

Chapter

8

Cost Estimating and Budgeting

A billion here and a billion there. Pretty soon it starts to add up to real money.

—SENATOR EVERETT
DIRKSEN

Cost estimates, budgets, work breakdown structures (WBSs), and schedules are interrelated concepts. Ideally, cost estimates are based upon elements of the WBS and are prepared at the work package level. When the cost of a work task cannot be estimated because it is too complex, the task is broken down further until it can. When the cost cannot be estimated because of uncertainties about the work, the initial estimate is based upon judgment and later revised as information becomes available. Project schedules dictate resource requirements and the rate of expenditures, but as described in the last chapter, the converse is also true: constraints on resources and working capital dictate project schedules. Imposing practical constraints on costs is necessary so that realistic project budgets can be established. Failing to do so results in projects that are prematurely terminated for lack of funds, or are completed but at an exorbitant expense. Both occurrences are relatively commonplace.

Cost estimating, budgeting, and cost control sometimes are thought to be the exclusive concerns of planners and accountants, but in projects they should be of concern to everyone. Project participants who best understand

the work—the engineers, scientists, systems specialists, architects, or others who are the closest to the sources of costs—should be involved in the estimating and budgeting process (commonly, however, these same people are disdainful of budgets and ignorant about how they work and why they are necessary). Project managers must also be involved. They do not have to be financial wizards to contribute to the estimating and budgeting process, but they do need skill in organizing and using cost figures.

The project manager oversees the cost estimating and budgeting process, though often with the assistance of a staff cost accountant. Technical projects should also have a *cost engineer*, someone able to track and assess both technical and financial aspects of the project. The cost engineer reviews deliverables, their requirements, specifications and control methods, assesses the project from both cost and technical points of view, and provides cost and technical advice to the project manager.

8.1 COST ESTIMATING

The initial cost estimate can seal a project's financial fate. When project costs are overestimated (too high), the contractor risks losing out to a lower bidding competitor. Worse is when the cost is underestimated. A \$50,000 fixed price bid might win the contract, but obviously the contractor will lose money if the cost ends up at \$80,000. Underestimates are often accidental—the result of being overly optimistic, although sometimes they are intentional—the result of trying too hard to beat the competition. In a practice called *buy in*, the contractor reduces an initially realistic estimate just enough to win the contract, hoping to cut costs, or renegotiate higher fees after the work is underway. The practice is risky, unethical, and, sadly, relatively commonplace. In large capital projects the tendency is to underestimate costs (and over estimate benefits) to get the needed funding and the project underway, after which the original estimate is soon forgotten.

But a very low bid can signify more than the desire to get a contract. It may imply that the contractor has cut corners, left things out, or was just sloppy in arriving at the estimate. The consequences for both client and contractor can be catastrophic, from operating at a loss to bankruptcy. Cost estimates are used to develop budgets and become the baseline against which project performance is evaluated. After the project begins the rate of actual cost expenditure is compared to the rate of estimated expenditure (indicated in the budget) as an important measure of project work performance. Without good estimates it is impossible to evaluate work efficiency or to determine in advance how much the finished project will cost.

8.2 COST ESCALATION

Accurate cost estimating is sometimes a difficult task—largely because it begins during project conception and well before all necessary, final information about the project is available. The less well defined the project, the less information there is, and the greater the chances that the estimated costs will substantially differ from final, actual figures. As a rule, the difference will be on the side of a cost overrun. The amount by which actual costs increase to overrun the initial estimated costs is referred to as *cost escalation*.¹

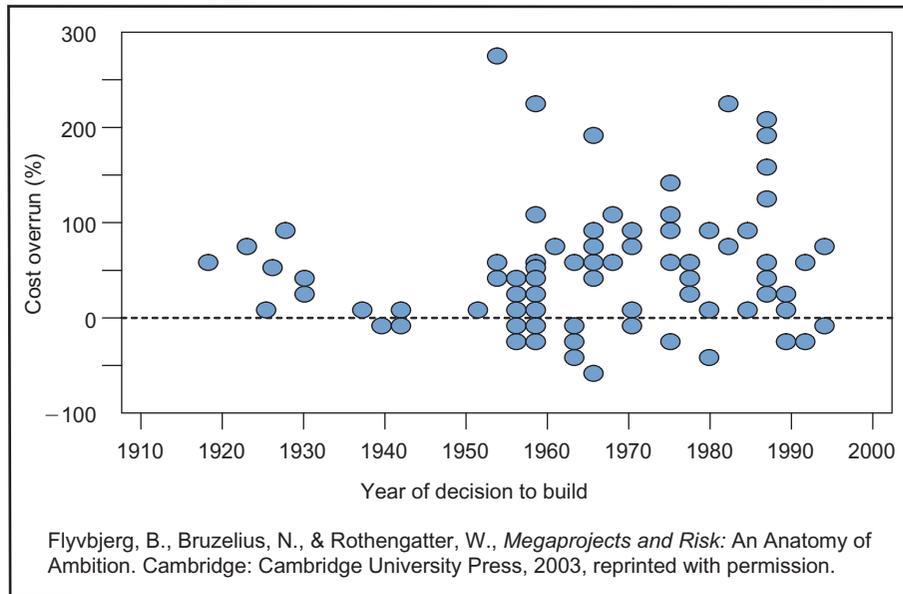


Figure 8-1
Projects versus Percent Cost Overrun.

Some escalation can be expected, and up to 20 percent is relatively common. Usually, the larger, more complex the project, the greater the potential for escalation. Cutting edge, high-technology, and R&D projects frequently show cost escalations upwards of several hundred percent. The Concorde supersonic airliner cost more than five times the original estimate, nuclear power plants frequently cost two to three times their estimates, and NASA spacecraft often exceed estimates by a factor of four to five.

Figure 8-1 shows a plot of percent cost overrun versus year of decision to build for 111 transportation-related projects spanning approximately 80 years.² The same study that produced this graph also looked at cost overrun versus year of completion for 246 other projects, and got a similar picture. Clearly, overruns have been and remain relatively common. How does that happen? There are many reasons, some avoidable, some not.

Uncertainty and Lack of Accurate Information

Much of the information needed to make accurate estimates is simply not available when early cost figures are first developed. In NASA, for example, lack of well-defined spacecraft design and unclear definition of experiments are the principal reasons for cost overruns. Not until later, when the design is finalized and work activities are well defined (usually during the definition phase or later) can material and labor costs be accurately determined. In most research and development projects the activities are unpredictable, of uncertain duration, or must be repeated.

But sometimes the uncertainty stems from lack of effort. In general, to reduce escalation from uncertainty, management should strive for the most definitive scope of work and clearest, most specific project objectives. The clearer the objectives, scope, and requirements definition, the better the work definition and the more accurate the cost estimates.

Whenever changes in product design or project schedule are needed due to changes in the state of the art or product concept, developmental barriers, strikes, legal entanglements, or skyrocketing wage and material costs, then the original cost estimate should be updated and become the new cost baseline for tracking and controlling project costs.

To make allowances for uncertainty, an amount called a *contingency fund* or *budget reserve* is added to the original estimate.³ This is the budget equivalent of the *schedule reserve* or *buffer* mentioned in the previous chapter. The contingency amount, which can be added to individual work packages or the project as a whole, is proportionate to the uncertainty of the work; the greater the uncertainty, the higher the contingency amount. The project manager controls the reserve and its allocation to cover overruns.

Contingency funds are intended to offset small variations arising from estimating errors, omissions, minor design changes, small schedule slippages, and so on. Each time the cost estimate is updated, so is the contingency fund. The contingency fund is not a “slush” fund. When no longer needed as intended, it should be cut from the project budget in order not to be used elsewhere; otherwise, the tendency is for costs to rise to expend whatever remains in the fund. Contingencies are discussed later as an aspect of the cost estimating process.

Changes in Requirements or Design

Another source of cost escalation is discretionary, nonessential changes to system requirements and plans. These changes come from a change in mind, not from oversights, mistakes, or environmental changes that would make them imperative. The routine tendency is for users and contractors alike to want to continually modify systems and procedures—to make “improvements” to original plans throughout the project life cycle. These kinds of changes are especially common in the absence of exhaustive planning or strict control procedures.

Contracts occasionally include a *change clause* that allows the customer to make certain changes to contract requirements—sometimes for additional payment, sometimes not. The clause gives the customer flexibility to incorporate requirements not envisioned at the time of the original contract agreement. It can be exercised at any time and the contractor is obligated to comply. Any change, however, no matter how small, causes escalation. To implement a change usually requires a combination of redesign or reorganizing work, acquiring new or different resources, altering previous plans, and undoing or scrapping earlier work. The further along the project, the more difficult and costly it is to make changes.

When accumulated, even small changes have a substantial effect on schedules, costs, and performances. Formal mechanisms such as a *change control system* described in Chapter 11 help reduce the number of changes and contain escalation.

Economic and Social Factors

Even with good initial estimates and few changes, cost escalation occurs because of social and economic forces beyond the contractor’s or user’s influence. Labor strikes, legal action by interest groups, trade embargoes, and materials shortages all serve to stifle progress and increase costs, but can neither be precisely anticipated nor factored in to plans and budgets. Whenever project work is suspended or interrupted, administrative and overhead costs continue to mount, interest and leasing expenses continue to accrue on borrowed capital and equipment, and the date when payback

begins and profit is earned is set back. Rarely can such problems be anticipated and their impacts incorporated into the contingency fund.

One economic factor that has major influence on cost escalation and project profitability is *inflation*.⁴ The contractor might try to offset increases from inflation by inflating the price of the project, although the actions of competitors or federal restrictions on price increases often preclude doing that. Some protection from inflation may be gained by including clauses in the contract that allow increases in wage or material costs to be appended to the contract price,⁵ but the protection may be limited. Inflation is not one dimensional; it varies depending on the labor, materials, and equipment employed, the geographical region, and the country. Subcontractors, suppliers, and clients use different kinds of contracts that have different inflation protection clauses and that might or might not be advantageous to other parties in the project.

Inflation also causes cash flow difficulties. Even when a contract includes an inflation clause, payment for inflation-related costs is tied to the publication of inflation indices, which always lags behind inflation. Although contractors pay immediately for the effects of inflation, not until later are they reimbursed for these effects.

Trend analysis of inflation in the industry and economy can improve the accuracy of cost estimates. In long-term projects especially, wage rates should be projected to forecast what they will be at the time they must be paid; this is done by starting with best estimates of labor hours and wage costs in current dollars, then applying inflation rates over the project's length.

In international projects, costs escalate also because of changes in *exchange rates*. When the costs are incurred in one currency but paid for in another, a change in the exchange rate will cause the relative values of costs and payments to change, resulting in an escalation of cost or price. This topic is considered further in Chapter 18.

Initial cost estimates are based upon prices at the time of estimating. After that, whenever actual costs are compared with initial estimates, inflation adjustments must be included so there remains a common basis upon which to identify variances and take corrective action.

Inefficiency, Poor Communication, and Lack of Control

Cost escalation also results from work inefficiency, poor management, poor planning, lack of supervision, and weak control. In large projects especially, poor coordination, miscommunication, and sloppy control lead to conflicts, misunderstandings, duplication of effort, and mistakes. This is *one* source of cost escalation where management can have a substantial influence. Meticulous work planning, tracking and monitoring of activities, team building, and tight control all help improve efficiency and contain cost escalation.

Ego Involvement of the Estimator

Cost escalation also comes from the *way* people estimate. Many people are overly optimistic and habitually underestimate the time and cost it will take to do a job, especially in areas where they have little experience. Have you ever estimated how long it would take for *you* to paint a room or tile a floor? How long did it *really* take? Many think of an estimate as an "optimistic prediction." They confuse estimates with goals and see the estimate as a reflection upon themselves, not an honest prediction of what it will take. The more "ego involvement" of the estimator in the job, the more unreliable the estimate. (Of course, sometimes the opposite happens: worried

they might not have estimated enough time or cost, people “pad” the estimates to avoid overruns.)

The problem can be reduced by obtaining cost estimates from professional estimators (people other than those who will actually do the work). Remember the earlier contention about the necessity of involving project participants in planning the project? Experienced workers are usually much better at estimating tasks, materials, and time than they are costs. Although the doers (those who do the work) should *define* the work and provide estimates for resources and time, professional estimators should review the estimates for accuracy, check with the doers, and then prepare the cost estimates. A cost estimate should not be a goal; it should be a reasonable prediction of what will happen. Estimators must be, organizationally, in a position where they will not be coerced to provide estimates that conform to anyone’s desires.⁶

Project Contract

Chapter 3 describes the relative merits of different forms of contracts, some of which are related to the contract’s influence on cost escalation.⁷ Consider, for example, the two basic kinds of contracts: fixed price and cost-plus. A fixed price agreement gives the contractor incentive to control costs because, no matter what happens, the amount paid for the project remains the same. In contrast, a strictly cost-plus contract offers little or no incentive to control costs. In fact, when profit is computed as a percentage of costs (rare these days), the contract motivates contractors to “allow” costs to escalate. Other forms of agreements such as incentive contracts permit cost increases, but encourage cost control and provide motivation to minimize escalation.

Bias and Ambition⁸

Finally, it is human for the champions of projects to be optimistically biased toward their projects. In fact, without champions most projects would never start and humankind might be worse off. That bias however might lead to not only overestimating benefits but also underestimating costs. Promoters of big projects have learned that if a project is important enough, sufficient funding to complete it will materialize, no matter the size of the overrun. The result is that the actual project cost, with near certainty, will overrun the estimate.

Example 1: Escalation of the Bandra-Worli Sea Link Project

January 1999—Government Clears Worli-Bandra Cable Bridge
February 2001—Worli-Bandra Sea link Enters Crucial Stage
October 2002—Bandra-Worli Sea Link Toll to Be Costlier
October 2003—Bandra-Worli Sea Link May Hit a Dead End
January 2004—Bandra-Worli Sea Link Project Under Threat
July 2005—Sea link in Trouble Over Extension
May 2006—Bandra-Worli Sea Link to Be Ready by 2008

The headlines from local news media refer to the Bandra-Worli Sea Link (BWSL) roadway and cable-stayed bridge in Mumbai—India’s equivalent to San Francisco’s Golden Gate Bridge and a good example of megaproject woes. The completed 8-kilometer bridge and its approaches will arc 200 meters into the Arabian Sea to connect downtown Mumbai with its western suburbs. The current route is 12 kilometers and takes an hour travel time; purportedly the link will cut that time in half.

The project was approved in early 1999 following 7 years of study: it was supposed to start in May, cost 650 crores (US \$120 million), and finish by mid-2001. But work did not begin until December, and by then the estimated completion

date had slipped to mid-2002. Then came the monsoons, which brought the project to a near halt in 2000 and 2001. In late 2001 the project's prime consultant, Sverdrup, was dropped for failure to provide a "competent project engineer." The replacement, Dar Consultants, modified the bridge design by adding 2.8 kilometers to its length and splitting the eight-lane main bridge into two, four-lane roadways. By January 2002 the scheduled completion date had slipped to March 2004. In October it was announced that project costs had increased by 50 crores; due to a "paucity of funds" work had to be slowed and the completion date pushed back to September 2004. A year later, monsoons and rough seas again halted work, delaying the completion date to 2005. Meantime, complaints grew from fishermen concerned about the link's interference with their boats, and from environmentalists about its harm to marine ecology. In 2003, rains again stalled the project for many months. The project's primary contractor, Hindustan Construction Company, requested an additional 300 crores to cover delays and design changes, but the government balked and offered to pay only 120 crores. The controversy stalled the project for almost a year, though eventually funds materialized and the project resumed—as did the delays and cost escalation: by June 2005 the completion date had slipped to September 2006 and the total project cost had risen to 1,306 crores (US \$291 M). In May 2006 the completion date was again pushed back, this time to April 2008.

As illustrated, schedule delays and cost escalation are inextricably connected. In the first 7 years of the BWSL project the target date had slipped 7 years and the price doubled. The contributing factors included unknowns (weather), changes in scope and requirements (bridge and roadway design), social factors (livelihood and environmental impact worries), economics (growing land values and interest), and management (dismissal of a major contractor).

8.3 COST ESTIMATING AND THE SYSTEMS DEVELOPMENT CYCLE⁹

Developing the project cost estimate is closely tied to the phases of the project life cycle:

- (A) *Conception*: initiation/feasibility
- (B) *Definition*: detailed planning/analysis
- (C) *Execution*: design/fabrication/implementation

The first cost estimate is made during project conception. At this time very little hard cost information is available so the estimate is the least reliable that it will ever be. Uncertainty about the cost and duration of the project may be large, as illustrated by the largest "region of time-cost uncertainty" in Figure 8-2. How much the project will *really* cost and how long it will *really* take are open questions. The project is compared to other, similar projects, and an estimate is made based upon standards of what it should take—labor time, materials, and equipment—to do the job. This approach is less useful when the project involves research and development because few of the tasks can be classified as "standard" and there are no similar projects. Initial estimates are largely "guesstimates" and might end up being nowhere close to actual costs.

If the project is unique and ill-defined, uncertainty in cost estimates often dictates that contracts awarded be of the cost-plus form. Only after much of the system and project has been defined can the material costs, labor requirements, and

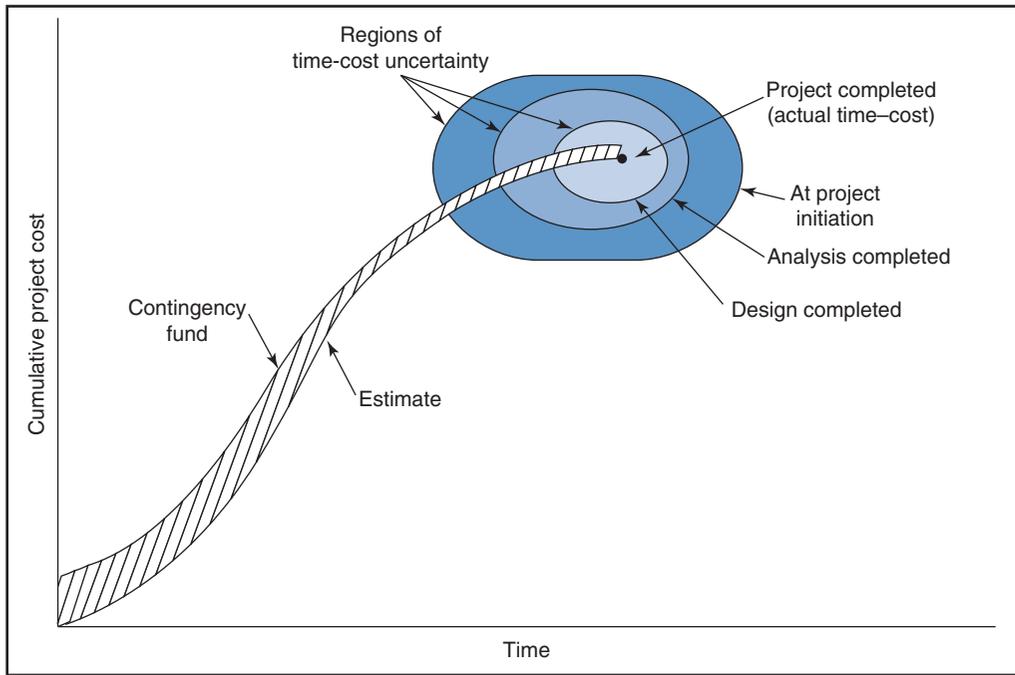


Figure 8-2 Time-cost graph showing cumulative project cost and regions of time-cost uncertainty.

labor rates be nailed down, and reliable cost estimates made. The shrinking time-cost uncertainty regions in Figure 8-2 illustrate this. When the system and project are fairly routine and the estimates somewhat reliable, contractors are willing to accept incentive-type or fixed price contracts. In fact, the awarding of contracts is sometimes put off until designs are somewhat complete so that cost estimates can be more certain. This of course requires contractors to do a lot of front-end work without assurances that they will be awarded the job. When contractors are required to bid before they can attain reliable estimates, they must include substantial contingencies in the estimates to cover the uncertainty.

As the project moves into middle and later phases with work being completed and funds expended, cost estimates become more certain. Often, to control usage of the contingency fund, the amount in the fund is decreased as the project progresses. A project starting out with a contingency of 15 percent of the base estimate might be decreased to a contingency of 8 percent when the project is half completed, then to 3 percent when it is three-fourths completed, and then to just 1 percent to cover small corrections during the final stages of installation and sign-off.

As discussed in Chapter 4, a detailed plan usually is developed only for the next (most immediate) phase of the project, and part of that plan will include a cost estimate and cost commitments for the upcoming phase. At the same time, every attempt is made to look beyond the upcoming phase and to develop realistic, accurate cost estimates for the entire project.

Once developed and approved, the cost estimate is used to establish the budget and becomes the baseline against which progress and performance will be evaluated. It is thus bad practice to frequently change the estimate later in the project life cycle because it destroys the purpose of having a baseline. Sometimes, however,

escalation factors render the estimate obsolete and mandate periodic revisions to the budget.

8.4 LIFE CYCLE COSTS

Life cycle costs (LCC) represent all the costs of a system, facility, or product throughout its full cradle-to-grave life cycle. The concept originated in military procurement when it was realized that product development represents but the tip of the cost iceberg—that the cost to operate (e.g., fuel consumption) and maintain (e.g., parts replacement) a system or product is usually far greater. Whereas the emphasis in this chapter is on *project costs*, i.e., costs incurred during the *project* life cycle phases of Definition and Execution, LCC include the remainder of the systems development cycle—the Operations phase and eventual disposal of the end-item—and, sometimes, for the Conception phase too (initiation and feasibility).

Anticipating the LCC is necessary because costs influence many decisions. For example, suppose three contractors submit proposals to build a plant, and each proposal contains not only the plant acquisition (construction) price but also the plant's expected operating costs. If the bids are similar in terms of construction costs and plant features, the bid with the lowest operating costs will likely win.

The LCC similarly affects decisions regarding research and development; indeed, the initial feasibility study of a project should take into account *all the costs* for acquisition, operation, maintenance, and disposal of the system, product, or facility. For example, most US aerospace manufacturers in the 1970s were hesitant to develop a supersonic commercial aircraft because of cost and environmental impact concerns. Costs to develop and produce the aircraft were projected to be high, as were costs for operation and maintenance. At issue were whether enough people would pay the high ticket prices necessary for the airlines to make a profit, and whether enough airlines would purchase the jet for the manufacturers to make money. Ultimately, many felt the answer was no on both counts. Congress canceled subsidies for developing the aircraft, and the program dissolved. Meantime the Europeans decided differently and went on to manufacture the Concorde, only 14 of which went into service. Concorde flew for nearly 27 years and the last one was retired in 2003. The LCC was never recouped, and had not the governments of Great Britain and France provided subsidies, the airlines and manufacturers would have lost money.

Key decisions affecting the operation, maintenance, and disposal of a system are made early in the project life cycle—during Conception and Definition. When a product is conceived and designed so as to have a relatively low operating cost, it becomes more appealing—even if its development cost and purchase price are higher. For example, the high cost of developing more fuel-efficient vehicles might require those vehicles to be priced higher than other less efficient vehicles, but customers will readily pay the price if they know that over the life of the vehicle they will recoup the price excess through fuel savings and lower pollution. Of course, estimating the LCC always involves assumptions about technology, market, and product demand, and relies on historical costs of similar systems and projects; nonetheless, it is a sensible way to approach projects, especially when a choice exists among alternative designs or proposals.

The LCC should also account for the time necessary to develop and build the end-item, i.e., the time before a facility or system becomes operational or a product is “launched” to market. Time is important: it determines how soon the end-item will start generating revenues, gaining market share, and accruing profits or other

benefits. The additional benefits gained from an early launch are compared to the higher costs of crashing the project using the time-cost tradeoff approach discussed in Chapter 7. Similarly, the *cost of disposal* at the end of the life cycle must also be estimated; for facilities such as mines and nuclear power plants that require shutdown and rehabilitation after their useful lives, this cost can be substantial.

Analysis of LCC is also necessary for setting targets on development and operating costs, and making design tradeoff decisions to achieve those targets. Following is an example.

Example 2: Life Cycle Costs for an Operational Fleet of Spaceships

(This illustration extends on previous SpaceshipOne examples, but the numbers are purely hypothetical.) Having gained experience from SpaceshipOne, a larger spaceship and mothership are being designed. The new spaceship will carry five people (pilot plus four paying passengers), go as high as 120 kilometers, and be capable of 20 flights per year over an operational life of 5 years. The cost of developing and producing four of these spaceships and two motherships is estimated at \$80 million. Meantime, a survey indicates that the number of people worldwide willing to pay the \$190,000 ticket price to fly into space is at least 1,000 per year.

A “spaceline” that will use and maintain the fleet of spaceships is being created for a startup cost of \$10 million. Operational costs for the spaceline consist of two parts: annual costs for ground operations (reservations, personnel, ground facilities, etc.) and per-flight costs for flight operations (fuel, parts, repairs, etc., for the spaceship and the mothership). Ground operations costs are placed at \$2 million per year and per-flight costs at \$0.4 million per flight. (The costs are assumed constant for every year and flight, respectively, although realistically they would vary up or down depending on inflation, the learning curve, efficiencies, and economies of scale as more spaceships are added to the fleet. Annual revenues are assumed constant too, though realistically they would start out small and grow over time until the full fleet of spaceships is operational.) Given these costs and ignoring other factors (e.g., time value of money), what is the LCC for the venture?

Assumptions

Four spaceships @ 20 flights/year each = 80 flights/year (320 passengers/year, which lies well within the estimated annual demand). Five years of operation.

Costs:

- *Development and manufacturing:* \$80 million
- *Spaceline startup:* \$10 million
- *Ground operations:* \$2 million per year
- *Flight operations:* \$0.4 million per flight

Ticket price: \$190,000 (marketing slogan: “Now YOU can go to space for under \$200,000!”)

LCC Model

$$\begin{aligned}
 \text{LCC (\$ million)} &= \text{Development and production cost} \\
 &\quad + \text{Startup cost} + \text{Operating cost (5 years)} \\
 &= \$80 + \$10 + ([5 \text{ year} \times \$2] + [5 \text{ year} \times 80 \text{ flights} \times \$0.4]) \\
 &= \$260 \text{ million}
 \end{aligned}$$

$$\begin{aligned}
 \text{Total revenues (\$ million)} &= (5 \text{ years} \times 80 \text{ flights} \times 4 \text{ passengers} \times \$0.190) \\
 &= \$304 \text{ million.}
 \end{aligned}$$

Bottom line: Assuming the assumptions are correct, revenues will exceed costs by \$44 million.

The numbers are of course estimates, but some are more certain than others. For example, based upon experience with SpaceShipOne, the development cost might be fairly certain, but due to lack of long-term operational experience the per-flight cost is fairly uncertain. Startup and ground operations costs, if analogous to airline operations, might be somewhat certain, although passenger demand might be fairly uncertain.

The LCC model plays an important role in system design and development. Using the model a sensitivity analysis can be performed to see what happens when costs are varied up or down and to show best-case, most-likely, and worst-case scenarios. The model can also be used to determine by how much and in what combination the costs must vary before the enterprise becomes lucrative or disastrous.

The LCC model is also used to set cost targets. If the decision is made to proceed with the \$80 million development and production cost, then the project must be planned, budgeted, and controlled so as to stay close to that amount. If the per-flight cost is set at \$0.4 million, the project must strive to develop a spacecraft and mothership that will cost no more than that to operate. This will affect innumerable design decisions pertaining to many details. Early on, the design analysis must consider major alternatives (e.g., a spaceship to carry five or six passengers instead of four) and the expected costs, revenues, and benefits for each.

The best and only truly comprehensive approach to estimating and analyzing LCC is with a team of people that represents all phases of the system or product life cycle—a cross-functional team of designers, builders, suppliers, and users, i.e., a *concurrent engineering team*. Concurrent engineering for life cycle costing is further discussed in Chapter 13.

8.5 COST ESTIMATING PROCESS

Estimate versus Target or Goal

Sometimes the word “estimate” is confused with “target” and “goal.” It shouldn’t be. An estimate is a *realistic assessment* based upon known facts about the work, required resources, constraints, and the environment, derived from estimating methods, whereas a target or goal is a desired outcome, commitment, or promise. Other than by chance, the estimate usually will *not* be the same as the target or goal. That said, once computed the estimate can be compared to a target value or goal, and revised by making hard-headed changes to the cost origins—work tasks, resources, schedules, etc. The point is, an estimate should be determined *independently* of any target or goal; afterward it can be altered by adjusting the work and resources to bring it as close as possible to the target, but never should the estimate be a simple plug-in of the target value.

Accuracy versus Precision

“Accuracy” represents the closeness of the estimated value to the actual value: the accuracy of a project estimated to cost \$99,000 but actually costing \$100,000 is very good. In contrast, “precision” is the number of decimal places in the estimate. An estimate of \$75,321 is more precise than one of \$75,000, though *neither* is *accurate* if the actual cost is \$100,000. Accuracy is more important than precision: the aim is to derive the most accurate estimate possible.

Classifying Work Tasks and Costs

The cost estimating process begins by breaking the project down into work phases such as design, engineering, development, and fabrication, or into work packages from the WBS. The project team, including members from the involved functional areas and contractors, meets to discuss the work phases or packages, and to receive specific work assignments.

The team tries to identify tasks in the project that are similar to existing designs and standard practices and can readily be adopted. Work is classified either as *developmental* or as an adaptation of existing or off-the-shelf (OTS) designs, techniques, or procedures. Because developmental work requires effort in design, testing, and fabrication, cost estimating is more difficult compared to OTS due to the greater uncertainty about what needs to be done. Overruns for developmental work are common, especially due to inaccurate labor estimates. In contrast, estimating for OTS items or duplicated work is straightforward because it is based upon known prices, or records of material and labor costs for similar systems or tasks. It is thus often beneficial to make use of existing designs and technology as much as possible.

Estimated costs are classified as *recurring* and *nonrecurring*.¹⁰ Recurring costs happen more than once and are associated with tasks periodically repeated, such as costs for quality assurance and testing. Nonrecurring costs happen once and are associated with development, fabrication, and testing of one-of-a-kind items, or procurement of special items.

In the pure project form of organization the project manager delegates the responsibility for the estimating effort, combines the estimated results, and presents the final figures to management. In a matrix organization, estimating is the joint responsibility of the project and functional managers, though the project manager coordinates the effort and accumulates the results. The estimating effort requires close coordination and communication between the estimating groups to avoid redundancies and omissions.

Although this typifies the cost estimating process, the actual method used to estimate cost figures will depend on the required accuracy of and the information available to make the estimate. Cost estimates are determined using variants of four basic techniques: expert opinion, analogy, parametric, and cost engineering.

Expert Opinion

An *expert opinion* is an estimate provided by an expert—someone who from breadth of experience and expertise is able to provide a reasonable, ballpark estimate. It is a “seat of the pants” estimate used when lack of information precludes a more-detailed, in-depth cost analysis. Expert opinion is usually limited to cost estimating during the conception phase and for projects that are poorly defined or unique, for which there are no previous, similar projects to compare.

Analogy Estimate

An *analogy estimate* is developed by reviewing costs from previous, similar projects. The method can be used at any level: overall project cost can be estimated from the cost of an analogous project; work package cost can be estimated from other, analogous workpackages; and task cost can be estimated from analogous tasks. The cost for a similar project or work package is analyzed and adjusted for differences between it and the proposed project or work package, taking into account factors such as dates, project scale, location, complexity, exchange rates, and so on. If, for

example, the analogy project was performed 2 years ago and the proposed project is to commence 1 year from now, costs from the analogy project must be adjusted for inflation and price changes during the 3-year interim. If the analogy project was conducted in California and the proposed project will be in New York, costs must be adjusted for site and regional differences. If the “size” (scope, capacity, or performance) of the proposed task is twice that of the analogy task, then the costs of the analogy task must be “scaled” up. However, twice the size does not mean twice the cost, and the size–cost relationship must be determined from analogy or formulas based on physical principles.

Example 3: Estimating Project Costs by Scaling an Analogy Project

So-called process industries such as petrochemicals, breweries, and pharmaceuticals use the following formula to estimate the costs of proposed projects:

$$\text{Cost (proposed)} = \text{Cost (analogy)}[\text{Capacity (proposed)}/\text{Capacity (analogy)}]^{2/3}$$

where “proposed” refers to a new facility and “analogy” to an analogous facility. In practice, the exponent varies from 0.35 to 0.9, depending on the kind of process and equipment used.¹¹

Suppose a proposed plant is to have a 3.5 million cum (cubic meter) capacity. Using an analogy project for a plant with 2.5 million cum capacity and a cost of \$15 million, the formula gives the estimated cost for the proposed plant as

$$\$15 \text{ million}[3.5/2.5]^{0.75} = \$15 \text{ million}[1.2515] = \$18.7725 \text{ million}$$

Because the analogy method involves comparisons to previous, similar projects, it requires an extant information database about prior projects. Companies that are serious about using the analogy method must rely on good project cost documentation and a database that classifies cost information according to type of project, work package, task, and so on. When a new project is proposed, the database is used to provide cost details about prior similar projects and work packages. Of course, the first assumption in the analogy method is that the analogy to be used is valid; sometimes this is where things go awry.

Example 4: A Case of Costly Mistaken Analogy¹²

In the 1950s and 1960s when nuclear power plants were first being built in the USA, General Electric and Westinghouse, the two main contractors, together lost a *billion* dollars in less than 10 years on fixed price contracts because they had underestimated the costs. Although neither had expected to make money on these early projects, certainly they had not planned to *lose* so much either. The error in their method was assuming that nuclear power plants are analogous to refineries and coal power plants—for which the marginal costs actually get smaller as the plants get larger. But nuclear power plants are not like the other plants. For one thing, they require more safeguards. When a pipe springs a leak in a coal power plant, the water is turned off and the plant shut down until the leak is fixed. In a nuclear plant the water cannot be simply turned off, nor the plant shut down; the reactor continuously generates heat and if not cooled will melt, cause pipes to rupture, and dispersal of radiation. The water-cooling system needs a backup system, and the backup system needs a backup. Typical of many complex systems, costs for nuclear power plants increase somewhat exponentially with plant size—although in the early years of nuclear power nobody knew that.

Parametric Estimate

A *parametric estimate* is an estimate derived from an empirical or mathematical relationship. The parametric method can be used with an analogy project (the case in Example 3) to scale costs up or down, or it can be applied directly—without an analogy project—when costs are a function of system or project “parameters.” The parameters can be physical features such as area, volume, weight, or capacity, or performance features such as speed, rate of output, power, or strength. Parametric cost estimating is especially useful when preliminary design characteristics are first being set and a cost estimate is needed quickly.

Example 5: Parametric Estimate of Material Costs

Warren Eisenberg, president of Warren Wonderworks, Inc., a warehousing facilities contractor, wants a quick way to estimate the material cost of a facility. The company’s engineers investigate the relationship between several building parameters and the material costs for eight recent projects comparable in terms of general architecture, layout, and construction material. Using the method of least squares (a topic covered in textbooks on mathematical statistics), they develop the following formula—a multiple regression model that relates material cost (y) to floor space (x_1 , in terms of 10,000 square feet) and number of shipping/receiving docks (x_2) in a building:

$$y = 201,978 + (41,490)x_1 + (17,230)x_2$$

The least squares method also indicates that the standard error of the estimate is small, which suggests that the model provides fairly accurate cost estimates for each of the eight projects.

Suppose a proposal is being prepared to construct a new 300,000 square feet facility with two docks. The estimated material cost using the model is thus:

$$y = 201,978 + (41,490)(30) + (17,230)(2) = \$1,481,138.$$

Cost Engineering

Cost engineering refers to detailed cost analysis of individual cost categories at the work package or task level. It is a bottom-up approach that not only provides the most accurate estimates of all the methods but also is the most time-consuming; it requires considerable work-definition information—which often is not available until later in the project. The method starts by breaking down the project into activities or work packages, then further divides these into cost categories. For small projects like Example 6 the approach is simple and straightforward.

Example 6: Cost Engineering Estimate for a Small Project

The project manager for the DMB project at Iron Butterfly Corp. is preparing a project cost estimate. He begins by breaking the project into eight work packages and creating a preliminary schedule. Three labor grades will be working on the project, and for each work package he estimates the number of required labor hours per week for each grade. Hours per week per labor grade are represented in the boxes in Figure 8-3.

For each work package he also estimates the cost of material, equipment, supplies, subcontracting, freight charges, travel, and other nonlabor expenses. Table 8-1 is a summary of the labor hours and nonlabor costs.

Total nonlabor cost (material, equipment, etc.) is thus \$26,500. For labor grades 1, 2, and 3, suppose the hourly rates are \$10, \$12, and \$15, respectively, and the overhead rates are 90, 100, and 120 percent, respectively (overhead rate

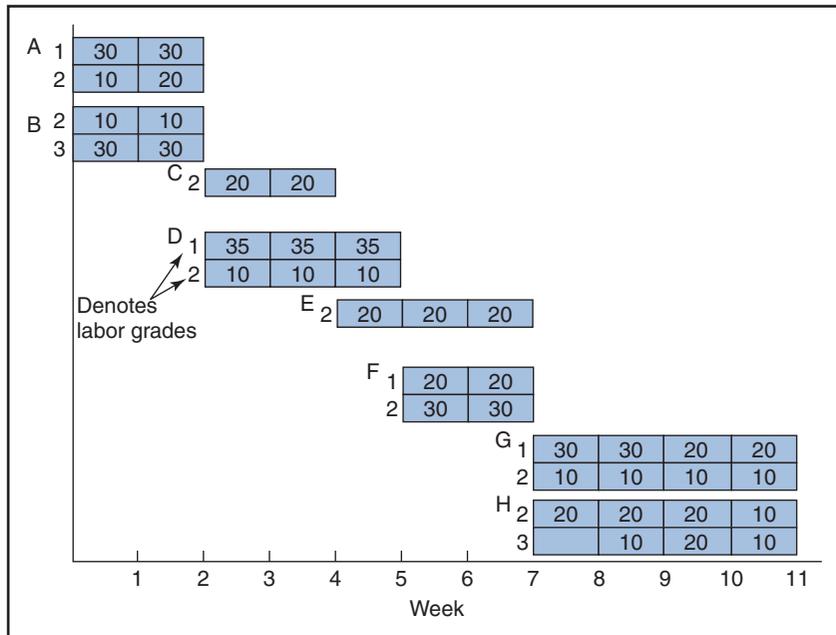


Figure 8-3 Schedule showing hours allocated to work packages by labor grade.

Table 8-1 Labor hours and nonlabor costs.

WORK PACKAGE	HOURS BY LABOR GRADE			NONLABOR COSTS			
	1	2	3	MATERIAL	EQUIPMENT	SUBCONTRACTS	OTHER
A	60	30		\$ 500			
B		20	60		\$1,000		
C		40			500		\$ 500
D	105	30			500		
E		60				\$4,500	
F	40	60		8,000	1,000	5,000	500
G	100	40		1,500			500
H		70	40		1,000		1,500
Total	305	350	100	\$10,000	\$4,000	\$9,500	\$3,000

is an amount *added* to the labor cost; determining overhead rates is discussed later). Therefore, labor-related costs are:

$$\begin{aligned}
 \text{Grade 1: } & 305(\$10)(100\% + 90\%) = \$5,795 \\
 \text{Grade 2: } & 350(\$12)(100\% + 100\%) = 8,400 \\
 \text{Grade 1: } & 100(\$15)(100\% + 120\%) = 3,300 \\
 & \underline{\hspace{10em}} \\
 & \text{\$17,495}
 \end{aligned}$$

The preliminary estimate for labor and nonlabor cost is $\$17,495 + \$26,500 = \$43,995$. Suppose Iron Butterfly Corp. routinely adds 10 percent to all projects

to cover general and administrative expenses, which puts the cost at $\$43,995(1.1) = \$48,395$. To this Ralph adds another 10 percent as a project contingency, giving a final cost estimate for the DMB project of $\$48,395(1.1) = \$53,235$.

At the work package or lower level, detailed estimates are sometimes derived with the aid of *standards manuals* and *tables*. Standards manuals contain time and cost information about labor and materials to perform particular tasks. In construction, for example, the numbers of labor hours to install an electrical junction box or a square foot of wall forms are both standard times. To determine the labor cost of installing junction boxes in a building, the estimator determines the required number of junction boxes, multiplies this by the labor standard per box, and then multiplies that by the hourly labor rate. For software development the industry standard is one person-year to create 2,000 lines of bug-free code.

For larger projects the estimating procedure is roughly the same as illustrated in Example 6 although more involved. First, the manager of each work package breaks the work package down into more fundamental or “basic” areas of work. For example, a work package might be divided into two basic areas: “engineering” and “fabrication.” The manager of the work package then asks his supervisors to estimate the hours and materials needed to do the work in each basic area. The supervisor overseeing engineering might further divide work into the tasks of structural analysis, computer analysis, layout drawings, installation drawings, manuals, and reproduction, then develop an estimate for each task duration and the labor grade or skill level required. In similar fashion, the fabrication supervisor might break the work down into fabricated materials (steel, piping, wiring), hardware, machinery, equipment, insurance, and so on, then estimate how much (quantity, size, length, weight, etc.) of each will be needed. Estimates of time and materials are determined by reference to previous, similar work, standards manuals, reference documents, and rules of thumb (“one hour for each line of code”). The supervisors submit their estimates to the work package manager who checks, revises, and then passes them on to the project manager. The more developmental and the less standardized the task, the more guesswork involved; even with routine or OTS items, accurate estimating is somewhat of an art.

The project manager and independent estimators or pricing experts on the project staff review the submitted time and material estimates to be sure that no costs were overlooked or duplicated, estimators understood what they were estimating, correct estimating procedures were used, and allowances made for risk and uncertainty.¹³ The estimates are then aggregated as shown in Figure 8-4 and converted

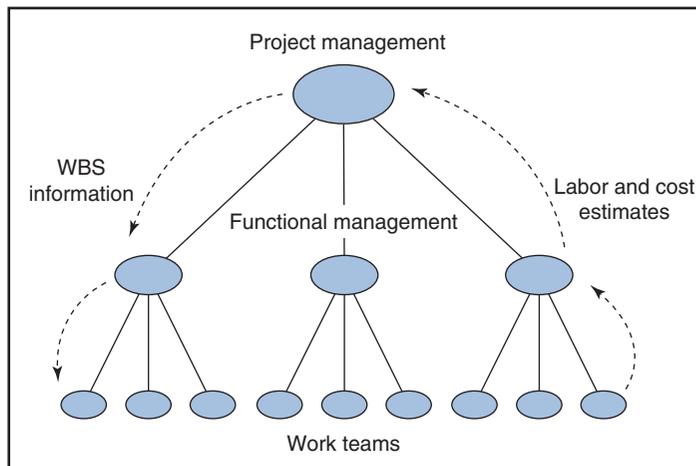


Figure 8-4
The estimating process.

into dollars using standard wage rates and material costs (current or projected). Finally, the project manager tallies in any project-wide overhead rates (to cover project management and administrative costs) and company-wide overhead rates (to cover the burden of general company expenses) to come up with a cost estimate for the total project. The accumulation of work package estimates (upward arrows in Figure 8-4) to derive the project estimate is called the “bottom-up” approach.

Contingency Amount

Contingency amounts are added to estimates to offset uncertainty. In general, the less well defined or more complex the situation, the greater the required amount. Contingency amounts can be developed for individual activities or work packages, or the project as a whole. *Activity contingency* is an amount estimated to account for “known unknowns” in an activity or work package, i.e., sources of cost increases that could or likely will occur; they include scrap and waste, design changes, increases in the scope, size, or function of the end-item, and delays due to weather. Later, when the project budget is established, this amount should be included in a special budget, subdivided into work package accounts and strictly controlled by the project manager. For the project cost estimate, the project manager sums these activity contingencies and adds them to the total project cost, yielding the *base estimate*.

To the base estimate the project manager might add yet another amount, a *project contingency*. This is to account for “unknown unknowns”—external factors that affect project costs but cannot be pinpointed. Examples include unforeseen fluctuation in exchange rates, shortages in resources, and changes in the market or competitive environment. The size of the contingency depends on the perceived risk and likelihood of cost escalation due to unknowns. Computing the contingency based on the perceived project risk is covered in Chapter 10. Any subsequent usage of project contingency funds, like that of the activity contingency, is controlled by the project manager. Adding the project contingency to the base estimate gives the *final cost estimate*, which is the *most likely cost*.

Besides the activity and project contingencies, the corporation might also set aside an additional allowance to cover overruns. This amount, the *overrun allowance*, is added to the most likely cost to yield a cost where the probability of exceeding it is less than 10 percent. The overrun allowance is controlled by a program manager or corporate managers and is ordinarily not available to the project manager without approval.

Top-down versus Bottom-up

In general, the application of the estimating techniques listed previously occur in two ways: top-down and bottom-up. Top-down refers to estimating the cost by looking at the project as a whole. A top-down estimate is typically based upon an expert opinion or analogy to other, similar projects. Bottom-up refers to estimating costs by breaking the project down into elements—individual project work packages and end-item components. Costs for each work package or end-item element are estimated separately and then aggregated to derive the total project cost. Example 6 is a bottom-up approach; Example 3 is a top-down approach. The two approaches can be used in combination: portions of a project that are well defined can be broken down into work packages and estimated bottom-up; other less-defined portions can be estimated top-down. In turn, the cost of each work package can be estimated by breaking the package into smaller elements and estimating the cost of each (bottom-up), or by making a gross estimate from analogy or expert opinion (top-down). The bottom-up

method provides more accurate estimates than the top-down method but requires more data and concise definition of tasks.

Reconciling Estimates

The project manager submits the final cost estimate to company management along with forecasts showing the effects of likely, potential escalation factors such as inflation and risks. The estimate is compared against top management's *gross estimate*, the goal or target set by the company or customer. Based on the difference between the gross and bottom-up estimates, management either accepts the estimate or mandates a revision. If the gross estimate is larger, the project manager reviews each work package estimate for possible oversights or over-optimism. If the bottom-up estimate is larger, the project manager reviews the work package estimates for incorrect assumptions, excesses, and other sources of excess cost.

Reducing Costs

What happens if competition or insufficient funding forces management to reduce costs? Managers will want to retain their share of the project and none will want to see budget or staff reduced. Nonmanagement professionals such as engineers, scientists, or systems analysts, unless actively involved in the budgeting process, are often unaware of budget constraints and resist cuts. Here is where communication, negotiation, and diplomacy between project managers and functional managers and staff are necessary to convince the latter to accept a share of budget reductions. When this fails the project manager must look for ways to reduce costs (e.g., reduce work scope or labor requirements or use less costly resources) and convince the team to accept the reductions (dashed arrows in Figure 8-4). If that fails, the final resort is to appeal to top management.¹⁴ To reconcile differences between estimates, top management sometimes exercises an across-the-board cut on all estimates. This is poor practice because it fails to account for judgmental errors or excessive costs on the part of just a few units. It also unfairly penalizes managers who tried to produce fair estimates and were honest enough not to pad them. Such indiscriminate, across-the-board cuts induce everyone to pad estimates for their own protection.

Suppose you are the project manager and it is clear that management insists on a budget that is too low to perform the work. There are only two courses of action: either undertake the project and attempt wholeheartedly to meet the budget, or hand it over to another manager.¹⁵ If you decide on the former, you should document your disagreement and report it to top management; later, the client might agree to changes that would reduce costs and enable it to be completed within budget. If the contract is cost-plus, then the risk is low because additional costs will be reimbursed. If the contract is fixed price and the budget is so underfunded as to likely require cutting corners or stalling the project, then you should suggest to management that they appoint another project manager (who, assuming your argument is valid, might then argue the same case). Not only is this good business practice, it is the only ethical alternative.

8.6 ELEMENTS OF BUDGETS AND ESTIMATES

Budgets and estimates are similar in that both state the cost of doing something. The difference is that the estimate comes first and is the basis for the budget. An estimate

may have to be refined many times, but once approved it becomes the budget. Organizations and work units are then committed to performing work according to the budget: It is the agreed-upon contracted amount of what the work should cost and the baseline against which expenditures will be compared for tracking and control purposes. Project budgets and fiscal operating budgets are similar; the difference is that the former covers the life of a project, the latter only a year at a time.

Estimates and budgets share most or all of the following elements:

- Direct labor expense
- Direct nonlabor expense
- Overhead expense
- General and administrative expense
- Profit and total billing

Direct Labor Expense¹⁶

Direct labor expense is the charge of labor for the project. For each task or work package, an estimate is made as to the number of people needed in each labor grade, and the number of hours or days for each. This gives the distribution of labor hours or days required for each labor grade. The labor hours for the various grades are then multiplied by their respective wage rates. The work package budget in Figure 8-5 is an example, showing the wage rates for three labor grades and the associated labor hours time-phased over a 6-month period.

When the wage rate is expected to change over the course of the work, a weighted average wage rate is used. In Figure 8-5, suppose the initial rate for assistant is expected to increase from \$20 to \$25 in months 3, 4, and 5. The labor cost for assistant in months 2, 3, 4, and 5 would then increase from \$8,000 to $100(\$20) + 100(\$25) +$

Figure 8-5
Typical 6-month budget for a work package.

Project <u>CASTLE</u>		Date <u>April 1, 1992</u>							
Department <u>Excavating</u>		Work package <u>Moat</u>							
Charge	Rate	Months ⁺						Totals	
		1	2	3	4	5	6	Hours	Cost
Direct labor									
Professional	\$35/hour	50				50		100	3,500
Associate	\$30/hour		100	100	100	100		400	8,000
Assistant	\$20/hour								
Direct labor cost		1,750	2,000	2,000	2,000	3,750			11,500
Labor overhead	75%	1,312	1,500	1,500	1,500	2,813			8,625
Other direct cost*			100						100
Total direct cost		3,062	3,600	3,500	3,500	6,563			20,225
General/administrative	10%	306	360	350	350	657			2,023
Total costs		3,368	3,960	3,850	3,850	7,220			22,248
Profit	15%								
Billing total									

⁺Should extend for as many months as required by the project.
*Should be itemized to include costs for materials, freight, subcontracts, travel, and all other nonlabor direct costs.

$100(\$25) + 100(\$25) = \$9,500$. (The average wage rate would thus be $\$9,500/400$ hours = $\$23.75/\text{hour}$.) Notice that the average wage rate changes whenever the distribution of hours changes. In the example, had the work been evenly distributed 100 hours/month over months 1 through 4 (instead of over months 2 through 5), the average wage for assistant would have been $\$9,000/400$ hours = $\$22.50/\text{hour}$.

Direct Nonlabor Expense

Direct nonlabor expense is the total expense of nonlabor charges applied directly to the task. It includes subcontractors, consultants, travel, telephone, computer time, material costs, purchased parts, and freight. This expense is represented in Figure 8-5 by the line "other direct cost." Material costs include allotments for waste and spoilage and should reflect anticipated price increases. Material costs and *freight* charges sometimes appear as separate line items called *direct materials* and *overhead on materials*, respectively; computer time and consultants may appear as *support*.

Direct nonlabor expenses also include items necessary for installation and operation such as maintenance manuals, engineering and programming documentation, instruction manuals, drawings, and spare parts. Note that these are costs incurred only for a specific project or work package. Not included are the general or overhead costs of doing business, unless those costs are tied to the specific project.

On smaller projects all direct nonlabor expenses are individually estimated for each work package. In larger projects, a simple percentage rate is applied to cover travel and freight costs. For example, 5 percent of direct labor cost might be included as travel expense and 5 percent of material costs as freight. These percentages are estimated in the same fashion as the overhead rates discussed next.

Overhead, General, and Administrative Expenses

Although direct expenses for labor and materials are easily charged to a specific work package, many other expenses cannot so easily be allocated to specific work packages, nor even to specific projects. These expenses, termed *overhead* or *nondirect expenses*, are the cost of doing business. They include whatever is necessary to house and support the labor, including building rents, utilities, clerical assistance, insurance, and equipment. Usually, overhead is computed as a percentage of the direct labor cost. Frequently, the rate is around 100 percent but it ranges from as low as 25 percent for companies that do most of their work in the field to over 250 percent for those with laboratories and expensive facilities and equipment.

The overhead rate is computed by estimating the annual business overhead expense, then dividing by the projected total direct labor cost for the year. Suppose projections show that total overhead for next year will be \$180,000. If total anticipated direct labor charges will total \$150,000, then the overhead rate to apply is $180,000/150,000 = 1.20$. Thus, for every \$1.00 charged to direct labor, \$1.20 is charged to overhead.

Although this is the traditional accounting method for deriving the overhead rate, for project management it results in an arbitrary allocation of costs, which is counterproductive for controlling project costs because most sources of overhead costs are not tied to any particular project. A better way is to divide overhead costs into two categories: *direct overhead*, which are costs that can be allocated in a logical manner; and *indirect overhead*, which cannot. Direct overhead costs can be traced to the support of a particular project or work package; these costs are allocated *only* among the specific projects or activities for which they apply. For example, the overhead cost for a department working on four projects is apportioned among the four projects based on the percentage of labor time it devotes to each. The department's overhead cost is not allocated to projects that it is not involved in.

The other kind of overhead, indirect overhead, includes general expenses for the corporation. Usually referred to as *general and administrative* expense, or *G&A*, it includes taxes, financing, penalty and warranty costs, accounting and legal support, proposal expenses on lost contracts, marketing and promotion, salaries and expenses of top management, and employee benefits. These costs might not be tied to any specific project or work package, so they are allocated across all projects, to certain projects, or parts of projects. For example, corporate-level overhead would be allocated across all projects, project management overhead on a per-project basis, and departmental overhead to specific project segments to which the department contributed. Often, G&A overhead is charged on a time basis, hence the longer the duration of the project, the greater the G&A expense for the project.

The actual manner in which indirect costs are apportioned varies in practice. The example for the SETI Company in Table 8-2 shows three methods for distributing

Table 8-2 Examples of indirect cost apportionment.

SETI Company Company-wide (indirect costs)			
Overhead (rent, utilities, clerical, machinery)		OH	120
General (upper management, staff, benefits, etc.)		G&A	<u>40</u>
		Indirect total	160
PROJECT COSTS	MARS PROJECT	PLUTO PROJECT	TOTAL
Direct labor (DL)	50	100	150
Direct nonlabor (DNL)	<u>40</u>	<u>10</u>	<u>50</u>
	90	110	200
		Direct total	200
		Direct and indirect total	360
Some methods for apportioning indirect costs:			
I. Total indirect proportionate to total direct costs			
	MARS PROJECT	PLUTO PROJECT	TOTAL
DL and DNL	90	110	200
OH and G&A	<u>72</u>	<u>88</u>	<u>160</u>
	162	198	360
II. OH proportionate to direct labor only; G&A proportionate to all direct costs			
	MARS	PLUTO	TOTAL
DL	50	100	150
OH on DL	40	80	120
DNL	40	10	50
G&A on (DL and DNL)	<u>18</u>	<u>22</u>	<u>40</u>
	148	212	360
III. OH proportionate to direct labor only; G&A proportionate to DL and OH and DNL			
	MARS	PLUTO	TOTAL
DL and OH and DNL	130	190	320
G&A	<u>16.25</u>	<u>23.75</u>	<u>40</u>
	146.25	213.75	360

indirect costs between two projects, MARS and PLUTO.¹⁷ Notice that although company-wide expenses remain the same, the cost of each project differs depending on the method of allocating indirect costs.

Clients want to know the allocation method used by the contractor, and the contractor should know the allocation method used by subcontractors. For example, Method I is good for the client when the project is labor (DL) intensive, but bad when it is direct nonlabor (DNL) intensive. Method III is the opposite and gives a lower cost when the project is relatively nonlabor intensive (i.e., when labor costs are low but material and parts expenditures are high). This can be seen in Table 8-2 by comparing MARS (somewhat nonlabor intensive) to PLUTO (somewhat labor intensive).

Overhead costs appear in projects in different ways. Any overhead expenses that *can* be traced to specific work packages are allocated directly to them. These appear in the budget, as shown in Figure 8-5. Remaining overhead expenses that cannot be traced to specific work packages are assigned to a special “overhead” work package. This can be a single work package for the entire project, or—if overhead costs can be tied to individual project stages or phases—a series of overhead work packages for each.

Profit and Total Billing

Profit is the amount left over for the contractor after expenses have been subtracted from the contractual price. It is an agreed-to fixed fee or a percentage of total expenses. (Determining profit depends on the kind of contract, discussed in the Appendix to Chapter 3.) Total billing is the sum of total expenses and profit. Profit and total billing are included for estimates of the project as a whole, for large groups of work packages, and for subcontracted work. They usually do not appear on budgets for lower-level work elements.

8.7 PROJECT COST ACCOUNTING SYSTEMS

A project is a system of workers, materials, and facilities, all of which must be estimated, budgeted, and controlled. Hundreds or thousands of items may be involved. To reduce confusion, improve accuracy, and expedite procedures, a system is needed to compute estimates, store and process budgets, and track costs. The term *project cost accounting system (PCAS)* refers to a manual or computerized structure and methodology that enables systematic planning, tracking, and control of project costs. The PCAS is set up by the project manager, project accountant, and involved functional managers. The PCAS focuses on project costs, but by relating project costs to schedules and work performance it also permits tracking and control of schedules and work progress. When combined with other project planning, control, and reporting functions, the PCAS is referred to as the *project management information system (PMIS)*.

During project conception and definition, costs estimates of work packages are accumulated through the PCAS to produce a total project estimate. This estimate later becomes the basis upon which total project and work package budgets are created.

After work on the project begins, the PCAS enables total project and subactivity costs to be accumulated, credited, and reported. Time-phased budgets are created to help managers monitor costs to ensure they are allocated against the appropriate work, and to verify that the work has been completed and charged. The system also provides for revision of budgets.

The functions of the PCAS are summarized in Figure 8-6.

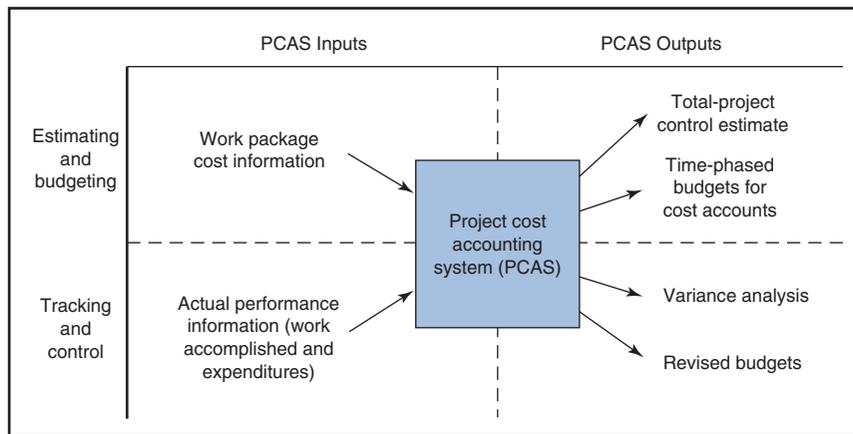


Figure 8-6
Functions of PCAS.

Example 7: Using a PMIS for Estimating Labor Requirements and Costs¹⁸

Sigma Associates is an architectural/engineering firm with a staff of over 100 architects, engineers, and draftsmen supported by 40 information system and office personnel. The firm has developed its own PMIS that in addition to performing planning and scheduling functions also stores information about all Sigma projects since 1978.

The project manager begins planning a project by creating a WBS to identify the major work activities (e.g., architectural schematics, design administration, construction cost estimating). Using a menu in the PMIS, she then reviews the history of similar work activities in previous projects and the kind and amount of labor they require. By entering factors related to project size, construction costs, and type of clients, she can forecast the labor requirements for every activity in the project.

The PMIS combines these labor requirements with requirements for existing projects to produce a 1-year manpower-loading forecast that enables the project manager to determine whether or not sufficient labor is available. If it is not, the system aids the project manager in reviewing options, including modifying the original schedule, scheduling overtime, and using resource-loading procedures as discussed in Chapter 6.

The labor requirements plan is then given to the comptroller to establish a budget. The comptroller uses the PMIS to apply 1 of 2 possible hourly rates to each activity. The first is the average hourly rate of all employees who might work on the activity, the second the average rate associated with all hours charged to that kind of activity in the last 90 days. The second rate is used more often because it reflects the actual mix of personnel currently employed in similar work. The comptroller then applies factors to incorporate employee benefits and labor overhead. The result is a budget for direct labor cost.

With information from the company general ledger, the comptroller computes the overhead amount per labor dollar. The project is then charged with this rate for its share of company-wide expenses. Project-related, nonlabor expenses that will not be reimbursed by the client (e.g., travel, reproduction, communications) are forecasted and rolled up through the PMIS into the total budget.

When the forecasted total budget is completed, the comptroller analyzes the project plan for profitability. If the plan shows a reasonable profit, the project is accepted. If not, a more profitable plan that maintains the same high-quality standards is sought. When both the comptroller and project manager agree to a plan, the project is accepted.

Time-Phased Budgets

In most projects, simultaneous control of work schedules and cost expenditures can be difficult. The project manager needs a way to keep track of where and when expenses are accruing, how well the project is progressing, and where problems are developing. That way is provided by a *time-phased budget*, which consolidates the project budget and the project schedule, and shows how budgeted costs are distributed over time according to the project schedule. Figure 8-5 is an example showing the distribution of costs over one 6-month period. Throughout the duration of the project the PCAS generates time-phased reports like this for each work package, allowing managers to compare planned expenditures with actual expenditures month-by-month. The reports help ensure that work is completed and accurately charged, and estimates and budgets are revised as needed.

For projects where a substantial amount of the costs originate from purchased items or services, a special separate time-phased budget should be prepared for *procured* materials, equipment, and components, and outsourced work. In large projects this budget will be controlled by a materials or procurement manager.

8.8 BUDGETING USING CONTROL (COST) ACCOUNTS¹⁹

In small projects, budgeting and cost performance monitoring is done using one simple budget for the project as a whole. This budget, perhaps similar in appearance to the one in Figure 8-5, is used as the basis for comparing actual costs with budgeted costs throughout the project.

On larger projects, however, a single, project-wide budget is too insensitive; once the project is underway, should actual costs begin to exceed budgeted costs it would be difficult to quickly locate the source of the overrun. The better way is to break down the project-wide budget into smaller budgets called *control accounts* (also called cost accounts). Large projects have tens of control accounts; very large projects have hundreds.

The control account is the basic project tracking and control unit of the PCAS. A system of control accounts is set up in a hierarchy, similar or identical to the WBS. Although the lowest level control account usually corresponds to a work package, when the number of work packages is very large, several work packages can be combined into one control account. A multilevel numerical coding scheme is used to organize, communicate, and control the accounts. For example,

LEVEL	NUMERICAL ASSIGNMENT (COST ACCOUNT NUMBER)
1	01-00-0000 . . .
2	01-01-0000 . . .
3	01-01-1000 . . .
3	01-01-2000 . . .
2	01-02-0000 . . .
3	01-02-1000 . . .
4	01-02-1010 . . .

Control accounts and work packages are analogous. Each cost account includes:

- A description of the work
- A time schedule
- Who is responsible

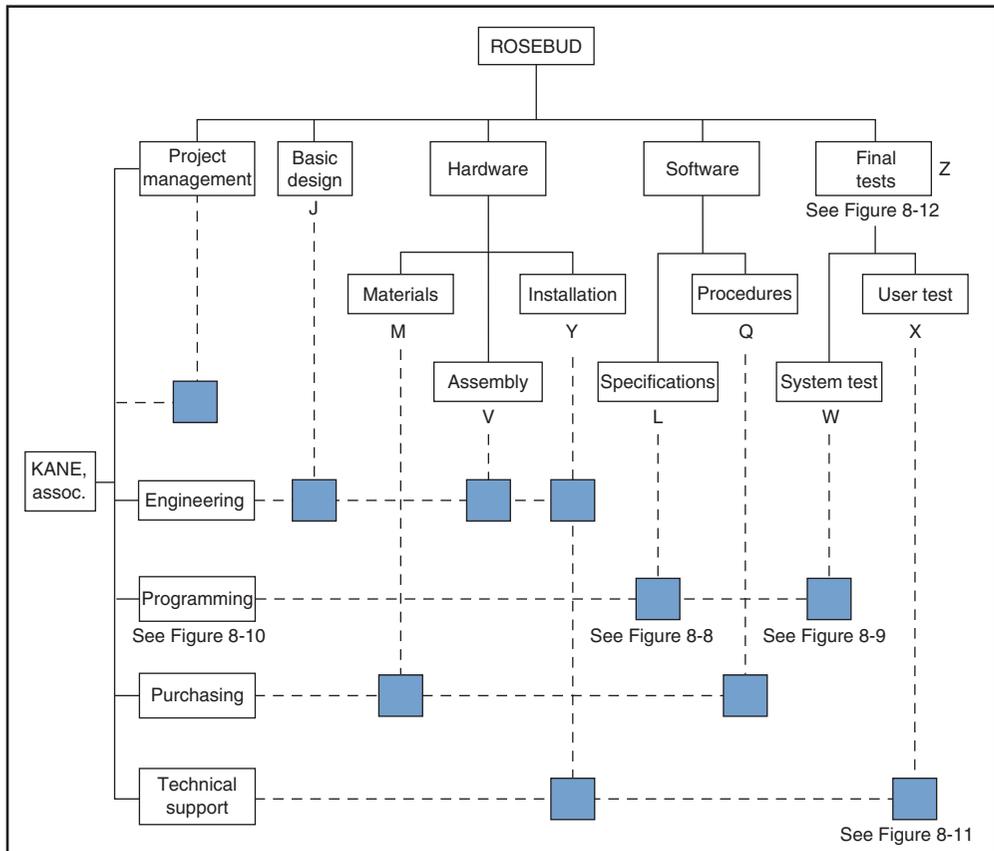
- Material, labor, and equipment required
- A time-phased budget

The time-phased budget is derived from the work schedule and shows the expected distribution of costs throughout the period of the work. In practice, both the schedule and time-phased budget should be developed simultaneously to account for resource and cash flow limitations.

Control accounts also are established for *nondirect* project costs—costs not readily attributable to any work packages or specific tasks. For example, monies allocated to a project for general purpose items, materials, or equipment that can be used by anyone on any task, or for jobs not specific to particular activities such as administration, supervision, or inspection jobs that apply across the project, are budgeted to separate control accounts or, where appropriate, to special work packages for general project items. These accounts are usually set up for the duration of the project and extended, period-by-period, as needed or as funds are appropriated.

With the PCAS and the control-account structure, cost performance can be monitored for a work package, groups of work packages, and the project as a whole. As an example consider again the Robotics Self-Budgeting (ROSEBUD) project. Figure 6-5 in Chapter 6 is the project network for ROSEBUD, and Figure 8-7 is the WBS and organization chart for the ROSEBUD contractor, KANE & Associates. The shaded

Figure 8-7
Integration of WBS and organization structure showing control accounts. (See Figures 8-8 through 8-12 for details.)



Project <u>ROSEBUD</u>		Date _____							
Department <u>Programming</u>		Work package <u>L- S/W Specifications</u>							
Charge	Rate	Months ⁺						Totals	
		1	2	3	4	5	6	Hours	Cost
Direct labor									
Professional	\$35/hour		130					130	4,550
Associate	\$30/hour		50	100				150	4,500
Assistant	\$20/hour			100				100	2,000
Direct labor cost			6,050	5,000					11,050
Labor overhead	75%		4,538	3,750					8,288
Other direct cost*									0
Total direct cost			10,588	8,750					19,338
General/administrative	10%		1,059	875					1,934
Total costs			11,647	9,625					21,272

⁺Should extend for as many months as required by the project.
*Should be itemized to include costs for materials, freight, subcontracts, travel, and all other nonlabor direct costs.

Figure 8-8
Budget for programming department for Work Package L.

Project <u>ROSEBUD</u>		Date _____							
Department <u>Programming</u>		Work package <u>W- System test</u>							
Charge	Rate	Months ⁺						Totals	
		1	2	3	4	5	6	Hours	Cost
Direct labor									
Professional	\$35/hour						20	20	700
Associate	\$30/hour						50	50	1,500
Assistant	\$20/hour								0
Direct labor cost							2,200		2,200
Labor overhead	75%						1,650		1,650
Other direct cost*							0		0
Total direct cost							3,850		3,850
General/administrative	10%						385		385
Total costs							4,235		4,235

⁺Should extend for as many months as required by the project.
*Should be itemized to include costs for materials, freight, subcontracts, travel, and all other nonlabor direct costs.

Figure 8-9
Budget for programming department for Work Package W.

boxes represent locations of control accounts: notice that each represents all or part of a work package for which a single functional area is responsible. For the same project, Figures 8-8 and 8-9 show, respectively, the time-phased budget portions of the cost accounts for the programming department and for work packages L and W.

The WBS for ROSEBUD consists of nine work packages performed by four functional departments plus an additional work package for project management. During the estimating phase each department submits a cost estimate for the work packages in its part of the project. Through the PCAS these estimates are accumulated “bottom-up” to derive the total project estimate. Upon approval, with additions for overhead and G&A, each departmental estimate becomes a budget. Thus, the 10 shaded boxes in Figure 8-7 represent units for which initial cost estimates were made and where budgets and control accounts are set up.

8.9 COST SUMMARIES²⁰

As shown in Figure 8-7, the control account structure is a matrix through which higher-level summary accounts can be developed by consolidating control accounts for the WBS and organizational hierarchies. Such consolidation is useful for monitoring the performance of individual departments and segments of the project. For example, consolidating accounts horizontally in Figure 8-7 results in a control account for each functional department. Figure 8-10 shows this in the time-phased budget summary for the programming department, which is the sum of the control accounts for work packages L and W (Figures 8-8 and 8-9). This is the programming department’s cost account budget for the ROSEBUD project.

Control accounts also can be consolidated vertically through the WBS. This information is useful for tracking and controlling individual work packages, clusters of work packages, or the project as a whole. Figure 8-12 illustrates this with the budget summary for final tests, which sums the costs from work packages W (Figure 8-9) and X (Figure 8-11).

Figure 8-10
Budget summary for programming department.

Project <u>ROSEBUD</u>		Date _____							
Department <u>Programming</u>		Work package <u>ALL</u>							
Charge	Rate	Months ⁺						Totals	
		1	2	3	4	5	6	Hours	Cost
Direct labor									
Professional	\$35/hour		130				20	150	5,250
Associate	\$30/hour		50	100			50	200	6,000
Assistant	\$20/hour			100				100	2,000
Direct labor cost			6,050	5,000			2,200		13,250
Labor overhead	75%		4,538	3,750			1,650		9,938
Other direct cost*									0
Total direct cost			10,588	8,750			3,850		23,188
General/administrative	10%		1,059	875			385		2,319
Total costs			11,647	9,625			4,235		25,507

⁺Should extend for as many months as required by the project.
*Should be itemized to include costs for materials, freight, subcontracts, travel, and all other nonlabor direct costs.

Project <u>ROSEBUD</u>		Date _____							
Department <u>Technical support</u>		Work package <u>X - User test</u>							
Charge	Rate	Months ⁺						Totals	
		1	2	3	4	5	6	Hours	Cost
Direct labor									
Professional	\$35/hour							10	350
Associate	\$30/hour							40	1,200
Assistant	\$20/hour								
Direct labor cost							1,550		1,550
Labor overhead	75%						1,163		1,163
Other direct cost*						1,200	2,107		3,307
Total direct cost						1,200	4,820		6,020
General/administrative	10%					120	482		602
Total costs						1,320	5,302		6,622

⁺Should extend for as many months as required by the project.
^{*}Should be itemized to include costs for materials, freight, subcontracts, travel, and all other nonlabor direct costs.

Figure 8-11
Budget summary for user test work package.

Project <u>ROSEBUD</u>		Date _____							
Department <u>Technical support; Programming</u>		Work package <u>(W + X) Final Tests</u>							
Charge	Rate	Months ⁺						Totals	
		1	2	3	4	5	6	Hours	Cost
Direct labor									
Professional	\$35/hour							30	1,050
Associate	\$30/hour							90	2,700
Assistant	\$20/hour								0
Direct labor cost							3,750		3,750
Labor overhead	75%						2,813		2,813
Other direct cost*						1,200	2,107		3,307
Total direct cost						1,200	8,670		9,870
General/administrative	10%					120	867		987
Total costs						1,320	9,537		10,857

⁺Should extend for as many months as required by the project.
^{*}Should be itemized to include costs for materials, freight, subcontracts, travel, and all other nonlabor direct costs.

Figure 8-12
Budget summary for final tests.

The highest-level control accounts are for the project and the company. Figure 8-13 shows how costs are aggregated vertically and horizontally to derive these costs. Through the PCAS and control-account structure, any deviation from budget at the project level can readily be traced to the work packages and departments responsible. Chapter 11 describes how this is done.

Most PCASs can be used to create a variety of cost summaries, depending on the purpose. Table 8-3, for example, shows the allocation of direct labor, overhead,

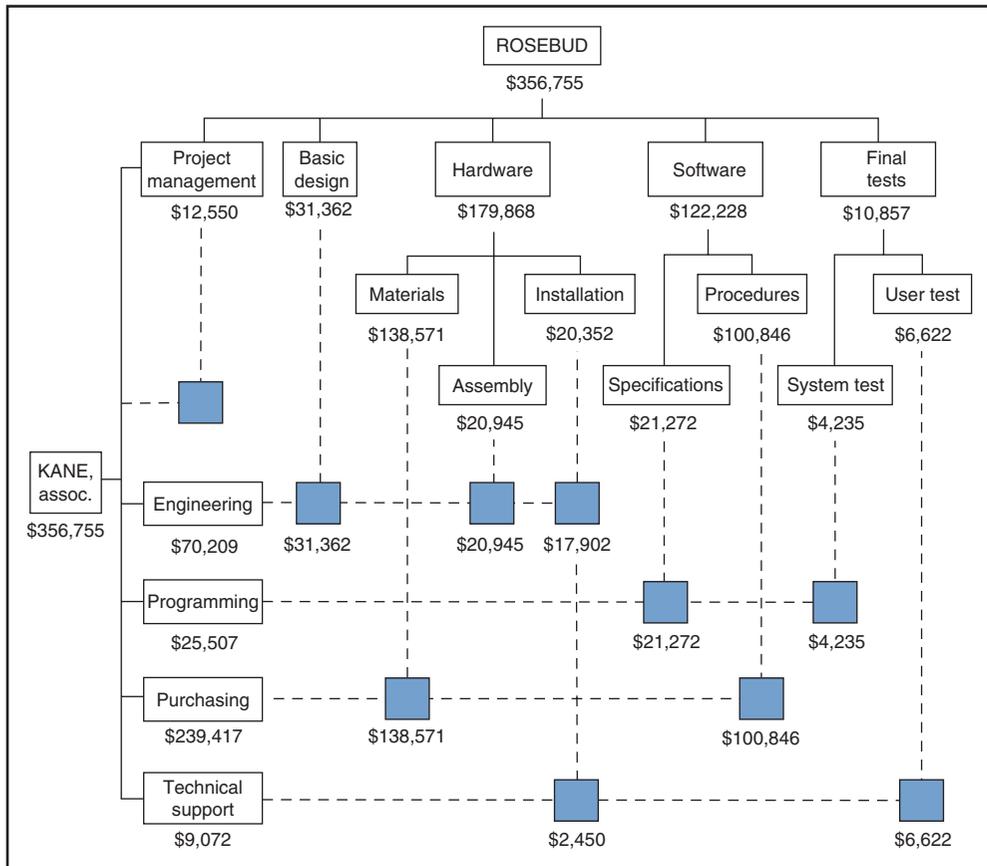


Figure 8-13 Aggregation of control account information by project and organization.

materials, and G&A among the 4 departments and 9 work packages that comprise the ROSEBUD project.

8.10 COST SCHEDULES AND FORECASTS²¹

Questions arise during planning and budgeting about what the project expenditures rate will look like, which periods will have the heaviest cash requirements, and how expenditures will compare to income. To answer these and other questions, the project manager analyzes the “pattern of expenditures” using work package cost estimates and cost forecasts derived from the project schedule. Following are some examples.

Cost Analysis with Early and Late Start Times

One simplifying assumption used in cost forecasts is that costs in each work package are incurred uniformly. For example, a 2-week, \$22,000 work package is assumed to have a weekly cost of \$11,000 per week. With this assumption, a *cost schedule* for the project can be easily created by adding costs period-by-period, for all the work packages scheduled in each period. As an example, look at Figure 8-14, which is the time-based network for the LOGON project using early start times. Also look at

Table 8-3 Cost summary for ROSEBUD project.

	LABOR (\$)					OVERHEAD (\$)					TOTAL COST	
	ENGINEERING	PROGRAMMING	PURCHASING	TECHNICAL SUPPORT		ENGINEERING	PROGRAMMING	PURCHASING	TECHNICAL SUPPORT	GENERAL AND ADMINISTRATIVE		
Total project	22,800	13,250	2,230	2,850		22,800	9,938	1,673	2,138	235,236	31,290	356,755
Project management												12,550
Activity J	7,200					7,200				14,111	2,851	31,362
Activity L*		11,050					8,288				1,934	21,272
Activity M			1,100					825		124,050	12,596	138,571
Activity Q			1,300					818		89,700	9,168	100,846
Activity V	8,200					8,200				2,641	1,904	20,945
Activity Y	7,400			1,300		7,400			975	1,427	1,850	20,352
Activity W		2,200					1,650				385	4,235
Activity X				1,550					1,163		602	6,622

*Refer to Figure 8-8 to see, for example, how costs in this row were developed.

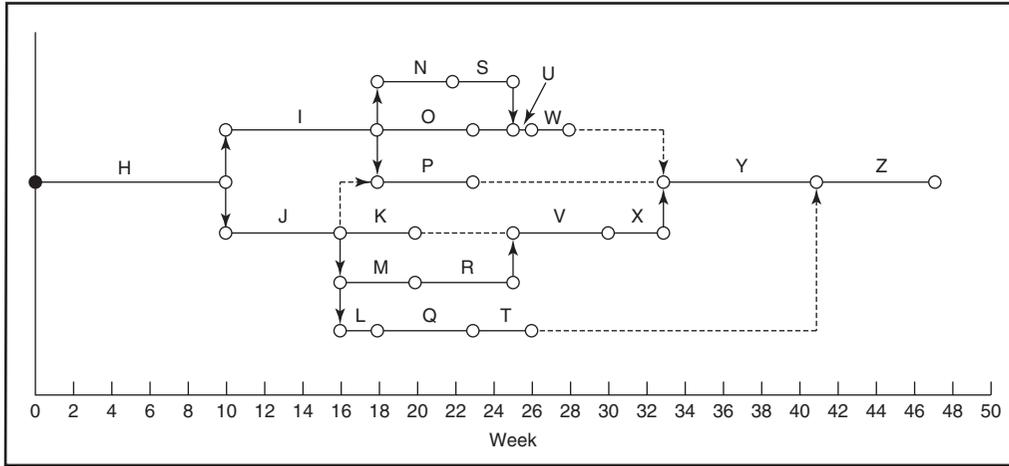


Figure 8-14
Time-based network for the LOGON project using early start times.

Table 8-4 Activities, time, cost, and labor requirements (result of work breakdown analysis).

ACTIVITY	TIME (WEEKS)	TOTAL COST (\$K)	WEEKLY DIRECT COST (\$K)	WEEKLY LABOR REQUIREMENTS (WORKERS)
H	10	100	10	5
I	8	64	8	4
J	6	96	16	8
K	4	16	4	2
L	2	36	18	6
M	4	84	21	3
N	4	80	20	2
O	5	50	10	5
P	5	60	12	6
Q	5	80	16	2
R	5	0	0	0
S	3	0	0	0
T	3	0	0	0
U	1	14	14	9
V	5	80	16	14
W	2	24	12	6
X	3	36	12	6
Y	8	104	13	14
Z	6	66	11	5
		Total direct cost—\$990K		

Table 8-4, which shows LOGON work packages and for each the time, total cost, and resulting average weekly direct cost (derived using the simplifying assumption). For example, the average weekly direct cost for Activity H is computed as \$100K/10 weeks = \$10K/week.

Using the early start schedule (Figure 8-14), the total weekly project cost can be computed by summing the costs for all activities on a week-by-week basis. The procedure is the same as that described in Chapter 6 for determining the resource loading. In the first 10 weeks, only Activity H is scheduled, so the weekly cost stays at \$10K. Over the next 6 weeks, activities I and J are scheduled, so the weekly cost is their sum total, $\$16K + \$8K = \$24K$. Further along, in weeks 17 and 18, four work packages—I, K, L, and J—are scheduled, so the weekly expense is their sum total, $\$8K + \$4K + \$18K + \$21K = \$51K$. These weekly expenses, summarized in the third column in Table 8-5, represent the *cost schedule* for the project. The fourth column in Table 8-5 shows the cumulative project expense, which is interpreted as the forecasted total project cost as of a given week. These costs are graphed in Figure 8-15.

Using the same procedure, project cost schedules and forecasts can be prepared based on late start times. Figure 8-16 is the time-based network for LOGON using late start times; the last two columns of Table 8-5 are the late start weekly and cumulative costs.

Given the early and late cost profiles in Table 8-5 it is possible to analyze what effect delayed activities will have on project costs and budgets. The cost and budget implication of using early start times versus late start times is shown in Figure 8-17; the influence of schedule changes on project costs is clearly apparent. The shaded area in the top figure represents the *feasible budget region*, the range of budgets permitted by changes in the project schedule. The lower part of the figure shows the weekly impact on the cost schedule of delaying activities.

When funding restrictions constrain project expenditures, cost schedules reveal the places of conflict. For example, Figure 8-17 shows a peak weekly expense of \$82,000 in Weeks 18 and 19. What if the weekly budget ceiling is only \$60,000? In that case the late start times would be preferred because they provide a more “leveled” cost profile and a peak expense of only \$54,000. The method for leveling resources discussed in Chapter 6 is also applicable to leveling project costs; costs are treated as just another resource.

The forecasts in the previous example were based upon the total budgeted costs for each work package. Similarly, cost schedules and forecasts can be prepared for other specific kinds of costs or portions of budgets—such as direct labor or materials. Table 8-6 shows the labor cost schedule for the ROSEBUD project using early start times. This kind of cost schedule is useful for identifying periods where scheduling changes may be necessary to meet payroll ceilings (i.e., when the monthly total direct labor cost cannot exceed a payroll ceiling).

Effect of Late Start Time on Project Net Worth

Because of the time value of money, work that is done farther in the future has a lower net present value than the same work if done earlier. Delaying all activities in a lengthy project can thus provide substantial savings because of differences in the present worth of the project. For example, suppose the LOGON project has a long duration, say 47 *months* instead of the 47 weeks used so far. If an annual interest rate of 24 percent were used, compounded monthly at 2 percent per month, the present worth for the project would be \$649,276. This is computed by using the monthly expenses in Table 8-5 (again, assuming the weeks shown to be months instead) and discounting the amounts back to time zero. Now, when the late start times are used instead, the present worth is only \$605,915—a savings of \$43,361.

Does this mean that activities should be delayed until their late start date? Not necessarily. Remember, delaying activities uses up slack time and leaves nothing for unexpected problems. If a problem arises, slack is needed to absorb the

Table 8-5 LOGON project weekly expense using early and late start times (\$1000).

WEEK	EARLY START			LATE START		
	ACTIVITIES DURING WEEK	WEEKLY EXPENSE	CUMULATIVE EXPENSE	ACTIVITIES DURING WEEK	WEEKLY EXPENSE	CUMULATIVE EXPENSE
1	H	10	10	H	10	10
2	H	10	20	H	10	20
3	H	10	30	H	10	30
4	H	10	40	H	10	40
5	H	10	50	H	10	50
6	H	10	60	H	10	60
7	H	10	70	H	10	70
8	H	10	80	H	10	80
9	H	10	90	H	10	90
10	H	10	100	H	10	100
11	I, J	24	124	J	16	116
12	I, J	24	148	J	16	132
13	I, J	24	172	J	16	148
14	I, J	24	196	J	16	164
15	I, J	24	220	I, J	24	188
16	I, J	24	244	I, J	24	212
17	I, K, L, M	51	295	I, M	29	241
18	I, K, L, M	51	346	I, M	29	270
19	K, M, N, O, P, Q	83	429	I, M	29	299
20	K, M, N, O, P, Q	83	512	I, M	29	328
21	N, O, P, Q	58	570	I, R	8	336
22	N, O, P, Q	58	628	K, I, R	12	348
23	O, P, Q	38	666	K, R	4	352
24	—	0	666	K, R, N	24	376
25	—	0	666	K, R, N	24	400
26	U, V	30	696	N, O, V	46	446
27	V, W	28	724	N, O, V	46	492
28	V, W	28	752	S, O, V	26	518
29	V	16	768	S, O, P, V	38	556
30	V	16	784	S, O, P, V	38	594
31	X	12	796	U, P, X	38	632
32	X	12	808	W, P, X, L	54	686
33	X	12	820	W, P, X, L	54	740
34	Y	13	833	Y, Q	29	769
35	Y	13	846	Y, Q	29	798
36	Y	13	859	Y, Q	29	827
37	Y	13	872	Y, Q	29	856
38	Y	13	885	Y, Q	29	885
39	Y	13	898	Y, T	13	898
40	Y	13	911	Y, T	13	911
41	Y	13	924	Y, T	13	924
42	Z	11	935	Z	11	935
43	Z	11	946	Z	11	946
44	Z	11	957	Z	11	957
45	Z	11	968	Z	11	968
46	Z	11	979	Z	11	979
47	Z	11	990	Z	11	990

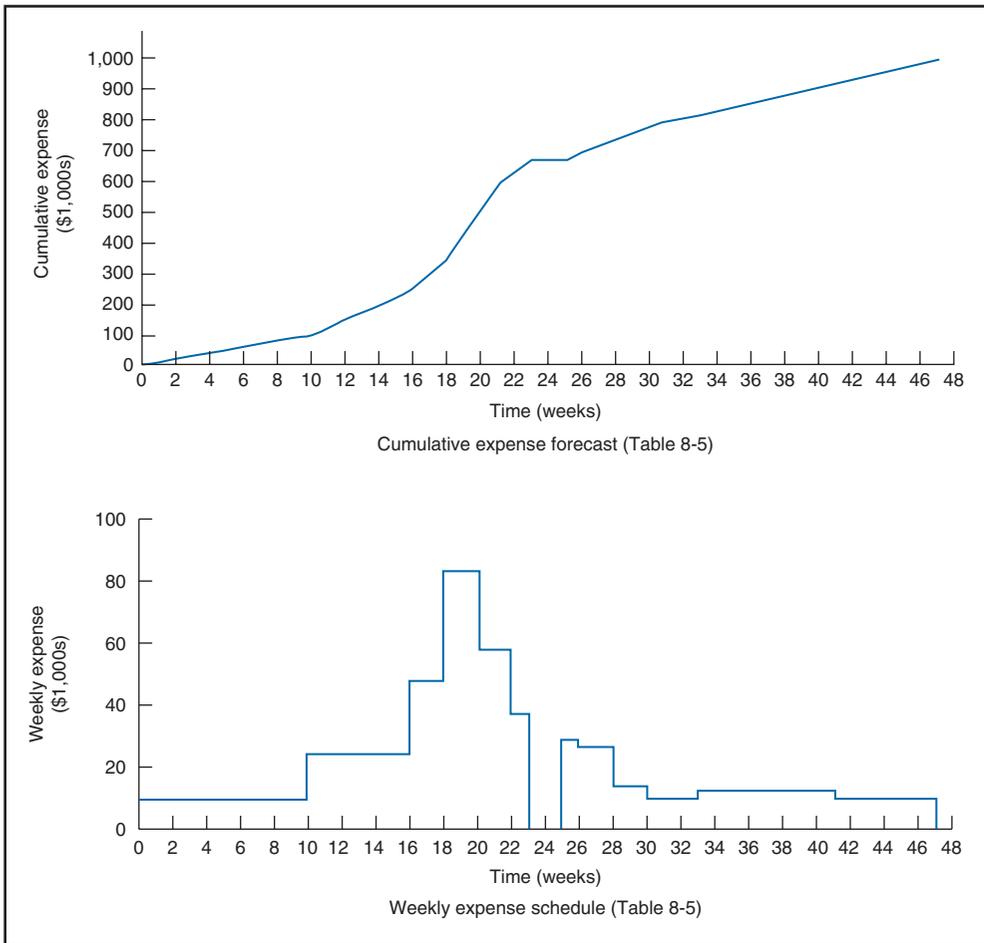
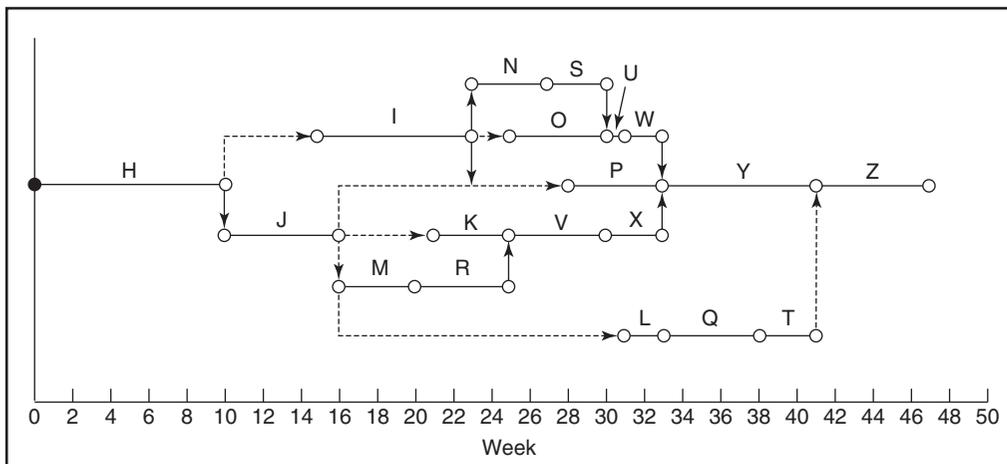


Figure 8-15
Planned weekly and cumulative expenses for the LOGON project.

Figure 8-16
Time-based network for the LOGON project using late start times.



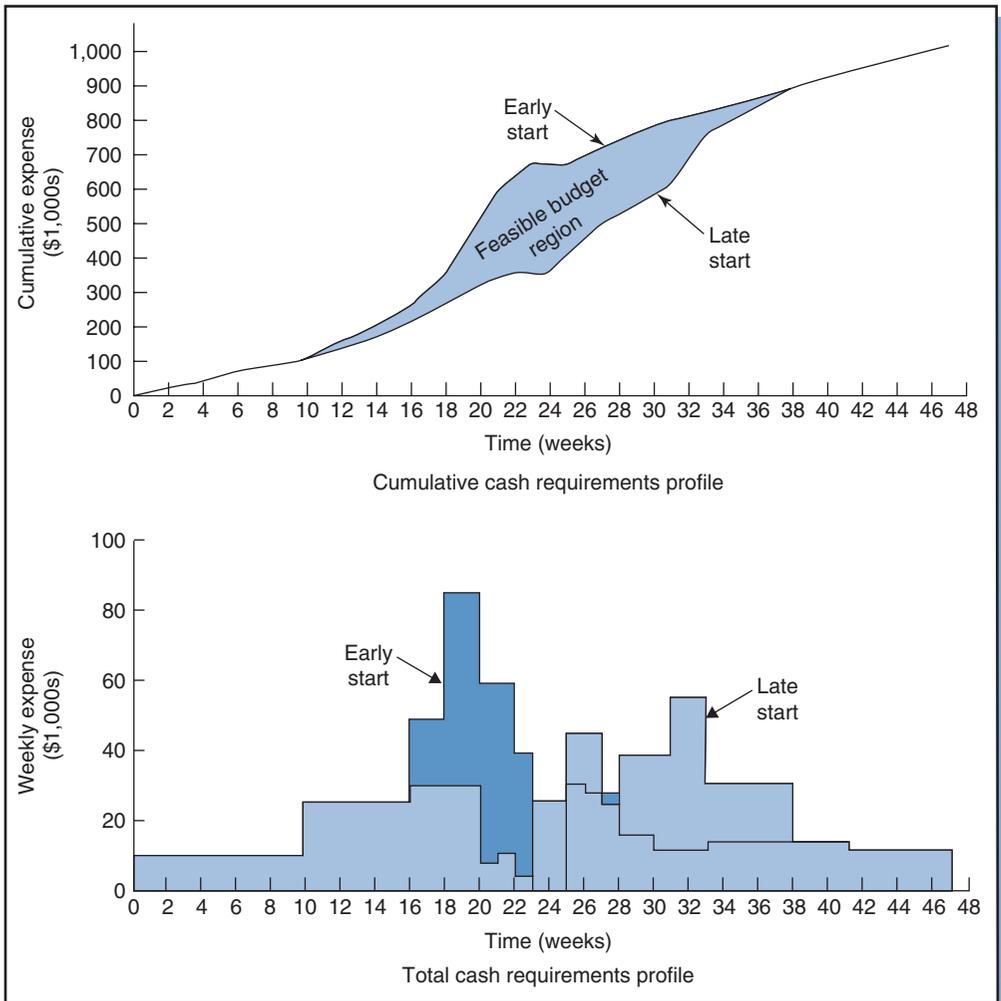


Figure 8-17 Comparison of cash requirements, early versus late start times.

Table 8-6 Labor cost schedule, ROSEBUD project.

DEPARTMENT	MONTHLY COST (\$)						TOTAL COST
	1	2	3	4	5	6	
Engineering (Project)	7,200	4,800	3,300	5,100	2,100	300	22,800
Programming*		6,050	5,000			2,200	13,250
Purchasing		1,100	580	550			2,230
Technical service				800	500	1,550	2,850
Total direct labor cost	7,200	11,950	8,880	6,450	2,600	4,050	41,130

*Refer to Figure 8-11, for example, to see how costs in this row were obtained.

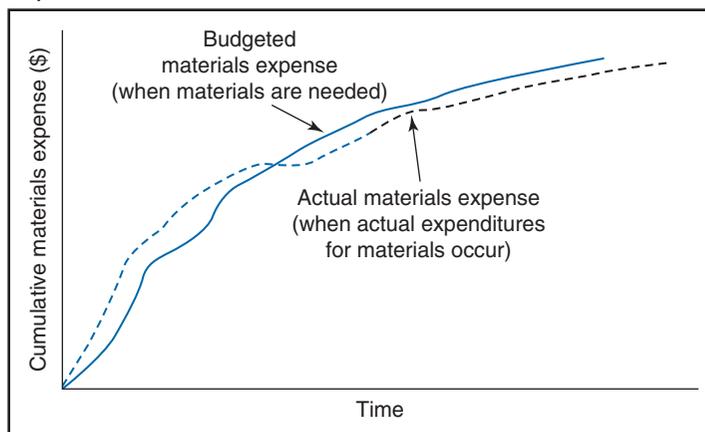
delay and keep the project on schedule. Thus, whether or not an activity should be delayed depends on the *certainty of the work*. Activities that are familiar and unlikely to encounter problems can be started later to take advantage of the time value of money. However, intentionally eliminating slack in schedules of uncertain activities is risky. Activities that are less familiar, such as research and development work, should be started earlier to retain valuable slack that might be needed to absorb unanticipated delays. (This assumes the critical path method; critical chain method (CCM) relies on resource buffers that preclude the need for slack). Also, whether or not to delay activities will depend on the schedule of customer payments. If payments are tied to completion of *stages* of the project, then activities essential to their completion cannot be delayed.

Material Expenditures, Payments, and Cash Flow

Cost schedules and forecasts are also used for estimating cash requirements to meet payments for materials, parts, and equipment.²² There are several ways to prepare such a cost forecast depending on the purpose. For example, the forecast might represent the cost of materials “when needed”; i.e., the cost of materials corresponding to the date when the materials are needed for use. Alternatively, the forecast might represent the date when payments for materials are due. This forecast will be different from the “when needed” forecast because often a portion of the payment must be made at the time the material is ordered—in other words, the expense *precedes* when the material is needed. Other times, payment can be delayed until after the order is received—in other words, the expense *follows* when the material is needed. The costs shown in the time-phased budget usually reflect costs of materials when needed and not when actual payments are due. Because the times when actual expenditures occur seldom correspond to the times shown on time-phased budgets, forecasts should be made to reveal places of major discrepancy. Figure 8-18 illustrates this point.

A problem often facing the project manager is maintaining a positive cash flow, i.e., that the cumulative cash inflow (payments received) always exceeds the cumulative cash outflow (payments made). Ideally, differences between cash in and cash out throughout the project will be small.²³ The project manager must do a juggling act to hold income from the client in balance with payments for labor, subcontractors, materials, and equipment expenses. To help maintain this balance, management can,

Figure 8-18
Material expenses showing budgeted versus actual expenditures.



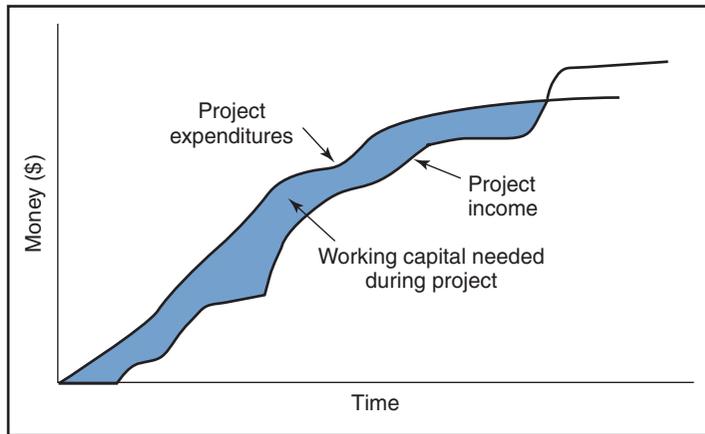


Figure 8-19
Balancing project income and expenditures.

for example, take advantage of the time lag between when materials are needed and the payments for them are required.

Figure 8-19 shows an example of forecast cash flow. All sources of income over the life of the project based on contractual agreements are compared to all foreseeable expenditures—direct and indirect, as well as scheduled payments and any penalty costs, should the project have to be completed late or terminated. The deficit between forecasted income and estimated expenditures represents the amount of invested or working capital needed to meet payment commitments. Based upon this cash flow forecast, a *funding plan* should be created to ensure sufficient working capital will be available throughout the project.²⁴

Subcontractors often insist on *milestone payments*, or payments made upon completion of deliverables or phases of the project. Such payments make sense because they help contractors to cover their costs. The drawback is that, should the project encounter serious problems, some unscrupulous subcontractors, having already received several payments, simply walk away from the job and forfeit the final payment, of course leaving the customer in a fix! One way to keep “hold” on the contractor is to withhold a significant portion of the agreed upon payment, called *retention money*, until the work is satisfactorily completed. A second way, called a *performance guarantee*, is to withhold some portion of the final payment for a period following handover of the end-item (called the *guarantee period*, retention period, or defects liability period). During this period any hidden (“latent”) defects or visible (“patent”) defects discovered by the customer must be rectified. Retention money and performance guarantees need to be agreed upon and included in the contract, and should apply to all project agreements—between customer and prime contractor, as well as prime contractor and its subcontractors. The cost schedule and cash flow plan should include these amounts—payments to be withheld until after handover (to ensure satisfactory delivery) and the guarantee period following the handover (to ensure correction of defects) of any contingency reserves.

8.11 SUMMARY

Cost estimation and budgeting are part of the project planning process. Cost estimation logically follows work breakdown and precedes project budgeting. Accurate

cost estimates are necessary to establish realistic budgets and to provide standards against which actual costs will be measured; they are thus a prerequisite for tracking and control, and crucial to the financial success of the project.

Costs in projects have a tendency to escalate beyond original estimates. The accuracy of estimates can be improved and escalation minimized by defining clear requirements and work tasks, employing skilled estimators, being realistic, and anticipating escalation factors such as inflation and project changes. Accuracy is partly a function of the stage in the systems development cycle during which the estimates are prepared; the further along the cycle, the easier it is to produce accurate estimates. However, good estimates are needed early in the project. Besides clearly defining project scope and objectives, accuracy is improved by subdividing the project into activities and work packages, and employing standard technology and procedures. In general, the smaller the work element being estimated and more standardized the work, the greater the accuracy of the estimate. The aggregate of cost estimates for all subelements of the project plus overhead costs becomes the cost estimate for the overall project. Approved estimates become budgets.

The project budget is subdivided into smaller budgets called control or cost accounts. Control accounts are derived from the WBS and project organization hierarchies and are the financial equivalent to work packages. In larger projects a systematic methodology or PCAS is useful for aggregating estimates and maintaining a system of control accounts for budgeting and control.

Cost schedules are derived from time-phased budgets and show the pattern of costs and expenditures throughout the project. They are used to identify cash and working capital requirements for labor, materials, and equipment.

Scheduled and forecasted project expenditures, payments and other cash outflows are compared to scheduled and forecasted payment receipts and income sources to predict cash flow throughout the project. Ideally expenditures and income are balanced so that the contractor can maintain a positive cash flow. The forecasts are used to prepare a funding plan that guarantees adequate financial support for the project.

The last four chapters described aspects of the project planning process, focusing on scope and work definition, scheduling, and budgeting. The next chapter continues in this direction and the topic of project quality management.

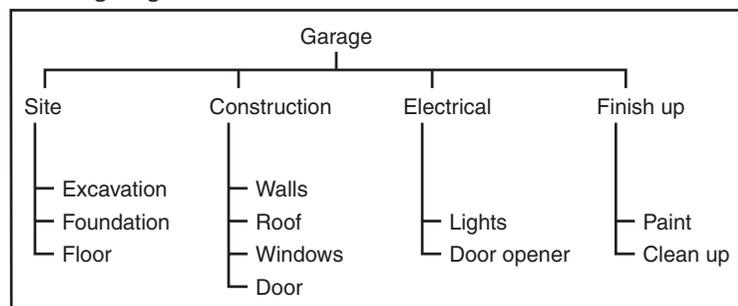
REVIEW QUESTIONS AND PROBLEMS



1. Why are accurate cost estimates so important, yet so difficult, in project planning? What are the implications and consequences of overestimating costs? Of underestimating costs?
2. Define cost escalation. What are major sources of cost escalation?
3. What is the purpose of a contingency fund (management reserve)? How is the contingency fund used and controlled?
4. Describe what the term “phased project planning” means.
5. How do changes in requirements cause cost escalation?
6. How does the type of contractual agreement influence the potential for cost escalation?
7. What is the relationship between phases of the project life cycle and cost escalation?
8. Explain: what are LCC’s and how are they different from project costs?
9. Explain the difference between a cost estimate and a cost target. What are the problems in confusing the two—in using cost targets as cost estimates?

10. Explain the difference between accuracy and precision. Give two original examples that illustrate the difference.
11. For each of the following estimating methods, briefly describe the method, when it is used, and the estimate accuracy it provides:
 - (a) Expert opinion
 - (b) Analogy
 - (c) Parametric
 - (d) Cost engineering
12. Describe the process of using the WBS to develop cost estimates. How are these estimates aggregated into total project cost estimates?
13. What is the role of individual functional and subcontracting units in cost estimating?
14. Describe the different kinds of contingency amounts and the purposes each serves.
15. Describe the PCAS. What is its purpose and how is it used in project planning?
16. What is a time-phased budget? What is the difference between a budget and a cost estimate?
17. Distinguish recurring costs from nonrecurring costs.
18. What are six cost elements shared by most estimates and budgets?
19. How are direct labor expenses determined?
20. What expenses are included under direct nonlabor?
21. How is the overhead rate determined?
22. What is a control account and what kinds of information does it contain? How does a control account fit into the structure of the PCAS?
23. How are control accounts aggregated horizontally and vertically? Why are they aggregated like this?
24. How are time-based forecasts prepared and how are they used?
25. What are the reasons for investigating the influence of schedules on project costs? What is the feasible budget region?
26. What might happen if top management submitted a bid for a project without consulting the business unit or department to be involved in the project?
27. Refer Case 5-1, the Barrage Construction Company, in Chapter 5. In the case, the project manager Sean Shawn employed the analogy method with an adjustment to estimate the cost of constructing a three-car garage. Specifically, he started with the cost of an average two-car garage, \$143,000, and increased it by 50 percent to \$214,500. Comment on the accuracy of the three-car garage estimate. Suggest a different approach that would probably yield a more accurate cost estimate, then use this approach and made-up time and cost figures to compute the estimate. Argue why your estimate is better than Sean's. Figure 8-20 is Sean's WBS.

Figure 8-20
Sean's garage WBS.



28. The example in Table 8-2 shows three possible ways of apportioning total direct costs. Using the same example, suppose, the direct nonlabor (DNL) cost and G&A are broken down as follows:

	Direct Nonlabor			G&A
	MARS	PLUTO		
Materials	30	5	Freight	8
Other	<u>10</u>	<u>5</u>	Other	<u>32</u>
	40	10		40

Assuming all remaining costs shown in Table 8-2 are unchanged, compute the project costs for MARS and PLUTO using the following apportioning rules:

- Overhead (OH) is proportionate to direct labor (DL).
 - Freight G&A is proportionate to materials.
 - Other G&A is proportionate to DL, OH, DNL, and freight.
29. Chapter 7 discussed the impact of crashing activities and the relationship of schedules to cost. The method assumes that as activity duration is decreased, the direct cost increases, in some cases owing to increases in direct labor rates from overtime. Overhead rates also may vary, although the overhead rate is often *lower* for overtime work. For example, the overhead rate may be 100 percent for regular time but only 20 percent for overtime. In both cases, the overhead rate is associated with the wage rate being used.

Suppose that in the MARS project in Table 8-2, 1,000 direct hours of labor are required at \$50 per hour, and the associated overhead rate is 100 percent for regular time. Now suppose an overhead rate of 10 percent and overtime wage rate of time-and-a-half.

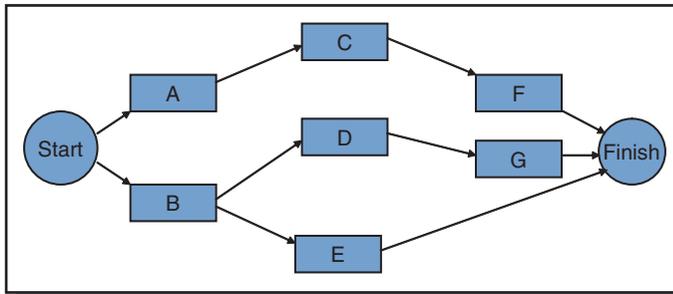
Compare the project cost if it were done entirely on regular time with the cost if it were done entirely on overtime. Which is less expensive?

30. Use the table below and network in Figure 8-21 to answer questions about the ARGOT project:

Activity	Time (Weeks)	Weekly Cost (\$K)	Total (\$K)
A	4	3	12
B	6	4	24
C	3	5	15
D	4	5	20
E	8	3	24
F	3	4	12
G	2	2	<u>4</u>
			111

- Compute the ESs and LSs for the project. Assume T_s is the same as the earliest project completion date.

Figure 8-21
ARGOT project.



- (b) Construct a time-based network for the project such as Figure 8-14 (use early start times).
 - (c) Construct two diagrams similar to those in Figure 8-15 showing the weekly and cumulative project expenses.
31. Using the data in problem 30, repeat Steps b and c using late start times. Then identify the feasible budget region using the cumulative curves.
 32. Explain retention money and performance guarantee.

QUESTIONS ABOUT THE STUDY PROJECT



1. How were project costs estimated? Who was involved? Describe the process.
2. When did estimating take place? How were estimates checked and accumulated? How were they related to the WBS?
3. What, if any, were the principle causes of cost escalation in the project?
4. Was an LCC analysis performed? If so, who did it, when, and using what methods? How did the analysis affect the design, development, and production of the project deliverables or main end item?
5. How often and under what circumstances were cost estimates revised during the project?
6. How were overhead costs determined? What basis was used for establishing overhead cost rates?
7. How were cost estimates tallied to arrive at a total project cost estimate? Who did this?
8. What kind of PCAS was used? Was it manual or computerized? Describe the system and its inputs and outputs. Who maintained the system? How was it used during the project?
9. Describe the process of creating the project budget. Show a sample budget (or portion thereof).
10. How were management and supervisory costs handled in the budget?
11. Was the project budget broken down into cost accounts? If so
 - (a) How were they related to the work packages and WBS?
 - (b) How were they tied into the PCAS?
12. What kinds of costs summaries were prepared? Who were they sent to? How were they used? Show some examples.
13. Did the PCAS produce time-phased cost schedules and forecasts? Show some examples. How were they used by the project manager?

Case 8-1 Life Cycle Costs for Fleet of Tourist Spaceships

At the time of writing, Burt Rutan and Sir Richard Branson had teamed up to form The Spaceship Company, which will develop and manufacture commercial spacecraft (SpaceShipTwo, or SS2), launch aircraft (WhiteKnightTwo, or WK2), and support equipment. Branson's "spaceline," Virgin Galactic, will handle the operations for space tourist flights. Their hope is to eventually reduce by half the proposed initial ticket price of \$190,000.

No information has been released about development and operating costs for the spaceline and equipment, so the figures used in this case are guesses. Refer to Example 2 for *hypothetical* life

cycle costs for the spaceline and spaceship fleet, but assume the following changes to the numbers:

- Five spaceships, seven passengers per spaceship
- Development and manufacturing cost, \$120 million
- Flight operations cost: \$0.5 million per flight
- Ticket price: \$190,000 for passengers on the first 100 flights, then \$150,000 for passengers on the next 100, and \$100,000 for passengers on flights thereafter.

QUESTIONS

1. Assuming all other numbers from Example 2 are the same, what is the "bottom line" profit of the venture for 5 years of operation?
2. If the profit goal is \$70 million
 - (a) What is the maximum development & production cost for the fleet?
 - (b) What is the maximum per-flight operational cost? (Note: assume \$120 million development/production cost.)
3. Brainstorm. What are some ways the development cost might be reduced? What are some possible design decisions for the spacecraft and mothership that would reduce the per-flight operational cost? Next, research articles and news releases about SS2 and WK2 to see what the developers, Scaled Composites and The Spaceship Company, have been doing to contain costs.

Case 8-2 Estimated Tunnel Costs for the Chunnel Project²⁵

Before construction began on the English Channel Tunnel (Chunnel) Project, the banks underwriting the project hired consulting engineers to review cost estimates prepared by the contractors. The consultants concluded that the tunneling estimates were 20 percent too high. Their analysis was based on comparisons of costs from recent European tunnel projects, including 50 German railroad tunnels ranging in length from 400 meters to 11 kilometers, to the Chunnel, which would be 49 kilometers in length. The costs of the tunnels ranged from £55 to £140 per cum (cubic meter) of open tunnel; the cost of the Chunnel was estimated at £181 per cum on the British side of the

channel and £203 on the French side (the difference owing to more difficult geological conditions on the French side). The Chunnel is actually three interconnected tunnels—one for trains going in each direction and a smaller service tunnel between them. Note, however, that the cost estimates are per cubic meter of tunnel, so *presumably*, differences in tunnel lengths and diameters are not major factors. Why might the estimates for the Chunnel be so much higher per cum than the costs for the analogy projects? Discuss possible, logical adjustments to the analogy tunnel project costs to arrive at a cost estimate for the Chunnel tunnel.

ENDNOTES

1. See F.L. Harrison, *Advanced Project Management* (Hants, England: Gower, 1981): 147–148.
2. B. Flyvbjerg, N. Bruzelius and W. Rothengatter, *Megaprojects and Risk: An Anatomy of Ambition* (Cambridge: Cambridge University Press, 2003): 16.
3. See R.D. Archibald, *Managing High-Technology Programs and Projects* (New York: John Wiley & Sons, 1976): 167–168.
4. See Harrison, *Advanced Project Management*, 148–152.
5. *Ibid.*, 172–173, gives an example of an escalation clause.
6. Politically, how independent should the estimators be? So independent, says DeMarco, that the project manager has “no communication with the estimator about how happy or unhappy anyone is about the estimate.” See Tom DeMarco, *Controlling Software Projects* (New York: Yourdon Press, 1982): 19.
7. A more complete discussion is found in Harrison, *Advanced Project Management*, 162–171.
8. B. Flyvbjerg, N. Bruzelius and W. Rothengatter, *Megaprojects and Risk: An Anatomy of Ambition*.
9. Harrison, *Advanced Project Management*, 154–161.
10. Archibald, *Managing High-Technology Programs and Projects*, 171.
11. J. Dingle, *Project Management: Orientation for Decision Makers* (London: Arnold/John Wiley & Sons, 1997): 105.
12. R. Pool, *Beyond Engineering: How Society Shapes Technology* (New York: Oxford University Press, 1997); T.A. Heppenheimer, “Nuclear Power,” *Invention and Technology*, Fall 18, no. 2 (2002): 46–56.
13. A complete discussion of the pricing review procedure is given by Harold Kerzner, *Project Management: A Systems Approach to Planning, Scheduling, and Controlling*, 5th ed. (New York: Van Nostrand Reinhold, 1995): 724–728.
14. Discussed in M. Rosenau, *Successful Project Management* (Belmont, CA: Lifetime Learning, 1981): 91.
15. *Ibid.*, 91–92.
16. A thorough discussion of labor pricing is given by Kerzner, *Project Management*, 728–732. This example is derived from Kerzner.
17. This example is derived from a similar one in Rosenau, *Successful Project Management*, 89–91.
18. This example is derived from Thomas Wilson and David Stone, “Project Management for an Architectural Firm,” *Management Accounting* (October 1980): 25–46.
19. See Harrison, *Advanced Project Management*, 199–202 for further discussion of cost accounts.
20. The kinds of cost summaries used often depend on what is available in the software, though many software packages permit customizing of reports.
21. J.D. Wiest and F.K. Levy, *A Management Guide to PERT/CPM*, 2nd ed. (Upper Saddle River, NJ: Prentice Hall, 1977): 90–94.
22. See Kerzner, *Project Management*, 396–398, for an example of a material expenditure forecast.
23. Harrison notes that keeping cash in balance in foreign contracts is especially difficult because foreign currency use must be managed: “In many cases, the profits from [currency dealings] can exceed the profits from the project; in others, if this is not managed effectively, the losses from foreign currency commitments can bring about large losses on a project and lead to bankruptcy.” See Harrison, *Advanced Project Management*, 185.
24. See Archibald, *Managing High-Technology Programs and Projects*, 168.
25. Drew Fetherston, *The Chunnel* (New York: Times Books, 1997): 141–142.