000/month, we multiply this figure by 40.1 to determine that our estimated cost for completing the job is $200,500.

Function point analysis is not an exact science. Complexity determinations are based on historical estimates that can change over time and so must be continuously updated. Further, they may not be comparable across organizations with differing estimation procedures and standards for technical complexity. Nevertheless, function point analysis does give organizations a useful system for developing cost estimates for software projects, a historically difficult class of projects to estimate with any accuracy.[18]

Problems with Cost Estimation

In spite of project management's best efforts, a variety of issues affect the ability to conduct reasonable and accurate project cost estimates. Highly innovative projects can be notoriously difficult to estimate in terms of costs. Surprisingly, however, even projects that are traditionally viewed as highly structured, such as construction projects, can be susceptible to ruinously expensive cost overruns. Among the more common reasons for cost overruns are:[19]

1. ***Low initial estimates***—Caused by misperception of the scope of the project to be undertaken, low initial estimates are a double-edged sword. In proposing the low estimates at the start of a project, management is often setting themselves up to fail to live up to the budget constraints they have imposed. Hence, low estimates, which may be created either willingly (in the belief that top management will not fund a project that is too expensive) or unwillingly (through simple error or neglect), almost always guarantee the result of cost overrun. Part of the reason why initial estimates may be low can be the failure to consider the project in relation to other organizational activities. If we simply cost-out various project activities without considering the other surrounding organizational activities, we can be led to assume the project team member is capable of performing the activity in an unrealistic amount of time. (See Chapter 11 on critical chain project scheduling.)

Low estimates may also be the result of a corporate culture that rewards underestimation. For example, in some organizations, it is widely understood that cost overruns will not derail a project manager's career nearly as quickly as technical flaws. Therefore, it is common for project managers to drastically underestimate project costs in order to get their project funded, continually apply for supplemental funding as the project continues, and eventually turn in a product with huge cost overruns. Political considerations also can cause project teams or top management to view a project through rose-colored glasses, minimizing initial cost estimates, particularly if they run contrary to hoped-for results. The Denver International Airport represents a good example of a community ignoring warning signs of overly optimistic cost estimates in the interest of completing the project. The resulting cost overruns have been enormous.

2. ***Unexpected technical difficulties***—A common problem with estimating the costs associated with many project activities is to assume that technical problems will be minimal; that is, the cost estimate is often the case of seeming to suggest that "All other things being equal, this task should cost $*XX*." Of course, all other things are rarely equal. An estimate, in order to be meaningful, must take a hard look at the potential for technical problems, start-up delays, and other technical risks. It is a fact that new technologies, innovative procedures, and engineering advances are routinely accompanied by failures of design, testing, and application. Sometimes the impact of these difficulties is the loss of significant money; other times the losses are more tragic, resulting in the loss of life. The Boeing V-22 Osprey transport aircraft, for example, employs a radical "tilt-rotor" technology that was developed for use by the U.S. Marines and Navy. Prototype testing identified design flaws, contributing to the deaths of test pilots in early models of these aircraft.
3. ***Lack of definition***—The result of poor initial scope development is often the creation of projects with poorly defined features, goals, or even purpose (see Chapter 5 on scope management). This lack of a clear view of the project can quickly spill over into poorly realized cost estimates and inevitable cost overruns. It is important to recognize that the process of cost estimation and project budgeting must follow a comprehensive scope statement and work breakdown structure. When the first steps are done poorly, they effectively render futile any attempt at reasonable estimation of project costs.
4. ***Specification changes***—One of the banes of project management cost estimation and control is the midcourse specifications changes (sometimes referred to as "scope creep") that many projects are so prone to. Information technology projects, for example, are often riddled with requests for additional features, serious modifications, and updated processes—all while the project's activities are still in development. In the face of serious changes to project scope or specification, it is no wonder that many projects routinely overrun their initial cost estimates. In fact, with many firms, initial cost estimates may be essentially meaningless, particularly when the company has a well-earned reputation for making midcourse adjustments to scope.
5. ***External factors***—Inflation and other economic impacts can cause a project to overrun its estimates, many times seriously. For example, in the face of a financial crisis or an unexpected worldwide shortage of a raw material, cost estimates that were made without taking such concerns into account are quickly moot. To cite one example, in the early part of this decade, China and India's aggressive modernization and industrialization efforts, coupled with a weak American dollar, had been driving the price of crude oil to near-record highs. Because crude oil is benchmarked against the U.S. dollar, which is currently being kept weak by the Federal Reserve, it was taking more dollars to purchase oil. Further, Chinese and Indian demand for oil had led to higher international prices. A project that requires significant supplies of crude oil would have had to be recalculated upward due to the significant increase in the cost of this critical resource. Other common external effects can occur in the case of political considerations shaping the course that a project is expected to follow. This phenomenon is often found in government projects, particularly military acquisition contracts, which have a history of cost overruns, governmental intervention in the form of oversight committees, multiple constituents, and numerous midcourse change requests.

BOX 8.2

Project Management Research in Brief

"Delusion and Deception" Taking Place in Large Infrastructure Projects

This should be the golden age of infrastructure projects. A recent issue of *The Economist* reported that an estimated $22 trillion is to be invested in these projects over the next 10 years, making spending on infrastructure "the biggest investment boom in history." Because of this long-term commitment to large infrastructure improvements, coupled with the enormous costs of successfully completing these projects, it is critical that the governments and their agents responsible for designing and managing them get things right. In other words, too much is at stake to mismanage these projects.

Unfortunately, as previous examples in this chapter make clear, private organizations as well as the public sector have terrible performance records when it comes to successfully managing and delivering on their large infrastructure cost and performance targets. Examples such as the Sydney Opera House (original projected cost of 7 million Australian dollars; final cost of 102 million), the Eurotunnel (final costs more than double the original projections), and the Boston "Big Dig" (original estimated cost of $2.5 billion; final cost of nearly $15 billion) continue to be the rule rather than the exception when it comes to infrastructure project performance. The long list of incredibly overrun projects begs some simple questions: What is going on here? Why are we routinely so bad at cost estimation? What factors are causing us to continually miss our targets when it comes to estimating project costs?

Professor Bent Flyvbjerg, a project management researcher at Oxford University, and several colleagues have studied the track records of large infrastructure projects over the years and have arrived at some startling conclusions about the causes of their runaway costs: In most cases, the causes come from one of three sources—over-optimism bias, deliberate deception, or simple bad luck.

1. ***Optimism bias***—Flyvbjerg's work showed that executives commonly fall victim to delusions when it comes to projects, something he refers to as the "planning fallacy." Under the planning fallacy, managers routinely minimize problems and make their decisions on the basis of delusional optimism—underestimating costs and obstacles, involuntarily spinning scenarios for success, and assuming best-case options and outcomes. Optimism bias leads project managers and top executives to err on the side of underestimation of costs and time for project activities even in the face of previous evidence or past experiences. In short, we tend to develop overly positive scenarios of schedule and cost for projects and make forecasts that reflect these delusions.
2. ***Deliberate deception***—Large capital investment projects often require complex layers of decision making in order to get them approved. For example, governments have to work with private contractors and other agents who are responsible for making initial cost projections. Flyvbjerg found that some opportunities to inappropriately bias the project (deception) occur when a project's stakeholders all hold different incentives for the project. For example, the construction consortium wants the project, the government wants to provide for taxpayers and voters, bankers want to secure long-term investments, and so on. Under this situation, contractors may feel an incentive to provide estimates that are deliberately undervalued in order to secure the contract. They know that "true" cost estimates could scare off the public partners so they adopt a policy of deliberate deception to first win the contract, knowing that once the government is committed, it is extremely difficult for them to change their minds, even in the face of a series of expanding cost estimates. In short, the goal here is to get the project contracts signed; once the project is "on the books," it tends to stay there.

   Government representatives themselves can play a role in deception when it comes to "green-lighting" expensive projects. They may do this from a variety of motives, including altruism, reasoning that full disclosure of a project's costs will alienate the public, regardless of how much societal good may come from it, or their motives may be more self-serving. For example, the Willy Brandt International Airport in Berlin was scheduled to open in 2010. With a cost that has ballooned to over $7 billion and no fixed opening date in sight, critics have argued that the airport was a politicians' vanity project from the beginning. As one writer noted: "Many politicians want prestigious large-scale projects to be inseparably connected with their names. To get these expensive projects started, they artificially calculate down the real costs to get permission from parliament or other committees in charge."[20]
3. ***Bad luck***—A final reason for escalating project costs is simple bad luck. Bad luck implies that in spite of sound estimates, due diligence from all parties involved in the project, and the best intentions of both the contractors and project clients, there are always going to be cases where circumstances, environmental impacts, and sheer misfortune can conspire to derail a project or severely cripple its delivery. Though there is no doubt that bad luck does sometimes occur, Flyvbjerg warns that it is usually a handy excuse to attribute project problems to "bad luck," when the reality is that overruns and schedule slippage are typically caused by much more foreseeable reasons, as suggested above.

The research on serious project overruns and their causes offers some important insight into reasons why we keep missing our targets for critical projects. It also suggests additional effects that are equally important: Underestimating costs and overestimating benefits from any project leads to two problems. First, we opt to begin many projects that are not (and never were) economically viable. Second, starting these projects means we are effectively ignoring alternatives that actually could have yielded higher returns had we made a better initial analysis. Ultimately, the common complaint about large infrastructure projects ("Over budget, over time, over and over again") is one for which most organizations have no one to blame but themselves.[21]

8.3 CREATING A PROJECT BUDGET

The process of developing a project budget is an interesting mix of estimation, analysis, intuition, and repetitive work. The central goal of a budget is the need to support rather than conflict with the project's and the organization's goals. The **project budget** is a plan that identifies the allocated resources, the project's goals, and the schedule that allows an organization to achieve those goals. Effective budgeting always seeks to integrate corporate-level goals with department-specific objectives; short-term requirements with long-term plans; and broader, strategic missions with concise, needs-based issues. Useful budgets evolve through intensive communication with all concerned parties and are compiled from multiple data sources. Perhaps most importantly, the project budget and project schedule must be created in tandem; the budget effectively determines whether or not project milestones can be achieved.

As one of the cornerstones of project planning, the project budget must be coordinated with project activities defined in the Work Breakdown Structure (see Chapter 5). As Figure 8.7 suggests, the WBS sets the stage for creating the project schedule; the project budget subsequently assigns the necessary resources to support that schedule.

A number of important issues go into the creation of the project budget, including the process by which the project team and the organization gather data for cost estimates, budget projections, cash flow income and expenses, and expected revenue streams. The methods for data gathering and allocation can vary widely across organizations; some project firms rely on the straight, linear allocation of income and expenses, without allowing for time, while others use more sophisticated systems. The ways in which cost data are collected and interpreted mainly depend upon whether the firm employs a top-down or a bottom-up budgeting procedure. These approaches involve radically different methods for collecting relevant project budget information and can potentially lead to very different results.

Top-Down Budgeting

Top-down budgeting requires the direct input from the organization's top management; in essence, this approach seeks to first ascertain the opinions and experiences of top management regarding estimated project costs. The assumption is that senior management is experienced with past projects and is in a position to provide accurate feedback and estimates of costs for future project ventures. They take the first stab at estimating both the overall costs of a project and its major work packages. These projections are then passed down the hierarchy to the next functional department levels where additional, more specific information is collected. At each step down the hierarchy, the project is broken into more detailed pieces, until project personnel who actually will be performing the work ultimately provide input on specific costs on a task-by-task basis.

This approach can create a certain amount of friction within the organization, both between top and lower levels and also between lower-level managers competing for budget money. When

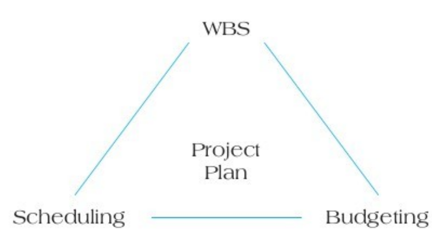

FIGURE 8.7 The Relationship Among WBS, Scheduling, and Budgeting

top management establishes an overall budget at the start, they are, in essence, driving a stake into the ground and saying, "This is all we are willing to spend." As a result, all successive levels of the budgeting process must make their estimates fit within the context of the overall budget that was established at the outset. This process naturally leads to jockeying among different functions as they seek to divide up the budget pie in what has become a zero-sum game—the more budget money engineering receives, the less there is for procurement to use.

On the positive side, research suggests that top management estimates of project costs are often quite accurate, at least in the aggregate.[22] Using this figure as a basis for drilling down to assign costs to work packages and individual tasks brings an important sense of budgetary discipline and cost control. For example, a building contractor about to enter into a contract to develop a convention center is often knowledgeable enough to judge the construction costs with reasonable accuracy, given sufficient information about the building's features, its location, and any known building impediments or worksite constraints. All subcontractors and project team members must then develop their own budgets based on the overall, top-down contract.

Bottom-Up Budgeting

Bottom-up budgeting takes a completely different approach than that pursued by top-down methods. The **bottom-up budgeting** approach begins inductively from the work breakdown structure to apply direct and indirect costs to project activities. The sum of the total costs associated with each activity are then aggregated, first to the work package level, then at the deliverable level, at which point all task budgets are combined, and then higher up the chain where the sum of the work package budgets are aggregated to create the overall project budget.

In this budgeting approach, each project manager is required to prepare a project budget that identifies project activities and specifies funds requested to support these tasks. Using these first-level budget requests, functional managers develop their own carefully documented budgets, taking into consideration both the requirements of the firms' projects and their own departmental needs. This information is finally passed along to top managers, who merge and streamline to eliminate overlap or double counting. They are then responsible for creating the final master budget for the organization.

Bottom-up budgeting emphasizes the need to create detailed project plans, particularly Work Breakdown Structures, as a first step for budget allocations. It also facilitates coordination between the project managers and functional department heads and, because it emphasizes the unique creation of budgets for each project, it allows top managers a clear view for prioritization among projects competing for resources. On the other hand, a disadvantage of bottom-up budgeting is that it reduces top management's control of the budget process to one of oversight, rather than direct initiation, which may lead to significant differences between their strategic concerns and the operational-level activities in the organization. Also, the fine-tuning that often accompanies bottom-up budgeting can be time-consuming as top managers make adjustments and lower-level managers resubmit their numbers until an acceptable budget is achieved.

Activity-Based Costing

Most project budgets use some form of activity-based costing. **Activity-based costing (ABC)** is a budgeting method that assigns costs first to activities and then to the projects based on each project's use of resources. Remember that project activities are any discrete task that the project team undertakes to make or deliver the project. Activity-based costing, therefore, is based on the notion that projects consume activities and activities consume resources.[23]

Activity-based costing consists of four steps:

1. Identify the activities that consume resources and assign costs to them, as is done in a bottom-up budgeting process.
2. Identify the cost drivers associated with the activity. Resources, in the form of project personnel, and materials are key cost drivers.
3. Compute a cost rate per cost driver unit or transaction. Labor, for example, is commonly simply the cost of labor per hour, given as:

$$\text{Cost rate/unit} \longrightarrow \$\text{Cost/hour}$$

TABLE 8.6 Sample Project Budget

Activity	Direct Costs	Budget Overhead	Total Cost
Survey	3,500	500	4,000
Design	7,000	1,000	8,000
Clear Site	3,500	500	4,000
Foundation	6,750	750	7,500
Framing	8,000	2,000	10,000
Plumb and Wire	3,750	1,250	5,000

4. Assign costs to projects by multiplying the cost driver rate times the volume of cost driver units consumed by the project. For example, assume the cost of a senior software programmer is $40/hour and that she is to work on the project for a total of 80 hours. The cost to the project would be:

$$(\$40/\text{hr})(80\,\text{hours}) = \$3{,}200.00$$

As we discussed earlier in this chapter, numerous sources of project costs (cost drivers) apply to both the direct and the indirect costs of a project. Activity-based costing, a technique employed within most project budgets, requires the early identification of these variables in order to create a meaningful control document.

Table 8.6 demonstrates part of a project budget. The purpose of the preliminary budget is to identify the direct costs and those that apply to overhead expenses. It is sometimes necessary to further break down overhead costs to account for separate budget lines. The overhead figure of $500 for *Survey,* for example, may include expenses covering health insurance, retirement contributions, and other forms of overhead, which would be broken out in a more detailed project budget.

Table 8.7 shows a budget in which the total planned expenses given in Table 8.6 are compared against actual accrued project expenses. With periodic updating, this budget can be used for variance reporting to show differences, both positive and negative, between the baseline budget assigned to each activity and the actual cost of completing those tasks. This method offers a central location for the tabulation of all relevant project cost data and allows for the preliminary development of variance reports. On the other hand, this type of budget is a static budget document that does not reflect the project schedule and the fact that activities are phased in following the network's sequencing.

Table 8.8 shows a sample from a time-phased budget, in which the total budget for each project activity is disaggregated across the schedule when its work is planned. The **time-phased budget** allocates costs across both project activities and the anticipated time in which the budget is to be expended. It allows the project team to match its schedule baseline with a budget baseline, identifying milestones for both schedule performance and project expense. As we will see in Chapter 13, the creation of a time-phased budget works in tandem with more sophisticated project control techniques, such as earned value management.

TABLE 8.7 Sample Budget Tracking Planned and Actual Activity Costs

Activity	Planned	Budget Actual	Variance
Survey	4,000	4,250	250
Design	8,000	8,000	- 0 -
Clear Site	4,000	3,500	(500)
Foundation	7,500	8,500	1,000
Framing	10,000	11,250	1,250
Plumb and Wire	5,000	5,150	150
Total	38,500	40,650	2,150

TABLE 8.8 Example of a Time-Phased Budget

	Months					
Activity	**January**	**February**	**March**	**April**	**May**	**Total by Activity**
Survey	4,000					4,000
Design		5,000	3,000			8,000
Clear Site		4,000				4,000
Foundation			7,500			7,500
Framing				8,000	2,000	10,000
Plumb and Wire				1,000	4,000	5,000
Monthly Planned	4,000	9,000	10,500	9,000	6,000	
Cumulative	4,000	13,000	23,500	32,500	38,500	38,500

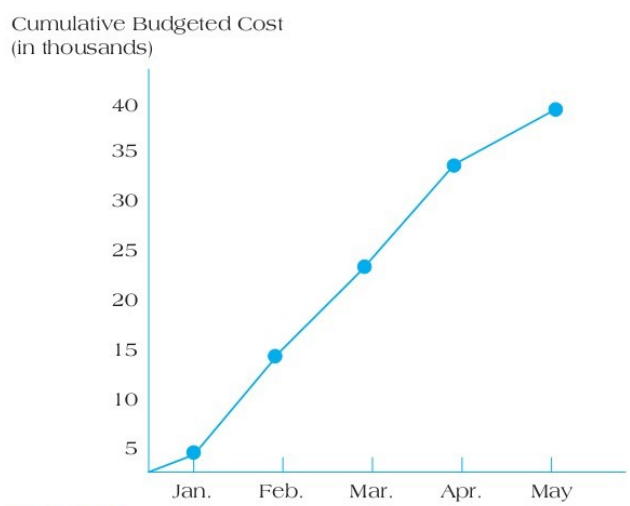

FIGURE 8.8 **Cumulative Budgeted Cost of the Project**

We can produce a tracking chart that illustrates the expected budget expenditures for this project by plotting the cumulative budgeted cost of the project against the baseline schedule. Figure 8.8 is a simple graphic of the plot and is another method for identifying the project baseline for schedule and budget over the anticipated life of the project.

8.4 DEVELOPING BUDGET CONTINGENCIES

Budget contingencies symbolize the recognition that project cost estimates are just that: estimates. Unforeseen events often conspire to render initial project budgets inaccurate, or even useless. (Suppose a construction project that had budgeted a fixed amount for digging a building's foundation accidentally discovered serious subsidence problems or groundwater.) Even in circumstances in which project unknowns are kept to a minimum, there is simply no such thing as a project developed with the luxury of full knowledge of events. A **budget contingency** is the allocation of extra funds to cover these uncertainties and improve the chances that the project can be completed within the time frame originally specified. Contingency money is typically added to the project's budget following the identification of all project costs; that is, the project budget does not include contingency as part of the activity-based costing process. Rather, the contingency is calculated as an extra cushion on top of the calculated cost of the project.

There are several reasons why it may make good sense to include contingency funding in project cost estimates. Many of these reasons point to the underlying uncertainty that accompanies most project cost estimation:[24]

1. ***Project scope is subject to change.*** Many projects aim at moving targets; that is, the project scope may seem well articulated and locked in. However, as the project moves through its development cycle, external events or environmental changes can often force us to modify or upgrade a project's goals. For example, suppose that our organization set out to develop an electronics product for the commercial music market only to discover, halfway through the development, that technological advances had rendered our original product obsolete. One option, other than abandoning the project, might be to engineer a product design upgrade midstream in the project's development. Those scope changes will cause potentially expensive cost readjustments.
2. ***Murphy's Law is always present.*** Murphy's Law suggests that if something can go wrong, it often will. Budget contingency represents one important method for anticipating the likelihood of problems occurring during the project life cycle. Thus, contingency planning just makes prudent sense.
3. ***Cost estimation must anticipate interaction costs.*** It is common to budget project activities as independent operations. Thus, in a product development project, we develop a discrete budget for each work package under product design, engineering, machining, and so forth. However, this approach fails to recognize the often "interactive" nature of these activities. For example, suppose that the engineering phase requires a series of iterative cycles to occur between the designers and the engineers. As a series of designs are created, they are forwarded to the engineering section for proofing and quality assessment. When problems are encountered, they must be shipped back to design to be corrected. Coordinating the several cycles of design and rework as a product moves through these two phases is often not accounted for in a standard project budget. Hence, contingency budgets allow for the likely rework cycles that link project activities interactively.
4. ***Normal conditions are rarely encountered.*** Project cost estimates usually anticipate "normal conditions." However, many projects are conducted under anything but normal working conditions. Some of the ways in which the normal conditions assumption is routinely violated include the availability of resources and the nature of environmental effects. Cost estimators assume that resources required for the project will be available when needed; however, personnel may be missing, raw materials may be of poor quality, promised funding may not materialize, and so forth. When resources are missing or limited, the activities that depend upon their availability are often delayed, leading to extra costs. Likewise, the geography and environmental effects on some projects demonstrate the difficulty in creating a "normal" project situation. For example, a project manager was assigned to develop a power plant in the West Bengal province of India only to discover, upon arrival, that the project was set to begin at the same time that the annual torrential monsoon rains were due to arrive! His first project activity, after reaching the construction site, was to spend three weeks erecting a five-foot retaining wall and coffer dam around the site to ensure it would not flood. Of course, the cost of this necessary construction had not been factored into his initial budget.

While project teams naturally favor contingencies as a buffer for project cost control, their acceptance by project stakeholders, particularly clients, is less assured. Some clients may feel that they are being asked to cover poor budget control on the part of the project firm. Other clients object to what seems an arbitrary process for calculating contingency. For example, it is common in the building industry to apply a contingency rate of 10%–15% to any structure prior to architectural design. As a result, a building budgeted for $10 million would be designed to cost $9 million. The additional million dollars is held in escrow as contingency against unforeseen difficulties during the construction and is not applied to the operating budget. Finally, does the contingency fund apply equally across all project work packages or should it be held in reserve to support critical activities as needed? Where or across what project activities contingency funds should be applied is the final point of contention. Despite these drawbacks, there are several benefits to the use of contingency funding for projects, including:

1. It recognizes that the future contains unknowns, and the problems that do arise are likely to have a direct effect on the project budget. In providing contingency, the project allows for the negative effects of both time and money variance.

2. Provision is made in the company plans for an increase in project cost. Contingency has sometimes been called the first project fire alarm. Allowing contingency funds to be applied to a project is a preliminary step in gaining approval for budget increases, should they become necessary.
3. Application to the contingency fund gives an early warning signal of a potential overdrawn budget. In the event of such signals, the organization's top management needs to take a serious look at the project and the reasons for its budget variance, and begin formulating fallback plans should the contingency prove to be insufficient to cover the project overspend. In large defense-industry contracts, for example, project organizations facing budget overruns often first apply any contingency money they possess to the project before approaching the governmental agency for additional funding. An Army project contract manager will understandably demand full accounting of project expenditures, including contingency funds, before considering additional funding.

Project cost estimation and budgeting are two important components of project control. Because a significant constraint on any project is its budget, the manner in which we estimate project costs and create realistic budgets is critical to effective project planning. Further, the best defense against overrunning our budgets is to prepare project cost estimates as carefully as possible. Although we cannot possibly anticipate every eventuality, the more care that is used in initial estimation, the greater the likelihood that we can create a budget that is a reasonably accurate reflection of the true project cost. Cost estimation challenges us to develop reasonable assumptions and expectations for project costs through clearly articulating the manner in which we arrive at our estimates. Budgeting is the best method for applying project expenditures systematically, with an eye toward keeping project costs in line with initial estimates. Taken together, cost estimation and budgeting require every project manager to become comfortable with not only the technical challenges of the project, but its monetary constraints as well.

Summary

1. **Understand the various types of common project costs.** Project budgeting comprises two distinct elements: cost estimation and the budgeting process itself. Among the well-known expenses in most projects are:
   a. ***Cost of labor***—the charge against the human resources needed to complete the project.
   b. ***Cost of materials***—costs relating to any specific equipment or supplies needed for project development.
   c. ***Subcontractors***—charges against the project budget for the use of consultants or other subcontracted work.
   d. ***Cost of equipment and facilities***—the costs of any plant and equipment, either at the project's location or off-site.
   e. ***Travel***—a sometimes necessary charge for the expense of having project team members in the field or at other sites.
2. **Recognize the difference between various forms of project costs.** The types of costs that a project can incur can be identified in a number of ways. Among the more common types of costs are:
   - ***Direct versus indirect***—Direct costs are those that can be directly assigned to specific project activities performed to create the project. Indirect costs relate to general company overhead expenses or administration. For example, overhead expenses charged to a project may include health benefits or retirement contributions. General administration includes shipping costs, secretarial or computer support, sales commissions, and so on.
   - ***Recurring versus nonrecurring***—Recurring costs are ongoing expenses, such as labor or material costs. They appear across the project's life cycle. Nonrecurring costs are typically one-time expenses related to some special expense or purchase, such as training or purchase of a building.
   - ***Fixed versus variable***—Fixed costs do not vary with respect to their usage. Variable costs generally increase in proportion to the degree they are used.
   - ***Normal versus expedited***—Normal costs are the normally scheduled costs of the project, set in relation to the schedule baseline. Expedited costs are sometimes referred to as "crashing costs" and increase due to the extra resources assigned to speed the completion of a specific project activity.
3. **Apply common forms of cost estimation for project work, including ballpark estimates and definitive estimates.** Cost estimating may follow one of several approaches, usually increasing in accuracy as estimates coincide more closely with the completion of project design work. Preliminary estimates for task completion, sometimes called "ballpark estimates," may be accurate only to ±30%. On the other hand, as the project gets closer to the

completion of the design phase, it is more realistic to expect more accurate, definitive estimates (±5%). One method for cost estimation is through the use of parametric techniques, which compare current project activities to the cost of past, similar activities and then assign a multiplier that considers inflation or other additional cost increases.

4. **Understand the advantages of parametric cost estimation and the application of learning curve models in cost estimation.** Parametric cost estimation allows project managers to develop detailed estimates of current project costs by taking older work and inserting a multiplier to account for the impact of inflation, labor and materials increases, and other reasonable direct costs. Parametric estimation allows project managers to begin formulating cost estimates from a position of past historical record, which can be very helpful in complex projects for which it is difficult to formulate reasonable estimates.

   One element in project cost estimation that cannot be ignored is the effect of learning rates on an individual's ability to perform a project task. Learning curve effects typically are relevant only in cases where a project team member is required to perform multiple iterations of a task. When these situations occur, it is usually easier and faster to complete the *n*th iteration than it was to complete the first, due to the effect of learning on repetitive activities. Using available formulas, we can readjust cost estimates for some project activities to reflect the effect of the learning curve on the cost of an activity.

5. **Discern the various reasons why project cost estimation is often done poorly.** Cost estimation may be poorly done for several reasons, including:
   - **a.** ***Low initial estimates***—These are caused by poor knowledge of the project's scope or due to an organizational atmosphere that rewards low initial estimates and does not sanction subsequent cost or schedule overruns.
   - **b.** ***Unexpected technical difficulties***—This is a common problem for many projects when technical performance is cutting-edge and unexpected problems emerge.
   - **c.** ***Lack of definition***—Poorly specified projects usually lead to poorly budgeted and controlled projects.
   - **d.** ***Specification changes***—The continuing distraction of specification change requests can quickly lead to cost overruns.
   - **e.** ***External factors***—The uncontrollable effects of inflation or economic or political interference in a project can render initial cost estimates invalid.

6. **Apply both top-down and bottom-up budgeting procedures for cost management.** Project budgeting involves the process of taking the individual activity cost estimates and creating a working document for planned project expenditures. Two approaches to budgeting involve the use of top-down and bottom-up efforts to better identify costs and allocate project budget money. Using activity-based budgeting techniques, project teams typically identify the activities that consume resources and assign costs to them. Second, they determine the cost drivers associated with the activities (usually human resources and materials costs), and third, a cost rate per cost driver is then computed. Activity-based budgeting allows for the creation of project budgets with specific budget lines for each task necessary to complete the project.

7. **Understand the uses of activity-based budgeting and time-phased budgets for cost estimation and control.** Taking activity-based budgeting one step further, we can create time-phased budgets when the specific activity costs are then allocated across the project schedule baseline to reflect the points on the project time line when the budget will be consumed. Using a time-phased budget approach allows the project team to link time and cost into a unified baseline that can be set to serve as the project plan. Project cost control, as the project moves forward, is predicated on creating the time-phased budget.

8. **Recognize the appropriateness of applying contingency funds for cost estimation.** In some projects, it is necessary, for a variety of reasons, to set aside a certain amount of the project budget into an account to handle any uncertainties or unexpected events that could not have been anticipated in the initial cost estimation and budgeting sequence. This account is referred to as a project contingency fund. In many types of projects, particularly construction projects, a contingency fund is a normal part of the project budget. Contingency is not assigned to any specific project activities; rather, it is used as a general project-level emergency fund to handle the costs associated with problems, should any arise.

Key Terms

Activity-based costing (ABC) *(p. 276)*
Ballpark estimates *(p. 263)*
Bottom-up budgeting *(p. 276)*
Budget contingency *(p. 278)*
Comparative estimates *(p. 263)*
Cost estimation *(p. 259)*
Crashing *(p. 262)*
Definitive estimates *(p. 264)*
Direct costs (p. *260)*
Expedited costs *(p. 262)*

Solved Problems

8.1 CALCULATING FULLY LOADED LABOR COSTS

Calculate the fully loaded cost of labor for the project team using the following data. What are the costs for the individual project team members? What is the fully loaded cost of labor?

Name	Hours Needed	Overhead Charge	Personal Time Rate	Hourly Rate	Fully Loaded Labor Cost
John	40	1.80	1.12	$21/hr	
Bill	40	1.80	1.12	$40/hr	
J.P.	60	1.35	1.05	$10/hr	
Sonny	25	1.80	1.12	$32/hr	
	Total Fully Loaded Labor Cost =				

SOLUTION

We use the formula for calculating fully loaded costs, given as:

$$\text{Hourly rate} \times \text{Hours needed} \times \text{Overhead charge} \times \text{Personal time} = \text{Total fully loaded labor cost}$$

Applying each rate given above in turn, we fill in the fully loaded cost table as follows:

Name	Hours Needed	Overhead Charge	Personal Time Rate	Hourly Rate	Fully Loaded Labor Cost
John	40	1.80	1.12	$21/hr	$1,693.44
Bill	40	1.80	1.12	$40/hr	3,225.60
J.P.	60	1.35	1.05	$10/hr	850.50
Sonny	25	1.80	1.12	$32/hr	1,612.80
	Total Fully Loaded Labor Cost =				$7,382.34

8.2 ESTIMATING SOFTWARE COSTS WITH FUNCTION POINTS

Suppose you were required to create a reasonably detailed estimate for developing a new student information and admissions system at a local college. Your firm's programmers average 6 function points on a person-month basis. After speaking with representatives from the college, you know that their request is based on the following screen requirements: inputs (4), outputs (7), interfaces (12), queries (20), and files (16). Further, we have determined that the relative complexity of each of these functions is as follows: inputs (low), outputs (medium), interfaces (high), queries (medium), and files (medium). Using this information and the following table, calculate the number of function points for this project.

	Complexity Weighting			
Function	Low	Medium	High	Total
Number of Inputs	3 × ____ =	6 × ____ =	9 × ____ =	
Number of Outputs	2 × ____ =	6 × ____ =	10 × ____ =	
Number of Interfaces	1 × ____ =	3 × ____ =	5 × ____ =	
Number of Queries	4 × ____ =	8 × ____ =	12 × ____ =	
Number of Files	4 × ____ =	6 × ____ =	8 × ____ =	

SOLUTION

Once we know the number of requirements for each of the five programmer functions and the complexity weighting for the activities, the calculation of total function points requires that we create a table as shown below, in which the relative complexity of the five programming functions is multiplied by the number of screen requirements. The table shows that the total number of function points for this project is 370.

	Complexity Weighting			
Function	**Low**	**Medium**	**High**	**Total**
Number of Inputs	3 × **4** =			**12**
Number of Outputs		6 × **7** =		**42**
Number of Interfaces			5 × **12** =	**60**
Number of Queries		8 × **20** =		**160**
Number of Files		6 × **16** =		**96**

8.3 CALCULATING BUDGET ESTIMATES USING THE LEARNING CURVE

Assume you have a software project that will require the coding services of a senior programmer to complete 14 coding sequences that are relatively similar. We know that the programmer's learning rate is .90 and that the first coding sequence is likely to take her 15 hours to complete. Using the learning curve formula, calculate the steady state time to code these sequences.

SOLUTION

Recall that the learning curve formula for calculating the time required to produce the steady state unit of output is represented as:

$$Y_x = aX^b$$

where

Y_x = the time required for the steady state, x, unit of output

a = the time required for the initial unit of output

X = the number of units to be produced to reach the steady state

b = the slope of the learning curve, represented as: log decimal learning rate/log 2

$$\begin{aligned} b &= \log 0.90/\log 2 \\ &= -0.4576/0.301 \\ &= -0.1521 \\ Y_x &= 15(14)^{-0.1521} \\ Y_x &= 10.04 \text{ hours} \end{aligned}$$

Discussion Questions

8.1 Describe an environment in which it would be common to bid for contracts with low profit margins. What does this environment suggest about the competition levels?

8.2 How has the global economy affected the importance of cost estimation and cost control for many project organizations?

8.3 Why is cost estimation such an important component of project planning? Discuss how it links together with the Work Breakdown Structure and the project schedule.

8.4 Imagine you are developing a software package for your company's intranet. Give examples of the various types of costs (labor, materials, equipment and facilities, subcontractors, etc.) and how they would apply to your project.

8.5 Give reasons both in favor of and against the use of a personal time charge as a cost estimate for a project activity.

8.6 Think of an example of parametric estimating in your personal experience, such as the use of a cost multiplier based on a similar, past cost. Did parametric estimating work or not? Discuss the reasons why.

8.7 Suppose your organization used function point analysis to estimate costs for software projects. How would the expertise level of a recently hired programmer affect your calculation of their function points on a monthly basis when compared to an older, more experienced programmer?

8.8 Put yourself in the position of a project customer. Would you insist on the cost adjustments associated with learning curve effects or not? Under what circumstances would learning curve costs be appropriately budgeted into a project?

8.9 Consider the common problems with project cost estimation and recall a project with which you have been involved. Which of these common problems did you encounter most often? Why?

8.10 Would you prefer the use of bottom-up or top-down budgeting for project cost control? What are the advantages and disadvantages associated with each approach?

8.11 Why do project teams create time-phased budgets? What are their principal strengths?

8.12 Project contingency can be applied to projects for a variety of reasons. List three of the key reasons why a project organization should consider the application of budget contingency.

